DLF

Line Differential Protection





Instructions Manual for **DLF** Models
M0DLFA1907Iv44

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Chapter 1.

Description and Start-Up

1.1 Introduction

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This instruction manual provides a technical and functional description of the relay **DLF**. The manual may be used as technical reference in engineering, installation, commissioning, and normal operation of the relay since the manual contains operating and handling instructions apart from descriptions relative to technical data, function lists, logic diagrams, input and output signals, parameter settings and detail explanation of every function.

ZIV has attempted to make this manual as accurate and easy to understand as possible. However, **ZIV** cannot guarantee that it is free of errors in the manuals and it could also be subject to possible upgrades. Therefore, **ZIV** would be very grateful to receive customer comments on possible errors or recommendations. Suggestions may be sent to **ZIV** through the following link.

1.1.1 Relay Overview and Applications

The IED generically designated as **DLF** combines all the necessary functions required for full protection of line positions. These IEDs use the most advanced digital technology based on powerful microprocessors and incorporates **Line Differential** protection, **Distance**, **Overcurrent**, **Over / Undervoltage** and **Over / Underfrequency** protection, **Recloser**, **Synchronism Detection**, **Control** and **Metering** functions.

DLF systems are of application in high and medium voltage lines, no matter whether overhead, underground or a combination of both, and no matter whether they incorporate series compensation or not.

DLF IEDs combine Phase, Neutral and Positive and Negative Sequence Differential units with **Distance** metering elements (and complementary units such as **Close-onto-Fault**, **Dead-Line**, **Remote Breaker Open Detector**, **VT Fuse Failure**, **Power Swing** and **Load Encroachment** detectors), **Voltage** metering elements (Phase Over / Undervoltage and Ground Overvoltage), **Current** metering elements (Phase, Ground and Negative Sequence Instantaneous and Time Overcurrent, Stub-Bus protection, Thermal Image protection, Breaker Failure Protection and Open Phase Detector) and **Frequency** metering elements (Over / Underfrequency and Frequency Rate of Change).

The Line Differential unit (composed of Phase, Neutral and Positive and Negative Sequence differentials) allows the protection of lines with two or three ends. It includes an External Fault Detector that increases safety against external faults with severe CTs saturation and in case of communication failures.

The communication between the different Line Differential bays can be carried out by means of a point-to-point scheme or by means of interconnection through SDH multiplexers and/or MPLS-TP multiplexers.

Protection Schemes can be added to both distance and overcurrent elements for instantaneous tripping along the entire length of the line.

This Instruction Manual refers to **DLF** models, which are mainly indicated for Line Protection applications. In the chapter dedicated to Model Selection, the characteristics specific to each of the existing options are specified.

The communications interface has secure access systems (SSH, SFTP, HTTPS), and supports several protocols including communications standard IEC61850 ED2, as well as redundancy protocols RSTP, PRP, and HSR; and synchronization protocols SNTP, PTP (1588).

1.1.2 Symbols

The following symbols can be found in the manual as well as in the back of the relay.



WARNING:
Hazards that may derived into personal injuries or damage to the equipment. Refer to the Instructions Manual.



WARNING:
Electrical risk hazard



Grounding



Protection Ground Terminal

1.1.3 Relay Family Features

Multifunction protection and control of **DLF** relays are provided with the state-of-the-art digital technology based on powerful microprocessors so that all measurements acquisition tasks and breaker supervision tasks are digitally processed within a modular design.

Relay analog inputs capture currents and voltages transmitted by instrument and protection transformers adapting them to internal processing level of the relay. **DLF** relays has a maximum of 10 analog inputs: 5 current inputs and 5 voltage inputs. Analog measurements are processed by an analog digital converter included in the analog input board which sends the digital samples to the microcontroller.

The microcontroller carries out all the management tasks and functions of the relay, which include, for example, the filtering and re-sampling of the measurements, protection algorithms, control functions, data storage, distribution of data to the communications ports, etc.

Relay configurable inputs may be used to receive data from switchgear or other equipment through hardwiring. All relay outputs are configurable and may be used for protection or control.

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The equipment can have two display options (depending on the model). A first option with a single alphanumeric display, and a second option with a single display that supports both alphanumeric and graphic functions.

The front alphanumeric screen has a resolution of 128x64 and can display 6 lines and 20 characters per line. The graphic screen has a resolution of 272x480, allowing the visualization of the screens configured in the user logic of the relay (single-line diagrams, alarm screens, etc.). Furthermore, both screens can display the status of all digital inputs and outputs and additional data via 16 configurable LEDs, whose activation will be shown by a red light. The status of the relay will be shown through a non-configurable tricolor LED (green/red/orange).

Models with *Standard Display* (model digit 5 = 1 or 2) feature 6 configurable bicolor LEDs (green/red) associated with the command buttons P1-P6.

Models with *Extended Buttons Display* (model digit 5 = 4) feature 12 configurable bicolor LEDs (green/red) associated with the command buttons P1-P12, plus other 2 configurable LEDs (fixed red) associated with the Local/Remote (L/R) button. For this model, only the graphic display option is available.

The **DLF** family has two front USB ports (1 type A and 1 type B) to carry out configuration and maintenance tasks and several rear communications ports: two serial ports, and another two or four Ethernet ports (depending on the model) that will allow the equipment to communicate in different protocols, with or without communications redundancy.

In addition, it has two or four other fiber ports (depending on the model) for communication between devices or with SDH multiplexers (using C37.94 protocol), used exclusively to perform the line differential function and for the exchange of digital signals.

Relay electronics will carry out its tasks thanks to an internal power supply whose features could be decided at the time of selecting the required model and the details will appear in Technical Data Chapter.

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1.1.3.a Hardware Design

The main components are:

- Main microcontroller module and memory that manage relay functions.
- Secondary microcontroller in the CPU board to gather data from the different modules or slots.
- Secondary microcontroller in the boards located in each Slot.
- Power supply board with inputs and outputs and coil supervision.
- Input and output expansion boards with coil supervision.
- Analogue boards
- Communications buses to link the various modules and to transmit the different types of data separately.

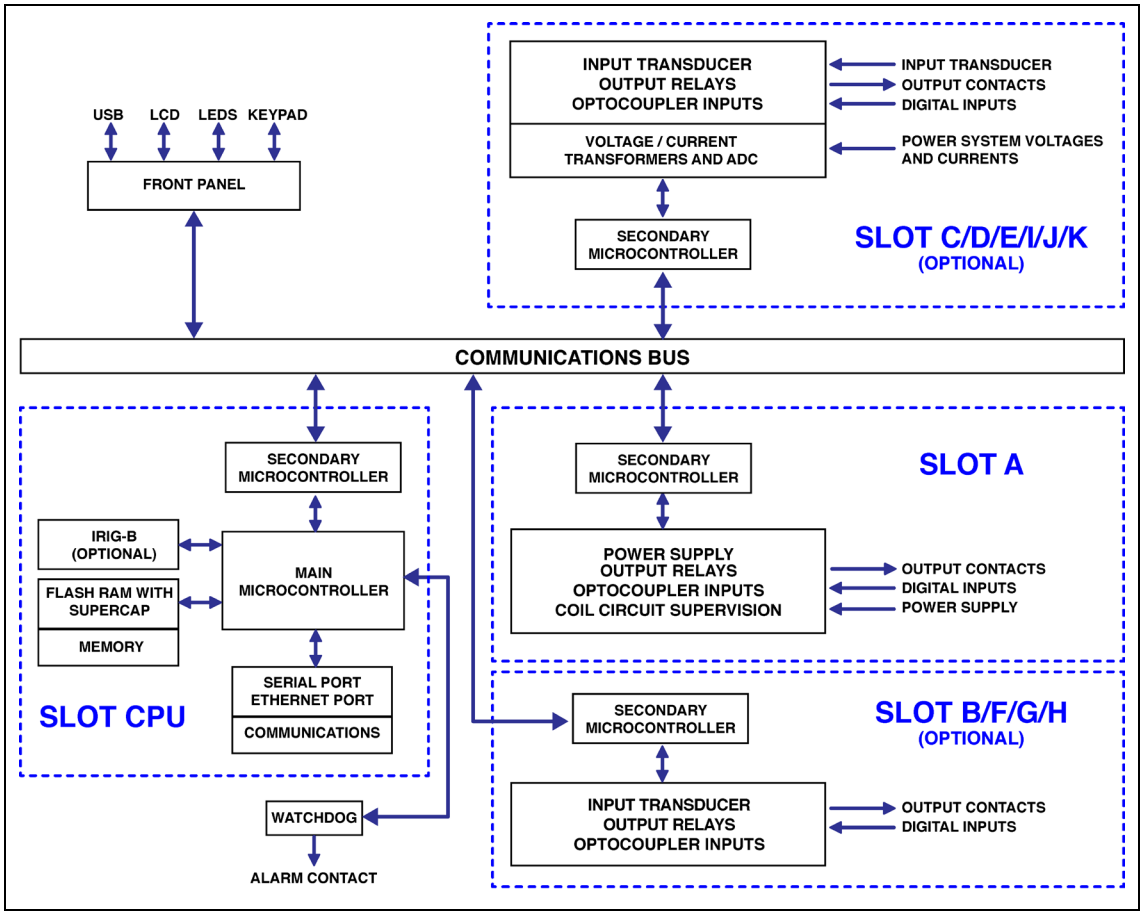


Figure 1.1.1 General HW Design.

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1.1.3.b Measurement Processing

DLF relays provide accurate measurement with high resolution in a broad dynamic range thanks to the high sampling frequency and the powerful measurement function they operate with.

Figure 1.1.2 (Measurement Processing) basically outlines the measurement processing from its capture point at the relay terminals, passing through the 24 bit analog digital converter and other elements up to having finally the measurement available.

After the measurement transformers, the relay is provided with a signal adapting stage together with analog low pass filter (antialiasing filter+ filter to strengthen the relay electromagnetic disturbance response). The A / D converter has an initial sampling frequency of 1 MHz. After applying a digital antialiasing filter, the A / D converter will generate, with a 24 bit resolution, an output frequency of 4800 Hz, in accordance with IEC 61869-9. The microcontroller included in each analog board performs two consecutive resamplings: the first, at 4800 Hz, to correct the magnitude and angle error introduced by the measurement chain (measurement transformers, analog filters, etc.). The second, at 80 samples / cycle, to adapt the sampling frequency to the network frequency (Frequency Tracking), ensuring, in this way, a correct RMS measurement in the 15 to 80 Hz frequency range. The adaptation to the network frequency will be carried out provided the PLL element enable setting (refer to section 3.2) is set to **YES**.

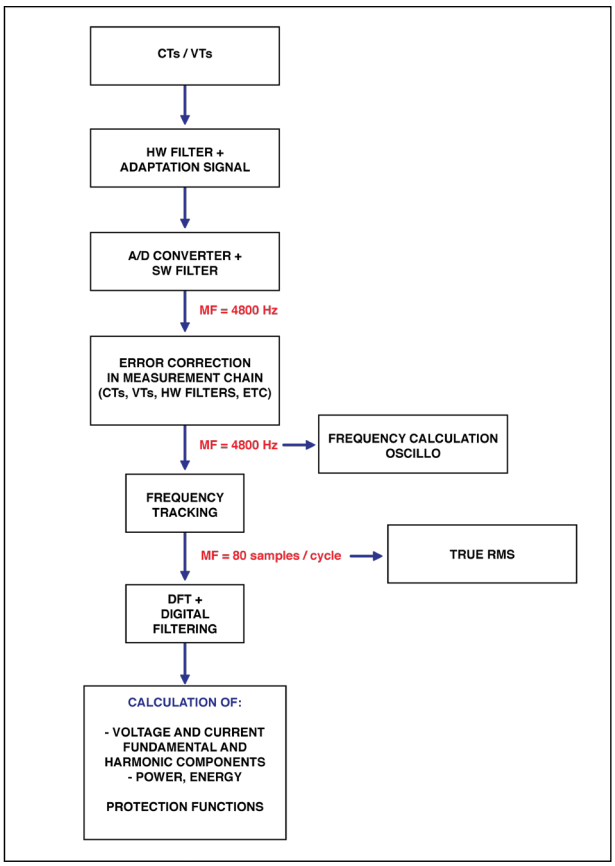


Figure 1.1.2 Measurement Processing.

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1.1.3.c Memory and Internal Clock

DLF relays include two different types of storage memory. All the relevant data will remain in non-volatile flash memory:

- Protection settings.
- Control logic.
- Events.
- Fault reports.
- Oscillography.
- Memorized LEDs.

In order to perform an adequate Flash memory management, the transference of data contained in circular records (Events and Fault Reports) will be made through a RAM powered by capacitors to be able to manage properly the task related to writing in Flash memory. In this way, data is stored firstly in the RAM memory to be later transferred periodically to the Flash memory. Memorized control logic signals (as well as the memorized LEDs, active table status, cumulative energy measurement, cumulative thermal image measurement, cumulative KA2 measurement, maximum and minimum current, voltage and power recordings, and recloser operating status) will always be stored into this RAM.

The relay RAM memory and the internal clock are powered by capacitors. This system keeps both the data stored and the internal clock around two weeks.

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1.1.4 Functional Diagram

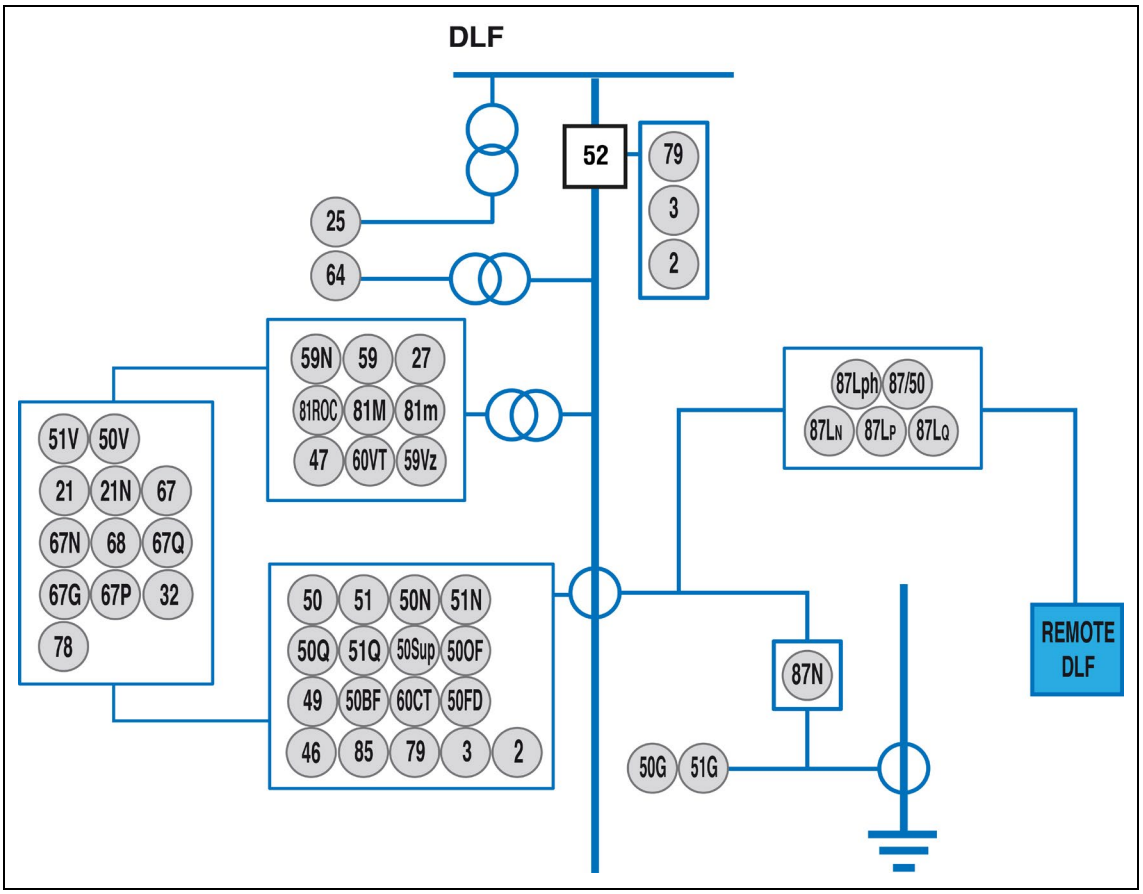


Figure 1.1.3 Functional Diagram.

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1.2 Model Selection

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1.2.1 Hardware Model Selection

The options available for configuring the model vary depending on the type of enclosure / chassis. According to the specific equipment, there will be 1/3, 1/2 or 1 x 19" rack models.

1.2.1.a 1/2 19" Rack Models

DLF		-									0	0	0	0
1-2-3	4		5	6	7	8	9	10	11	12	13	14	15	16

4	**Function**			
	A	Single/three-phase trip for Single-Breaker and 2/3 Terminal Lines.	**B**	Single / Three Phase Trip & Fast subcycle distance protection for double breaker/breaker and a half Bay with CT group in the line. 2-3 Terminal Line.
5	**User interface**			
	1	Standard with alphanumeric display.	**4**	Extended buttons with graphic display.
	2	Standard with graphic display.		
6	**DI Auxiliary Supply Voltage**			
	A	Selectable by Software.	**D**	125 VDC
	B	24 VDC	**E**	250 VDC
	C	48 VDC		
7	**Enclosure/Chassis and Conformal Coat**			
	2	6U x 19" 1/2 Rack. Conformal Coated Circuit Boards. Blade Terminal.	**5**	6U x 19" 1/2 Rack. Conformal Coated Circuit Boards. Ring Lug Terminal.
	A	6U x 19" 1/2 Rack. Conformal Coated Circuit Boards. Blade Terminal with Short-Circuitable (SC) connectors.	**C**	6U x 19" 1/2 Rack. Conformal Coated Circuit Boards. Ring Lug Terminal with Short-Circuitable (SC) connectors.
8	**Slot A**			
	1	24 - 60 VDC (±20%) 16DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO+ 1 Alm. DO.	**4**	90 - 250 VDC (±20%) and 100 – 240 VAC (-15%/+10%) 16DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO+ 1 Alm. DO.
9	**Slot B**			
	2	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 2 IT (-5 to 20mA).	**5**	20 DI (all independent).
			6	17 DO (6DO NO/NC).
	3	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 1 IT (-5 to 20mA) + 1 IT (0-300VDC).	**7**	6 DI (Dis distributed in 2 groups) (2 coil supervision, each one will use one group of 3 DIs) + 6 HSHD DO + 6 DO (2DO NO/NC).
10	**Slot C**			
	2	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 2 IT (-5 to 20mA).	**7**	6 DI (Dis distributed in 2 groups) (2 coil supervision, each one will use one group of 3 DIs) + 6 HSHD DO + 6 DO (2DO NO/NC).
	3	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 1 IT (-5 to 20mA) + 1 IT (0-300VDC).	**B**	5V + 5I (only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability or models with Single Breaker Bay configuration capability with SC connectors).
	5	20 DI (all independent).		
	6	17 DO (6DO NO/NC).		
11	**Slot D**			
	B	5V + 5I (only for models with Single Breaker Bay configuration capability without SC connectors).	**J**	2V. Extension for 21, 87L, 50/51 of breaker and a half with Line CT (only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability without SC connectors).
12	**Slot E**			
	Z	Communication board 87L.		

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0	0					-
17	18	19	20	21	22	

19	**Communication Interface 1-2 for Remote Communication (PROCOME, MODBUS, DNP3)**			
	A	RS232 Full Modem - RS232/RS485.	**C**	GFO ST - RS232/RS485.
	B	RS232 Full Modem - GFO ST.	**D**	GFO ST - GFO ST.
20	**Communication Interfaces for Relay to Relay Communication (87L/21)**			
	D	2 x Socket for SFP* (GFO LC).	**E**	2 x Multimode GFO ST.
21	**ETHERNET Interfaces 1 and 2**			
	1	10/100/1000BASE-T Connectors (RJ45).	**3**	100BASE-FX Connectors (Multimode GFO ST).
	2	Slot (socket) for SFP* (1000BASE-SX/LX & 100BASE-FX Connectors Multimode GFO LC).		
22	**ETHERNET Interfaces 3 and 4**			
	0	None.	**3**	100BASE-FX Connectors (Multimode GFO ST).
	1	10/100/1000BASE-T Connectors (RJ45).		
	2	Slot (socket) for SFP* (1000BASE-SX/LX & 100BASE-FX Connectors Multimode GFO LC).		

(*) SFP interfaces are considered as accessories, and they must be additionally ordered. See Accessories.

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1.2.1.b 19" Rack Models

DLF		-								0	0	0	0	
1-2-3	4		5	6	7	8	9	10	11	12	13	14	15	16

4	**Function**			
	A	Single/three-phase trip for Single-Breaker and 2/3 Terminal Lines.	**B**	Single / Three Phase Trip & Fast subcycle distance protection for double breaker/breaker and a half Bay with CT group in the line. 2-3 Terminal Line.
5	**User Interface**			
	1	Standard with alphanumeric display.	**4**	Extended buttons with graphic display.
	2	Standard with graphic display.		
6	**DI Auxiliary Supply Voltage**			
	A	Selectable by Software	**D**	125 VDC
	B	24 VDC	**E**	250 VDC
	C	48 VDC		
7	**Enclosure/Chassis, Conformal Coat and I/Os terminal blocks**			
	3	6U x 19" Rack. Conformal Coated Circuit Boards. Blade Terminal.	**6**	6U x 19" Rack. Conformal Coated Circuit Boards. Ring Lug Terminal.
	B	6U x 19" Rack. Conformal Coated Circuit Boards. Blade Terminal with short-circuitable connectors.	**D**	6U x 19" Rack. Conformal Coated Circuit Boards. Ring Lug Terminal with short-circuitable connectors.
8	**Slot A**			
	1	24 - 60 VDC (±20%) 16DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO+ 1 Alm. DO.	**4**	90 - 250 VDC (±20%) and 100 – 240 VAC (-15%/+10%) 16DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO+ 1 Alm. DO.
9	**Slot B**			
	2	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 2 IT (-5 to 20mA).	**5**	20 DI (all independent).
			6	17 DO (6DO NO/NC).
	3	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 1 IT (-5 to 20mA) + 1 IT (0-300VDC).	**7**	6 DI (Dis distributed in 2 groups) (2 coil supervision, each one will use one group of 3 DIs) + 6 HSHD DO + 6 DO (2DO NO/NC).
10	**Slot C**			
	2	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 2 IT (-5 to 20mA).	**5**	20 DI (all independent).
			6	17 DO (6DO NO/NC).
	3	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 1 IT (-5 to 20mA) + 1 IT (0-300VDC).	**7**	6 DI (Dis distributed in 2 groups) (2 coil supervision, each one will use one group of 3 DIs) + 6 HSHD DO + 6 DO (2DO NO/NC).
11	**Slot D**			
	2	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 2 IT (-5 to 20mA).	**5**	20 DI (all independent).
			6	17 DO (6DO NO/NC).
	3	16 DI (DIs distributed in 4 groups) (2 coil supervision, each one will use one group of 3 DIs) + 7 DO (2DO NO/NC) + 1 IT (-5 to 20mA) + 1 IT (0-300VDC).	**7**	6 DI (Dis distributed in 2 groups) (2 coil supervision, each one will use one group of 3 DIs) + 6 HSHD DO + 6 DO (2DO NO/NC).
16	**Slot I**			
	0	None	**B**	5V + 5I (only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability or models with Single Breaker Bay configuration capability with SC connectors).

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						-
17	18	19	20	21	22	

17	**Slot J**			
	B	5V + 5I (only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability)	**J**	2V. Extension for 21, 87L, 50/51 of breaker and a half with Line CT (only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability).
18	**Slot K**			
	Z	Communication board 87L.		
19	**Communication Interface 1-2 for Remote Communication (PROCOME, MODBUS, DNP3)**			
	A	RS232 Full Modem - RS232/RS485.	**C**	GFO ST - RS232/RS485.
	B	RS232 Full Modem - GFO ST.	**D**	GFO ST - GFO ST.
20	**Communication Interfaces for Relay to Relay Communication (87L/21)**			
	D	2 x Socket for SFP* (GFO LC).	**E**	2 x Multimode GFO ST.
21	**ETHERNET Interfaces 1 and 2**			
	1	10/100/1000BASE-T Connectors (RJ45).	**3**	100BASE-FX Connectors (Multimode GFO ST).
	2	Slot (socket) for SFP* (1000BASE-SX/LX & 100BASE-FX Connectors Multimode GFO LC).		
22	**ETHERNET Interfaces 3 and 4**			
	0	None.	**3**	100BASE-FX Connectors (Multimode GFO ST).
	1	10/100/1000BASE-T Connectors (RJ45).		
	2	Slot (socket) for SFP* (1000BASE-SX/LX & 100BASE-FX Connectors Multimode GFO LC).		

(*) SFP interfaces are considered as accessories, and they must be additionally ordered. See Accessories.

1.2.1.c Definition of Slots

Slot: each of the vertical layouts of the protection relay. See Chapter 1.5, Physical Description and Chapter 1.9, Schemes and Drawings. 6 slots for 1/2 rack IED and 8 slots for 19” rack IED.

Possible provisions of the different Slots for models without Short-Circuitable connectors:

Rack	19” Rack Models											
Slots	A	B	C	D	E	F	G	H	I	J	K	CPU
Power Supply	**X**				**0**	**0**	**0**	**0**				**X**
Inputs / Outputs	**X**	**X**	**X**	**X**								
V / I Analog Channels									**X***	**X**		
87L											**X**	

Rack	1/2 19” Rack Models					
Slots	A	B	C	D	E	CPU
Power Supply	**X**					**X**
Inputs / Outputs	**X**	**X**	**X**			
V / I Analog Channels			**X***	**X**		
87L					**X**	

In Slot B only the card with digit 7 will be allowed while in slot C cards with digits 2, 3, 6 and 7 will be allowed.

(*) Only for models with Double Breaker or Breaker-and-a-Half Bay configuration capability.

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Possible provisions of the different Slots for models with Short-Circuitable connectors:

Rack	19" Rack Models											
Slots	A	B	C	D	E	F	G	H	I	J	K	CPU
Power Supply	X					0	0	0				X
Inputs / Outputs	X	X	X	X	X							
V / I Analog Channels									X			
87L											X	

Rack	1/2 19" Rack Models					
Slots	A	B	C	D	E	CPU
Power Supply	X					X
Inputs / Outputs	X	X				
V / I Analog Channels			X			
87L					X	

In Slot B only the card with digit 7 will be allowed while in slot C cards with digits 2, 3, 6 and 7 will be allowed.

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1.2.1.d Accessories

Accessory devices should be ordered if needed. The necessary SFP interfaces must be provided by **ZIV**. All SFP interfaces sold by **ZIV** have been tested and homologated to ensure compatibility of both the application and external standard devices (for example, SDH/MPLS-TP multiplexers and converters for C37.94 protocol in the case of SFPs used for the 87L function), the operation in temperature range and the optical reach of the same. Therefore, the correct operation of the relays is only guaranteed if SFP interfaces are provided by **ZIV**.

ACCESORIES	REFERENCE
SFP ETHERNET Interfaces	
100BASE-FX Multimode Connectors GFO LC (2 units)	**2 x 4CZ07980007**
SFP 87L Interfaces	
Multimode GFO LC 850nm 2km (units depending on the configuration) with DDM (Digital Diagnostic Monitoring)	**4CZ07980014**
Multimode GFO LC 850nm 2km (units depending on the configuration) without DDM	**4CZ07980018**
Singlemode GFO LC 1310nm 30km (units depending on the configuration) without DDM	**4CZ07980017**
Singlemode GFO LC 1310nm 40km (units depending on the configuration) with DDM	**4CZ07980013**
Singlemode GFO LC 1550nm 120km (units depending on the configuration) with DDM	**4CZ07980015**
Singlemode GFO LC 1550nm 120km (units depending on the configuration) without DDM	**4CZ07980016**
Installation	
Iron Angles (right & left) for 1 Rack mounting	**2 x 4PF02090080**
Angles (left and right) for 1 Rack mounting (for 1 equipment of 1/2 rack)	**2 x 4PF02090095**
Angles (left and right) for 1 Rack mounting (for 1 equipment of 1/3 rack and 1 equipment of 1/2 rack)	**2 x 4PF02090097**
Iron Sheet for assembling of 2 devices together	**2 x 4PF02090081**
Iron Angles (upper-right & upper-left & lower-right & lower-left) for flush mounting	**4GL01950851**
Kit for IP54	**2 x 4PV01180026 +** **2 x 4PV01180029**

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1.2.2 Firmware Model Selection

			*	*	*	*	*
23	24	25	26	27	28	29	30

23	**Remote Communication Protocols** **2** PROCOME, MODBUS, DNP3.0, IEC 61850 Ed. II.
24	**Protection** **0** Initial version.
25	**Customer Code** **Z** Last firmware.
26	**Cybersecurity** **1** Basic cybersecurity. **3** Basic cybersecurity + Remote authentication (LDAP & RADIUS) + Enhanced firmware securitization + Mutual authentication + HMI authentication using user/password + Public Key Infrastructure (Basic).
27/28	**Version** **07** 05 + Modification in pickup and reset levels of overexcitation units + Configurable date format + Two directional power units. **20** 07 + COMFEDE Fault Report + Syslog: SoE + Disable IP change by HMI + Neutral current in the oscillograph + Trip Seal-In but No Sealing for Opening Command + Distance Unit Harmonic Blocking + CT Supervision by I2 + CT Supervision by INdiff. + Transient Earth Fault Unit TEFP. **23** Open Pole Current setting is single table + Improvements in the accuracy of inverse time overcurrent units + Instantaneous OC settable pick-up level + Timed OC settable pick-up level for definite time + Phase undervoltage is supervised by Open Pole Detector + Inverse polarity + Improvement on external fault detector algorithm for Stub Unit. **25** 23 + 59N with Pickup Reset Type setting. **28** 25 + Minimum pick up setting value of 59N, 59G and 59Q is reduced. **29** 28 + Setting minimum values of open pole and dead line current detection are reduced. **30** 29 + Phase directional units with "Self-Polarization" + 4 Overcurrent units + Overcurrent inverse time curves dial 0.01-10 + 4 Undervoltage & Overvoltage units with inverse time curves per IEC60255-121 + Setting Undervoltage Blocking by circuit breaker open + 87REF Setting Minimum level IG supervision Enable. + Voltage transducer supervision unit generates alarm status. **31** 30 + Adjustable Trip Delay setting for 50COF Unit added and COF Time setting range modified + Extended range for unit 59N. **32** 31 + Calendar with 10 connection periods with independent h/min settings + Increased Sensitivity Range of the Phase Differential Unit. **33** 32 + Fifth Subfrequency Unit added + Overvoltage Lockout Setting added to Synchronism Unit.
29/30	**Ethernet and Serial Ports Communication Version** **52** Communication protocols Ethernet ports: 1 PROCOME instance + 4 configurable instances (PROCOME, DNP3 or MODBUS RTU). Communication protocols (remote port): PROCOME, DNP3 or MODBUS. Communication Redundancy: Bonding, RSTP, PRP, HSR. PTP power utility profile IEC61850-9-3. IEC 61850 Data model 5 + modifications in PVPH and LTIM LNs. **70** 52 + IEC 61850 dynamic data model + substitution service. **71** 70 (unchanged). **72** 71 + Access points management. **73** 72 + New based on IEC 61850 SyslogSoE Event Record (replaces the former SyslogSoE Event Record) + New based on IEC 61850 Fault Report. **74** 73 + Selectable Syslog protocol UDP or TCP.

(*) Non-selectable digits are defined internally.

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1.2.3 Protection Functions according to Model

ANSI	Functions	DLF-A	DLF-B
87PH	Phase Differential unit with Restraint	**1**	**1**
87PH/50	Phase Differential unit without Restraint	**1**	**1**
87N	Neutral Differential unit with Restraint	**1**	**1**
87POS	Positive Sequence Differential unit with Restraint	**1**	**1**
87NEG	Negative Sequence Differential unit with Restraint	**1**	**1**
87/50FD	Fault Detector	**1**	**1**
27FD	Fault Detector in Weak Infeed conditions	**1**	**1**
87P	External Fault Detector	**1**	**1**
64REF	Restricted Earth Faults	**1**	**0**
50OF	Close-onto-Fault Detector	**1**	**1**
50	Phase Instantaneous Overcurrent	**3***	**4**
51	Phase Time-delayed Overcurrent	**3***	**4**
50N	Neutral Instantaneous Overcurrent (calculated IN)	**3***	**4**
51N	Neutral Time-delayed Overcurrent (calculated IN)	**3***	**4**
50Q	Negative Sequence Instantaneous Overcurrent	**3***	**4**
51Q	Negative Sequence Time-delayed Overcurrent	**3***	**4**
50G	Ground Instantaneous Overcurrent	**3***	**4**
51G	Ground Time-delayed Overcurrent (measured IG)	**3***	**4**
50STUB	STUB Bus Protection	**0**	**0**
50V	Voltage Dependent Instantaneous Overcurrent	**3**	**0**
51V	Voltage Dependent Time-delayed Overcurrent	**3**	**0**
67	Phase Directional	**1**	**1**
67N	Neutral Directional	**1**	**1**
67G	Ground Directional	**1**	**1**
67P	Positive-Sequence Directional	**1**	**1**
67Q	Negative Sequence Directional	**1**	**1**
	Harmonics Blocking	**1**	**1**
49W	Line Thermal Image (configurable with RMS or TRUE RMS)	**1**	**1**
49G	Neutral Thermal Image (configurable with RMS or TRUE RMS)	**0**	**0**
26	Hot Spot Thermal Image	**1**	**0**
50OL	Overload Instantaneous unit	**1**	**0**
51OL	Overload Time-delayed unit	**1**	**0**
27	Phase Undervoltage	**3***	**4**
59	Phase Overvoltage	**3***	**4**
59N	Neutral Overvoltage	**3***	**4**
47	Negative Sequence Overvoltage	**1**	**0**
64	Ground Overvoltage	**3***	**4**
81M	Overfrequency	**4**	**2**
81m	Underfrequency	**5***	**5***
81D	Rate of Change of the Frequency	**4**	**2**
	Load Shedding	**1**	**0**
59V/Hz	Overexcitation	**4**	**0**
25	Synchrocheck	**2**	**4**

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ANSI	Functions	DLF-A	DLF-B
50BF	Breaker Failure	**1**	**1**
	Cold Load	**1**	**1****
21N	Ground Distance Zones	**8 zones**	**8 zones**
21P	Phase Distance Zones	**8 zones**	**8 zones**
50SUP	Phase Overcurrent for Distance Supervision	**1**	**1**
	Load Encroachment	**1**	**1**
85-21	Teleprotection Schemes for Distance Units	**1**	**1**
85-67	Teleprotection Schemes for Overcurrent Units	**1**	**1**
	Open Phase Detector	**1**	**1**
	Remote Open Breaker Detector	**1**	**1**
60FF	Fuse Failure Detector	**1**	**1**
60VT	VT Supervision	**1**	**1**
68/78	Power Swing Detector	**1**	**1**
60CT	CT Supervision	**1**	**1**
3	Coil Supervision	**Up to 12 coils**	**Up to 12 coils**
	Breaker Supervision	**1**	**1****
	Phase Selector	**1**	**1**
	Open Pole Detector	**1**	**2**
2	Pole Discordancy	**1**	**2**
	Dead-Line Detector	**1**	**1**
	Saturation Detector	**1**	**1**
79	Recloser	**1**	**2**
	Trip logic and Command	**1**	**1**
	Fault Locator	**1**	**1**
	Multi Far-end Fault locator	**1**	**1**

(*) Depending on Firmware Model Selection.
(**) Only for single breaker.

- ## Analog Channels

Model	Analog Channels
DLF-A	VA, VB, VC, VSYNC, VG, IA, IB, IC, IPAR, IG
DLF-B	VA, VB, VC, VSYNC1, VSYNC2, VSYNC3, VG, IA, IB, IC, IPAR, IG

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1.2.4 Models Replaced by Others with Higher Functionality and Not Available Options

1.2.4.a Firmware Model Selection

			*	*	*	*	*
23	24	25	26	27	28	29	30

27/28	**Version** **00** Protection functionality: Profile 00. **05** Protection functionality: Profile 05.
29/30	**Ethernet and Serial Ports Communication Version** **00** Communication protocols Ethernet ports: 1 PROCOME instance + 4 configurable instances (PROCOME, DNP3 or MODBUS RTU). IEC61850 Data model 0. Communication protocols (remote port): PROCOME, DNP3 or MODBUS. Communication Redundancy: Bonding, RSTP, PRP, HSR. PTP power utility profile IEC61850-9-3. **50** Communication protocols Ethernet ports: 1 PROCOME instance + 4 configurable instances (PROCOME, DNP3 or MODBUS RTU). IEC61850 Data model 5. Communication protocols (remote port): PROCOME, DNP3 or MODBUS. Communication Redundancy: Bonding, RSTP, PRP, HSR. PTP power utility profile IEC61850-9-3.

(*) Non-selectable digits are defined internally.

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1.3 Technical Data

1.3.1 Power Supply Voltage 1.3-2
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1.3.1 Power Supply Voltage

IEDs have two types of auxiliary power supplies. Depending on the model, their values are selectable:

24 - 60 VDC (±20%)
90 - 250 VDC (±20%) & 100 - 240 VAC (-15%+10%)

Note: In case of power supply failure, a maximum interruption of 100 ms is allowed for 110 VDC input.

1.3.2 Power Supply Burden

Equipment of 1/2 rack. Maximum load	**<21W** (DOs activated).
Equipment of 1 rack. Maximum load	**<26W** (DOs activated).
Maximum Inrush Current	**<1A** (at **125 VDC**).

Note: the consumption of each digital output can be up to 0.12W.
Note: consumption generated by connected SFPs is not included.

1.3.3 Current Analog Inputs

Phase, Neutral and Polarization Currents

Frequency Range	**50 Hz**, **60 Hz**
Nominal Value	**In** = **5 A** or **1 A** (selectable in the IED)
Measurement Range	**0** - **40 A** x **In**
Thermal Withstand Capability	**4 A** x **In** (continuously) **30 A** x **In** (for 10 s) **100 A** x **In** (for 1 s)
Current Circuits Burden	**<0.2 VA** (**In** = **5 A** or **1 A**)

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1.3.4 Voltage Analog Inputs

Frequency Range	**50Hz**, **60Hz**
Nominal Value	**Un = 50** to **230 VAC** (selectable in the equipment)
Measurement Range	**0 - 300 V**
Thermal Withstand Capability	**300 VAC** (continuously) **400 VAC** (for 10s)
Voltage Circuits Burden	**<0.1 VA** (110/120 VAC)

1.3.5 Frequency

Operating range	**15 - 80 Hz**

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1.3.6 Measurement Accuracy at Environment Temperature (25ºC)

Measured currents	**±0.25%** or ±2 mA (the greater)
Phase, Ground, Ground Par	for 0.1*Inom≤I<1*Inom
	±0.2% for 1*Inom≤I≤5*Inom
Calculated currents	
Phase-Phase	**±0.2%** or **±6 mA** (the greater)
Neutral, I_1, I_2 and I_0	**±0.3%** or **±8 mA** (the greater)
	for 0.1*Inom<I≤5*Inom
Measured voltages	**±0.2%** or **±50 mV** (the greater)
Phase-Ground, Phase-Phase, Ground	for 0.2 V≤V<130 V
and Synchronism	**±0.25%** for 130 V≤V≤250 V
Calculated voltages	
Phase-Phase	**±0.3%** or **±75 mV** (the greater)
	for 0.2V≤V≤300 V
VNeutral, V_1, V_2 and V_0	**±0.3%** or **±100 mV** (the greater)
	for 0.2 V≤V≤250 V
Active and reactive powers	**±0.33% W/Var** (0º or ±90º or 180º)
(In = 1A and 5A and I_{phases}>1A calculated as	**±1.6% W/Var** (±45º or ±135º)
sum of the single-phase powers)	**±5% / 0.65% W** (±75º / ±115º)
Minimum current required to calculate the Power	4**mA**
Angles	**±0.5º**
Phase/Ground/Ground par Current	**±0.5º** for **0.1 A< I <25 A**
	±1º for **60 mA< I <100 mA**
Neutral Currents	**±0.5º** for **0.1 A< I <25 A**
	±1º for **60 mA< I <100 mA**
Sequence Currents (I1 and I2)	**±0.5º** for **0.1 A< I <25 A**
	±1º for **20 mA< I <100 mA**
Ground and Phase Voltages	**±0.5º** for **0.2 V< V <250 V**
	±1º for **50 mV< I <200 mV**
Sequence Voltages (V1 and V2)	**±0.5º** for **0.2 V< V <250 V**
	±1º for **50 mV< I <200 mV**
Power Factor	**±0.013**
Frequency	**±0.005 Hz** for **41<Fq<69Hz**

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Signal Processing

The equipment has the "Frequency Tracking" function to adapt the sampling frequency to the network frequency and, in that way, ensure accurate measurement of effective value in the frequency range of 15 to 80 Hz.

*The calculation of the network frequency is done by measuring the period of the network voltage which, at the same time, is calculated by measuring the time between the zero steps of the Alpha component of the Clark transform of said voltage (2 * Va – Vb – Vc) / 3). To prevent the offset, and high frequency signals, from producing an error in the frequency measurement, a cosine filter is applied to the alpha component of the Clark transform.*

Once the network frequency has been calculated, the sampling frequency of the analog channels is adapted, so that at all times it is 80 samples per cycle. In this way, the measurement algorithm maintains correct operation throughout the entire network frequency range (between 15 and 80 Hz).

When Protection and Control tasks are readjusted in accordance with the sampling function, phasor real and imaginary components of analog signals are calculated by means of the Fourier transform. Fourier components are calculated by means of said Discrete Fourier Transform (DFT) using 80 sample/cycle. Using DFT this way the magnitude and phase angle of the fundamental component at power system frequency of every analog input signal is obtained. The rest of measurements and calculations of Protection functions is obtained based on the fundamental components calculated by the Fourier method. DFT gives a precise measurement of the fundamental frequency component and it is an efficient filter for harmonics and noise.

For frequencies other than the rated frequency, harmonics are not fully attenuated. For small deviations of ±1Hz this is not a problem but, in order to admit higher operating frequency deviations, the setting automatic conversion to the sampling frequency, PLL, is included. In the absence of an adequate signal to carry out the conversion of the sampling frequency or with the setting PLL disabled, the frequency will be converted to the rated frequency at which the relay is operating (50/60Hz).

Angle reference for relay measurements is the channel VA or IA as per the setting.

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1.3.7 Effect of Temperature in Measurement Accuracy

Temperature Range	**-25ºC** to **70ºC** (operating range)
Measured Currents	for 0.1*Inom≤I<1*Inom
Any current channels	**±0.35%**
	for -25ºC ≤x≤20ºC
	for 1*Inom≤I≤5*Inom
	±0.15%
	for -25ºC ≤x≤5ºC
Measured Voltages	for 0.2 V≤V<1 V
Any voltage channel	**±0.35%**
	for 40ºC ≤x≤70ºC
	for 1 V≤V≤250 V
	±0.1%
	for -25ºC ≤x≤-5ºC

Note: These error margins will be added to the measurement accuracy at environment temperature ones. In the temperature range which is not defined, the measurement accuracy is not affected.

1.3.8 Accuracy of the Pickup and Reset of the Differential Units

Differential Units	
Pickup and Reset	**±3 %** or **±50mA**
	of the theoretical value (the greater)
	(for In = 1A and 5A)

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1.3.9 Measurement of Average Times of the Differential Unit with Restraint

Time Measurement			
Blocking Type	**Enable**	**Times I0 (Sensitivity)**	**Measuring Times (**)**
			50Hz
Blocking or Harmonics Restraint	NO*	1.5	26 ms
		5	20 ms
		15	16 ms

(*) The trip time, when the setting is 0 s, is reduced up to 5 ms using digital HSHD outputs. The point to point communication speed of 2Mbits has been used.

1.3.10 Measurement of Average Times of the Differential Unit without Restraint

Times Pickup	**Time Measurement (*)**
	50Hz
1.5	35 ms
5	15 ms
15	14 ms

(*) The trip time, when the setting is 0 s, is reduced up to 5 ms using digital HSHD outputs. The point to point communication speed of 2Mbits has been used.

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1.3.11 Influence of the Communications Speed on the Tripping Times of the Differential Unit

Times Pickup	Communication speed (kbits)	Time Measurement (*)
		50Hz
1.05	64	46.67 ms
	128	47.93 ms
	192	45.60 ms
	256	44.43 ms
	320	44.97 ms
	384	44.07 ms
	448	41.13 ms
	512	40.77 ms
	576	40.40 ms
	640	40.10 ms
	704	40.20 ms
	768	39.43 ms
	2000	37.93 ms
3	64	34.47 ms
	128	34.53 ms
	192	32.43 ms
	256	32.27 ms
	320	31.93 ms
	384	32.23 ms
	448	27.70 ms
	512	28.20 ms
	576	27.80 ms
	640	27.33 ms
	704	28.37 ms
	768	27.17 ms
	2000	24.90 ms

(*) The trip time, when the setting is 0 s, is reduced up to 5 ms using digital HSHD outputs. The point to point communication speed of 2Mbits has been used.

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1.3.12 Accuracy of the Pickup and Reset of the Distance Elements

Distance Elements	
Pickup in Line Angle (static test)	**±5%** or **±0.01** Ω **(V>0.5 V)** of the theoretical value (the greater)

Time Measurement	
Fixed Time	**±1%** of the setting or **±35 ms** (the greater)

1.3.13 Trip Time of Distance Elements

The following diagrams show the operating times of distance elements for different SIR (**System Impedance Ratio**) and different fault percentage with respect to the zone reach.

$SIR = \frac{ZS}{ZL}$ Where ZS represents the local source impedance and ZL the line impedance.

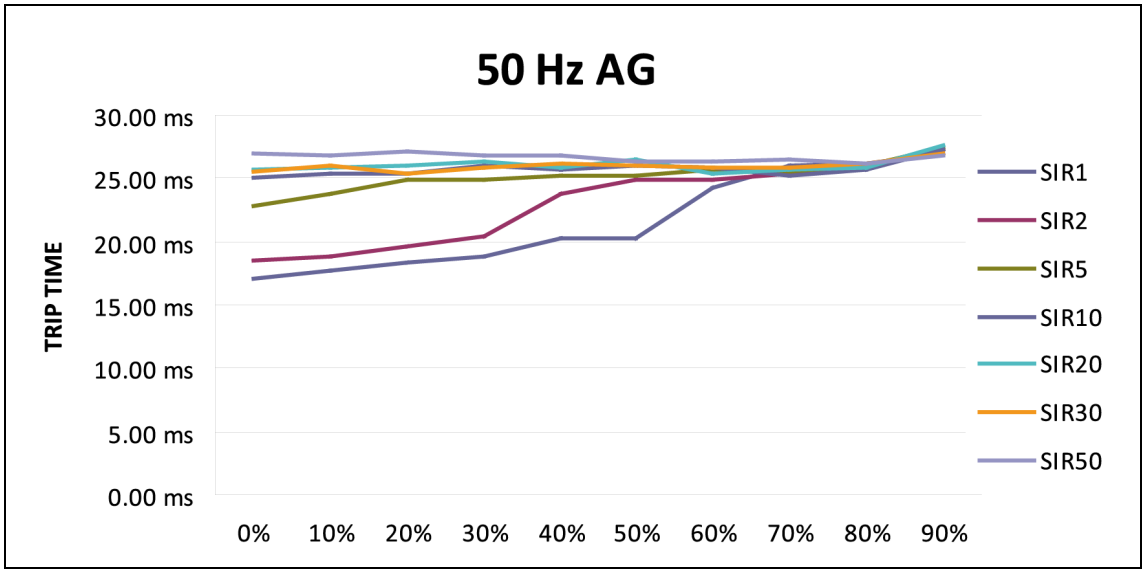


Figure 1.3.1 Trip Times for 50Hz Single-Phase Fault.

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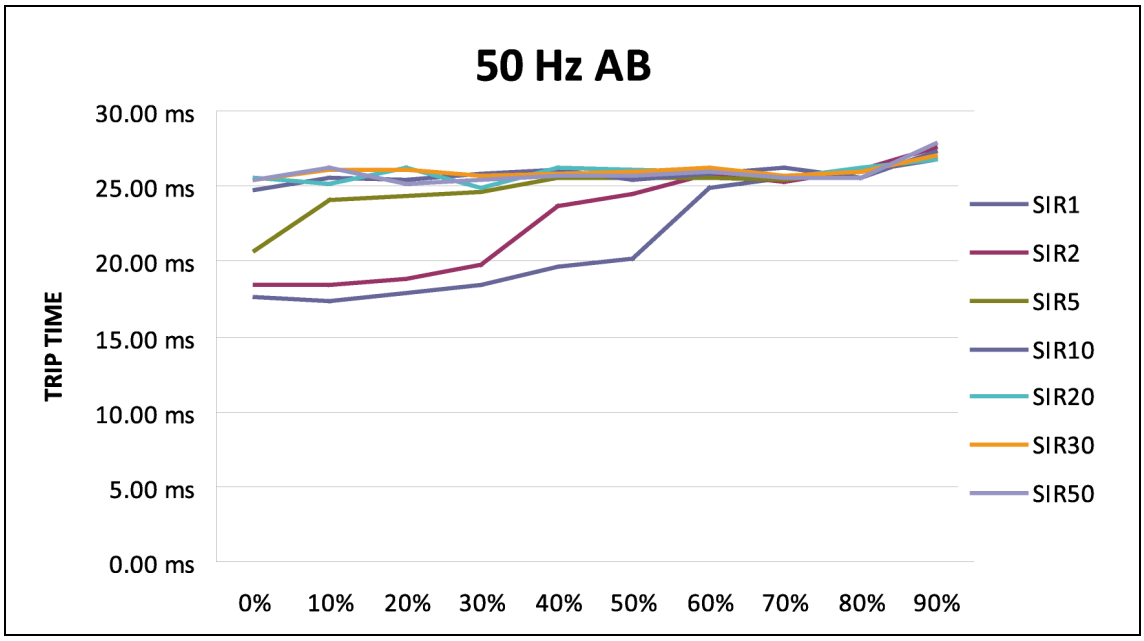


Figure 1.3.2 Trip Times for 50Hz Two-Phase Fault.

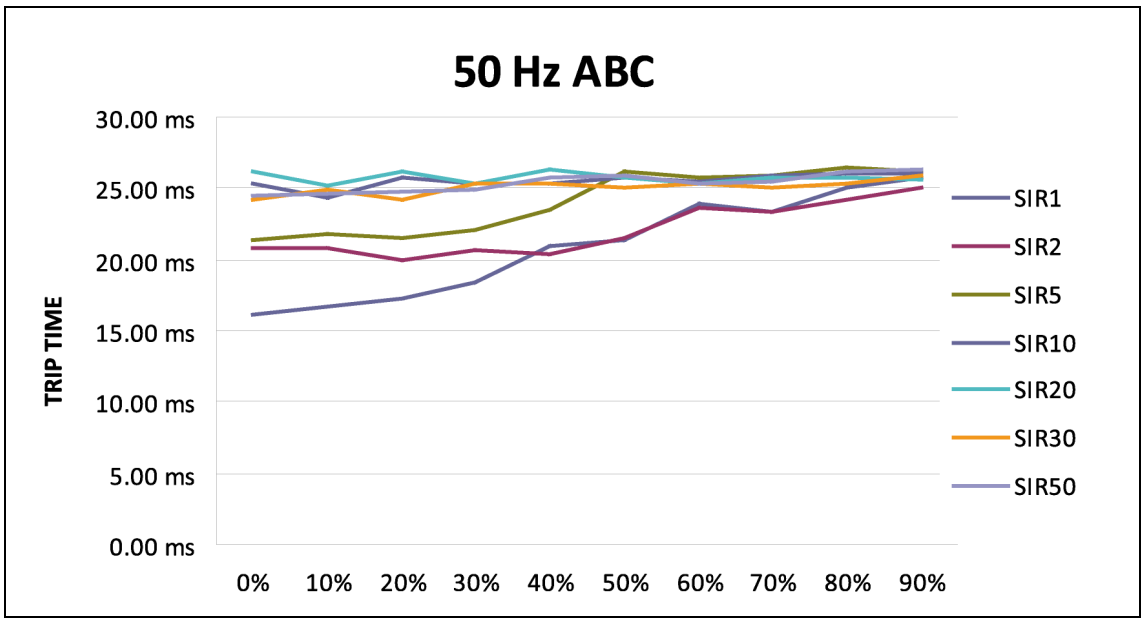


Figure 1.3.3 Trip Times for 50Hz Three-Phase Fault.

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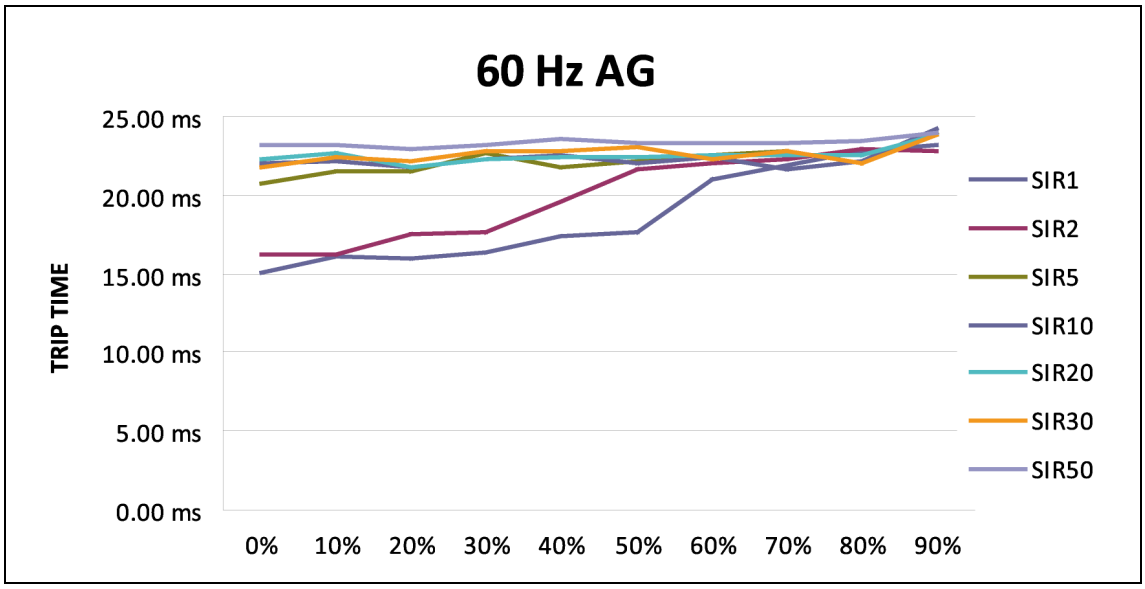


Figure 1.3.4 Trip Times for 60Hz Single-Phase Fault.

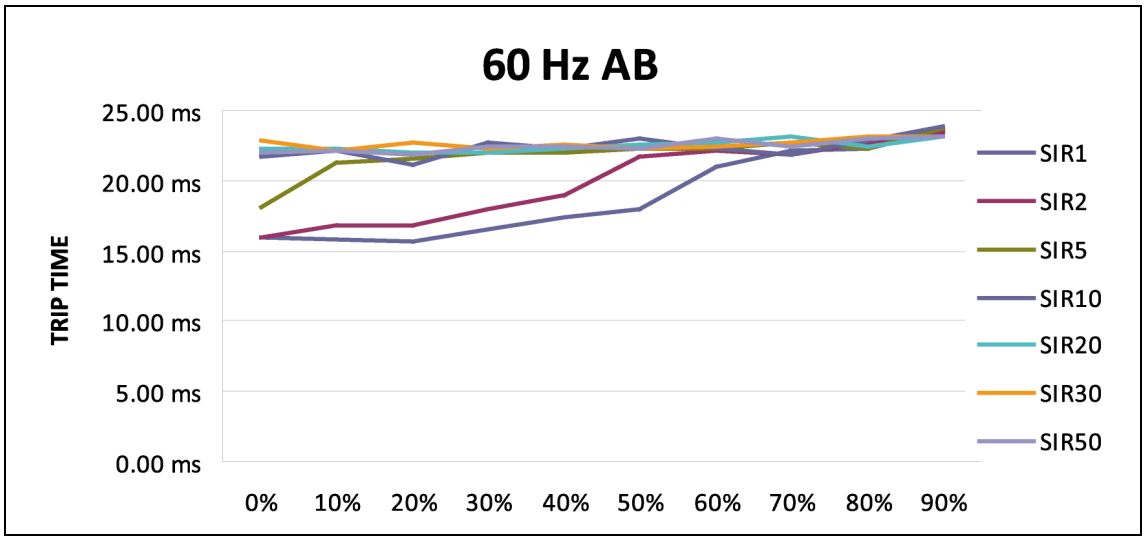


Figure 1.3.5 Trip Times for 60Hz Two-Phase Fault.

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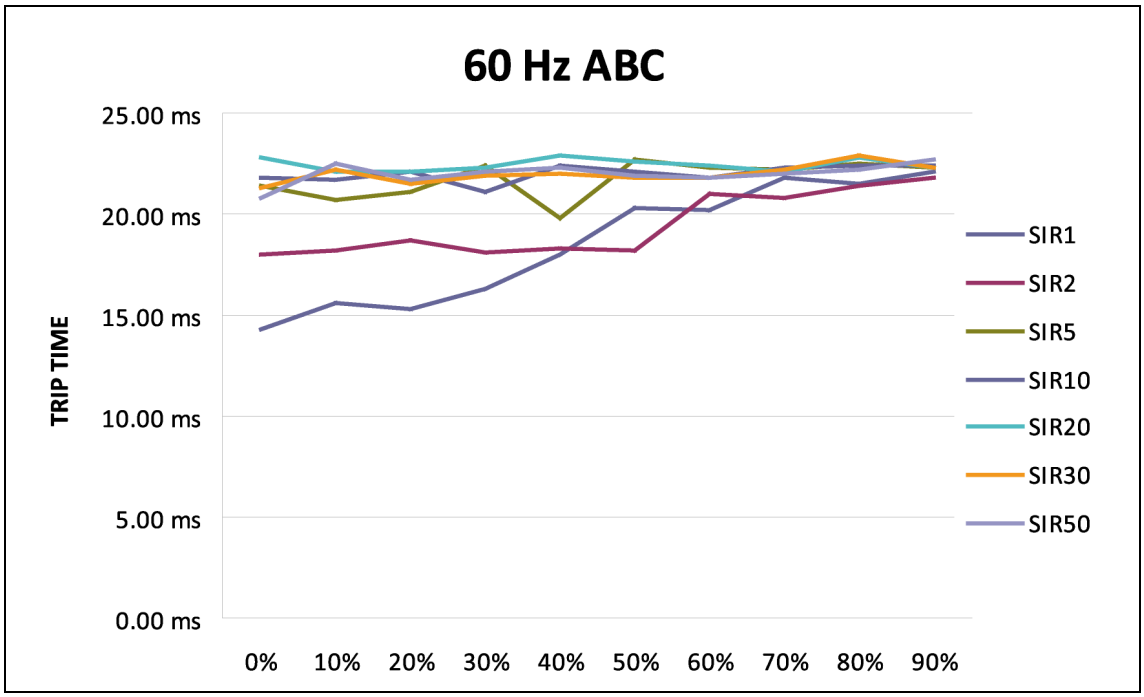


Figure 1.3.6 Trip Times for 60Hz Three-Phase Fault.

Note: Trip Times have been obtained with fast trip outputs HDSD.

1.3.14 Accuracy of the Pickup and Reset of the Overcurrent Elements

Overcurrent Elements

Pickup of Phases, Ground, Neutral and Negative Sequence (static test)	**±3%** or **±10mA** of the theoretical value (the greater) (In = 1A and 5A)

Note: the pick-up of overcurrent units takes place with a current value equal to 1.05 times the pick-up setting.

Reset of Phases, Ground, Neutral and Negative Sequence	**1.5 cycles** for 50 and 60Hz (*)

(*) If the reset time is measured using electromechanical DOs there will be an extra increment of up to ½ cycle.

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Time Measurement				
Mode	**Time Setting**	**Times Pick up**	**Time Measurement**	
			50Hz	**60Hz**
Fixed Time	0 s	1.5	±22 ms	±21 ms
		5	±13 ms	±13 ms
		15	±12 ms	±12 ms
Fixed Time	> 0 s		±1 % of the setting or ±25 ms (the greater)	
Inverse Time			Class 2 (E = 2) or ±35ms (the greater) (*) (UNE 21-136, IEC 255-4) (for measured currents of 100mA or greater). (*) In IEEE Extremely inverse curve the time error could reach 56 ms.	

The trip time, when the setting is 0 s, is reduced up to 5 ms using digital HSHD outputs.

Measuring Times with HSHD outputs					
Mode	**Torque Control**	**Time Setting**	**Times Pick up**	**Measuring Times**	
				50Hz	**60Hz**
Fixed Time	NO	0 s	1.1	±25 ms	±25 ms
			1.5	±20.5 ms	±17 ms
			5	±9.5 ms	±8.5 ms
			15	±8.5 ms	±7.5 ms
Fixed Time	YES	0 s	1.5	±31 ms	±29 ms
			5	±24.5 ms	±20.4 ms
			15	±18.4 ms	±17 ms
				±16.5 ms	±16.3 ms

Measuring time of a curve depending overcurrent unit is influenced not only by the time tolerance but also by the current pickup so both tolerances will be taken into account to calculate the accuracy of the unit.

1.3.15 Repeatability

Operating Time	**2 %** or **25 ms** (the greater)

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1.3.16 Accuracy of the Pickup and Reset of the Thermal Image Element

Activation Time	**10 %** or **0.08 min** for time **< 10 sec** **2 %** or **0.08 min** for time **> 10 sec**
Reset Time	**10 %** for time **< 10 sec** **2 %** for time **> 10 sec**

1.3.17 Accuracy of the Pickup and Reset of the Voltage Elements

Overvoltage and Undervoltage Elements

Pickup (static test)	**±2%** or **±250 mV** of the theoretical value (the greater)
Reset	**1.5 cycles** for 50 and 60Hz (*)

(*) If the reset time is measured using electromechanical DOs there will be an extra increment of up to ½ cycle.

Time Measurement

Mode	Time Setting	Time Measurement *	
		50Hz	60Hz
Fixed Time	0 s	16 ms	14.5 ms
Fixed Time	> 0 s	±1% of the setting or ±25 ms (the greater)	

(*) The trip time, when the setting is 0 s, is reduced up to 5 ms using digital HSHD outputs.

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1.3.18 Accuracy of the Pickup and Reset of the Frequency Elements

Overfrequency Elements	**±0.005 Hz** of the theoretical value
Pickup and reset	for **41<Fq<69 Hz**
	±0.01 Hz of the theoretical value
	for **Fq<41** and **Fq>69 Hz**
Underfrequency Elements	**±0.005 Hz** of the theoretical value
Pickup and reset	for **41<Fq<69 Hz**
	±0.01 Hz of the theoretical value
	for **Fq<41** and **Fq>69 Hz**
Measuring Times	**±1%** of the setting or **±25 ms**
Fixed Time	(the greater)

The total trip time is equal to the adjusted fixed time plus the time defined in "Activation Half-time" (see 5.2, Frequency Units).

1.3.19 Accuracy of the Reclosing Cycle Times

Accuracy	**1%** or **±20ms** (the greater)

1.3.20 Transient Overreach

Expressed as: $ST = \frac{I_A - I_T}{I_A} x100$

<10% for totally inductive lines
<5% for lines with an impedance angle of 70º

I_A = Pick up value for a current with no DC component
I_T = Pick up value for a current with maximum DC offset

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1.3.21 Digital Inputs

Configurable inputs (depending on the setting) with polarity (all the Inputs are DC are isolated by octocoupler).

Digital inputs with configurable activation threshold:

Nominal Voltage	Maximum Voltage	Burden	V ON / OFF (*)
24 VDC (*)	48 VDC	38 mW	Configurable
48 VDC (*)	90 VDC	75 mW	Configurable
125 VDC (*)	300 VDC	195 mW	Configurable
250 VDC (*)	300 VDC	390 mW	Configurable

Digital inputs with non-configurable activation threshold:

V Nominal Voltage	Maximum Voltage	Burden	V ON / OFF
24 VDC (*)	48 VDC	36 mW	15 V / 10 V
48 VDC (*)	90 VDC	72 mW	38 V / 25 V
125 VDC (*)	300 VDC	175 mW	80 V / 60 V
250 VDC (*)	300 VDC	350 mW	130 V / 96 V

(*) ED ON if VDC ≥ Setting
ED ON/OFF if Setting – X < VDC < Setting
ED OFF if VDC ≤ Setting - X

VDC= Supply voltage of the digital inputs.
Setting= Activation threshold (range 15 - 200VDC).
Hysteresis: X = 10 V if 15 V < *Activation Threshold* setting< 60 V
X = 20 V if 60 V ≤ *Activation Threshold* setting ≤ 200 V

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1.3.22 Breaker Trip and Close Outputs and Auxiliary Outputs

Outputs (electromechanical relay)
All relay contacts have the same physical features and all are configurable with the exception of the relay in service /failed.

I DC maximum limit (with resistive load)	**60 A** 1s
I DC continuous service (with resistive load)	**16 A**
Close	**5000 W**
Breaking capability (with resistive load)	**72 W** (**1.5 A - 48 VDC**) **60 W** (**0.5 A - 125 VDC**) **75 W** (**0.3 A - 250 VDC**)
Break (L/R = 0.04 s)	**60 W** at **125VDC**
Switching voltage	**250 VDC**
Momentary close time trip contacts remain closed	**100 ms**
Break delay	**<150 ms**

Fast Outputs HSHD (High Speed High Duty)
They do not require a certain polarity. All are configurable.

I DC maximum limit (with resistive load)	**60 A** 1s
I DC continuous service (with resistive load)	**16 A**
Close	**5000 W**
Breaking capability (with resistive load)	**10 A** (for **250/125/48/24VDC**)
Break (L/R = 0.04 s)	**10 A** (for **250/125/48/24VDC**)
Switching voltage	**250 VDC**
Momentary close time trip contacts remain closed	**100 ms**
Break delay	**<150 ms**

Contact Performance Test according to ***IEC60255-1 6.11***.

Mechanical endurance unloaded	**10000 cycles**.
Making capacity	**125 VDC** / **8.05 A** / **1006 W** / **R/L 0.04** / **1000 cycles**.
Breaking capacity	**125 VDC** / **0.242 A** / **30.3 W** / **R/L 0.04** / **1000 cycles**.
Continuous contact current	**5 A** / **125 VDC**.
Short time contact current	**30 A** / **125 VDC** / **Ton 200 ms** / **Toff 15 s** / **1000 cycles**.

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1.3.23 Input Transducers

-20mA to 20mA Input Transducers

Input impedance	**196 Ω ±5%**
Measurement accuracy	**±0.2 %** or **±10 μA** (the greater)

10V to 350V Voltage Transducer

Input impedance	**150 kΩ ±10%**
Measurement accuracy	**±0.2 %** or **±0.2 V** (the greater)

1.3.24 Communications Link

Local Communications Port

USB type B 1.1 (supports cable approved for USB USB 1.1 and USB 2.0).
USB type A 2.0 (host for downloading files).

Serial Remote Communications Ports

GFO (Glass Fiber Optics), RS232/RS485, RS232-Full Modem

Serial Communications Port 87L

Glass Fiber Optics in ST connector or LC connector (via SFP modules)

Glass Fiber Optics (Remote Ports)

Type	**Multimode**
Wavelength	**820 nm**
Connector	**ST**
Transmitter minimum power	
50/125 Fiber	**- 20 dBm**
62.5/125 Fiber	**- 17 dBm**
100/140 Fiber	**- 7 dBm**
Receiver sensitivity	**- 25.4 dBm**

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RS232 Port Signals (Remote Ports)

DB 9 (9 pin) connector. Used signals	**Pin 5 - GND**
	Pin 2 - RXD
	Pin 3 - TXD

RS485 Port Signals (Remote Ports)

DB 9 (9 pin) connector. Used signals	**Pin 4 - (A) TX+ / RX+**
	Pin 6 - (B) TX- / RX-

RS232 Full Modem Port Signals (Remote Ports)

DB 9 (9 pin) connector. Used signals	**Pin 1 - DCD**
	Pin 2 - RXD
	Pin 3 - TXD
	Pin 4 - DTR
	Pin 5 - GND
	Pin 6 - DSR
	Pin 7 - RTS
	Pin 8 - CTS
	Pin 9 - RI

Communications Ports 87L (ST)

Type	**Multimode**
Wavelength	**850 nm**
Communication Distance	**2 km**

Communications Ports 87L - 4CZ07980014 (SFP-LC Module) (*)

Type	**Multimodo**
Wavelength	**850 nm**
SFF-8472 DDM	**YES**
Reach	**2 km**
Connector	**LC**
Output optical power	
50/125 Fiber	**-19** to **-11 dBm**
62.5/125 Fiber	**-23** to **-11 dBm**
Extinction Rate (ER)	**12 dB**
Receiver sensitivity	**-32 dBm**

(*) The characteristics of the homologated module have been extracted from the manufacturer's datasheet.

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Communications Ports 87L - 4CZ07980018 (SFP-LC Module) (*)

Type	**Multimode**
Wavelength	**850 nm**
SFF-8472 DDM	**NO**
Reach	**2 km**
Connector	**LC**
Output optical power	
62.5/125 Fiber	**-10** to **-4 dBm**
Extinction Rate (ER)	**9 dB**
Receiver sensitivity	**-24 dBm**

(*) The characteristics of the homologated module have been extracted from the manufacturer's datasheet.

Communications Ports 87L - 4CZ07980017 (SFP-LC Module) (*)

Type	**Singlemode**
Wavelength	**1310 nm**
SFF-8472 DDM	**NO**
Reach	**30 km**
Connector	**LC**
Output optical power	
9/125 Fiber	**-15** to **-8 dBm**
Extinction Rate (ER)	**8,2 dB**
Receiver sensitivity	**-34 dBm**

(*) The characteristics of the homologated module have been extracted from the manufacturer's datasheet.

Communications Ports 87L - 4CZ07980013 (SFP-LC Module) (*)

Type	**Singlemode**
Wavelength	**1310 nm**
SFF-8472 DDM	**SÍ**
Reach	**40 km**
Connector	**LC**
Output optical power	
9/125 Fiber	**-5** to **0 dBm**
Extinction Rate (ER)	**12 dB**
Receiver sensitivity	**-35 dBm**

(*) The characteristics of the homologated module have been extracted from the manufacturer's datasheet.

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Communications Ports 87L - 4CZ07980016 (SFP-LC Module) (*)

Type	**Singlemode**
Wavelength	**1550 nm**
SFF-8472 DDM	**NO**
Reach	**120 km**
Connector	**LC**
Output optical power	
9/125 Fiber	**0** to **5 dBm**
Extinction Rate (ER)	**10 dB**
Receiver sensitivity	**-35 dBm**

(*) The characteristics of the homologated module have been extracted from the manufacturer's datasheet.

LAN Communications

Internet Protocol Version	**IPv4**
Ports	**RJ45 Electric Port**
	GFO Port LC Connector
	GFO Port ST Connector

RJ45 Electric Port

Physical medium standard	**10/100/1000 BASE-T**
Used signals	**Pin 1 - TX+**
	Pin 2 - TX-
	Pin 3 - RX+
	Pin 4 - N/C
	Pin 5 - N/C
	Pin 6 - RX-
	Pin 7 - N/C
	Pin 8 - N/C

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GFO Port LC. Socket and SFP module (*)

Socket for SFP module	
Type	**Multimode**
Physical medium standard	**100BASE-FX & 1000BASE-SX/LX**
SFP Module	
Type	**Multimode**
Physical medium standard	**100BASE-FX & FDDI ISO 9314-1**
Wavelength	**1310 nm**
Connector	**LC**
Communication distance	**2 km**
Transmitter minimum power (62.5/125 Fiber)	**- 20 dBm**
Receiver sensitivity	**- 32 dBm**
Hot Swap	

(*) Characteristics of the module homologated by the manufacturer.
Although the sockets for SFP connectors have compatibility with numerous manufacturers, it is recommended to use the SFP module homologated by the manufacturer (See Model Selection).

GFO ST Port

Type	**Multimode**
Physical medium standard	**100BASE-FX / ATM / FDDI PMD&LCF-PMD**
Wavelength	**1300 nm**
Connector	**ST**
Communication distance	**2 km**
Transmitter minimum power (62.5/125 Fiber)	**- 20 dBm**
Receiver sensitivity	**- 33 dBm**

PTP Synchronization (IEEE 1588 / IEC 61588)

Accuracy	**±1 us**
Power Utility Profile	**IEC61850-9-3** (compatible Power Profile IEEE C37.238)
Clock modes	**Transparent Clock** (*) **Ordinary Clock** (slave)
SNTP synchronization	**SNTPv4** Version
Accuracy	**1 - 10 ms**

(*) Compatible with 1 and 2 step clocks.
Calculation of channel time through P2P provided in 2 steps.

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Synchronization IRIG-;

B00X	**B12X**
B: 100pps	B: 100pps
0: By pulse width	1: Amplitude modulated wave
0: Without carrier	2: 1kHz/1ms
X: 0,.., 7	X: 0,.., 7

X: 0 (BCD, CF, SBS); 1 (BCD, CF); 2 (BCD); 3 (BCD, SBS); 4 (BCD, BCD, CF, SBS); 5 (BCD, BCD, CF); 6 (BCD, BCD); 7 (BCD, BCD, SBS).

BNC Type Connector

Input impedance	**211 Ω**
Maximum input voltage	**10 V**
Synchronization accuracy	**± 1us**

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1.4 Current Transformers Dimensioning

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1.4.1 Introduction

When dimensioning the Current Transformers (CTs), several factors are taken into account that influence the level of flux generated in the CT itself and, therefore, the tendency of the same to saturate. These include: load, internal resistance, incidence angle of the fault, primary and secondary time constants, remanence, etc.

The following points describe the data provided by different CT standards and the factors that must be calculated for the CT dimensioning

1.4.2 CT Dimensioning According to Different Standards

1.4.2.a Class P of IEC 61869-2 Standard

The CT is specified with the following data:

- Rated transformation ratio: the ratio of the rated primary current to the rated secondary current, e.g 600/5.
- Rated power: power provided by the CT at rated current and rated burden, e.g 10 VA.
- Accuracy class: 5P and 10P defines a maximum composite error of 5% or 10% at the accuracy limit current (accuracy limit factor (ALF) multiplied by the rated current).
- Accuracy limit factor: times the rated current, without DC offset, at which the accuracy class is fulfilled.
- Secondary internal resistance.

The CT will be adequate if K_total=Kssc*Kb*Ktf*Krem<ALF, where

Kssc: symmetrical short-circuit current factor.
Kb: burden factor.
Ktf: overdimensioning factor for DC offset.
Krem: remanence overdimensioning factor.

- **Symmetrical Short-Circuit Current Factor (Kssc)**

It is the ratio between the maximum short circuit current and the rated current.

- **Burden Factor (Kb)**

It is the ratio (Rct+Rburden)/(Rct+Rn), where:

Rn is the rated burden. Rn can be calculated from the CT rated power:

$$Rn = \frac{Pn}{I2n^2}$$

Rct: is the internal secondary resistance of the CT.
Rburden: is the burden resistance.
I2n: is the rated secondary current.

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The accuracy limit factor is defined for the rated burden. For a different burden the maximum symmetrical current that assures the fulfillment of the accuracy class will be different than the accuracy limit current (it will be higher than the accuracy limit current if the burden is lower than the rated one and it will be lower if the burden is higher than the rated one). This condition is taken into account by the burden factor.

- **Transient Overdimensioning Factor (Ktf)**

The flux created by a current with DC offset (asymmetrical current) is much higher than the flux generated by a current without any DC component (symmetrical current). As the ALF factor is defined for a symmetrical current, an overdimensioning factor for asymmetrical currents must be considered. This factor will be given by $\frac{\phi_{\text{MAX AC+DC}}}{\phi_{\text{MAX AC}}}$,which represents the ratio between the maximum total flux (sum of DC and AC fluxes) and the maximum AC flux. Ktf is calculated with the following formula:

$$Ktf = \frac{w \cdot T1 \cdot T2}{T1 - T2} \cdot \cos\theta \cdot (e^{\frac{-t}{T1}} - e^{\frac{-t}{T2}}) + \sin\theta \cdot e^{\frac{-t}{T2}} - \sin(wt + \theta) \qquad \text{(1.4.1), where}$$

T1 is the primary time constant.
T2 is the secondary time constant.
t is the saturation free time or time to saturation.
θ is the fault inception angle.

For saturation free times higher than 15 ms, the maximum flux will be obtained with $\theta = 0$, however, for saturation free times lower than 15 ms, the maximum flux will be obtained for other fault inception angles.

For each saturation free time tolerated by the protection function the worst inception angle should be determined.

- **Remanence Overdimensioning Factor (Krem)**

The remanent flux may worsen the CT transient response if it has the same sign of the flux generated by the current magnitude, burden value and DC offset. This is considered by the remanence overdimensioning factor $Krem = \frac{1}{(1 - Kr)}$, where Kr is the remanent factor (maximum remanent flux / saturation flux).

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1.4.2.b Class C of IEEE C57.13 Standard

The most common accuracy class in the IEEEC57.13 standard is the C class. The letter C is followed by a number that indicates the secondary voltage rating, which is defined as the CT secondary voltage that the CT will deliver when it is connected to a standard secondary burden at 20 times the rated secondary current, without exceeding a 10% ratio error. The common standard burdens for protection CTs are 1, 2, 4 and 8 ohms, which correspond, at 5 A rated current, to 100, 200, 400 and 800 V secondary rating voltages (for a C100 CT the voltage at the 1 ohm burden will be 20*5*1=100 V).

With the secondary voltage rating (burden voltage - Vb) we can obtain the internal magnetizing voltage by adding the voltage drop in the secondary resistance (Rct):

$$Emrated=Vb+Rct*20*I2n$$

The dimensioning of an IEEE CT can be done by calculating Em as:

$$Emcalc=Ktotal'*I2n*(Rct+Rb),$$

where Ktotal'=Kssc*Ktf*Krem.

If Emcalc<Emrated= Vb+Rct*20*I2n the CT will be valid

An easier deduction can be made considering that the ALF factor of a C class CT is always 20 (the 10% ratio error cannot be exceeded for a secondary current 20 times the rated current with the rated burden). If Ktotal<ALF the CT will be valid.

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1.4.2.c Class X of BS3938 Standard or Class PX of IEC61869-2

Class X CT is defined with:

- Primary and secondary rated currents.
- Transformation ratio.
- Rated knee-point voltage.
- Magnetizing current at rated knee-point voltage.
- Resistance of secondary winding.

The rated knee-point voltage is defined as the minimum voltage, at rated frequency, applied to the CT secondary terminals which increased by a 10% causes an increase in the magnetizing current of 50% (see Figure 1.4.1).

The relationship between the rated knee-point voltage (Vknee) and the magnetizing voltage at the accuracy limit current with rated burden (Emrated) is done by approximation, because the definition of the two voltages has no direct relation (Vknee has to do with the slope of the magnetizing characteristic and Emrated with the current composite error). It is normally considered that Emrated=(1.25 – 1.3)*Vknee.

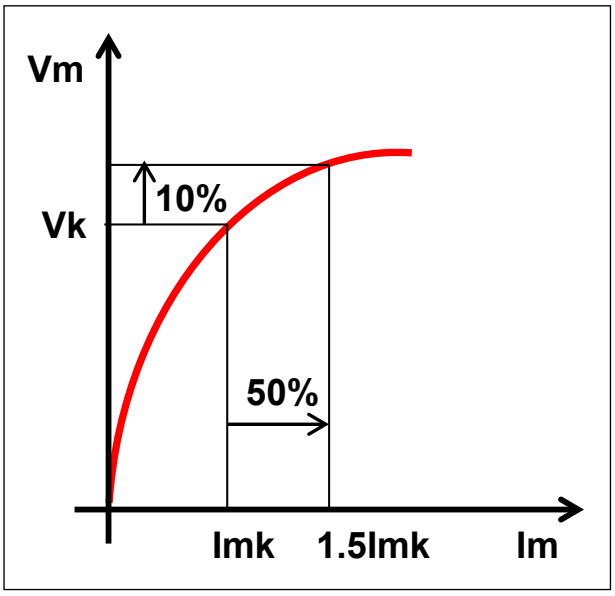


Figure 1.4.1 Knee Point Voltage Definition.

Once Emrated is calculated it can be compared with Emcalc= Ktotal'*I2n*(Rct+Rb). The CT will be valid if Emcalc<Emrated.

where Ktotal'=Kssc*Ktf*Krem

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1.4.3 CT Dimensioning for Different Protection Functions

Table 1.4-1 includes general parameters to be considered for the calculation of CT dimensioning factors.

Table 1.4-2 includes the saturation free times (for Ktf calculation) and current values (for Kssc calculation) that must be used for CT dimensioning.

Table 1.4-1: General Parameters

Data	Description	Units
f	Frequency (50 or 60 Hz)	(Hz)
IF	Maximum primary fault current (single phase fault current or three phase fault current, the highest one). It depends on the protection function – see Table 1.4-2	(A)
CT ratio	I1n/I2n	
I1n	Primary nominal current	(A)
I2n	Secondary nominal current	(A)
T1	Primary time constant = L/R (taking into account the total impedance from the source to the fault location).	(s)
T2	Secondary time constant (CT time constant) (Usual value = 3 s)	(s)
Rn	CT nominal resistance	(ohms)
Rct	CT internal resistance For CTs of 5 A nominal current, the Rct is around 0.2 ohms to 0.4 ohms. For the CTs of 1 A nominal current, the Rct is higher (10 ohms for example).	(ohms)
Rb	CT burden resistance = Relay burden + Cable resistance	(ohms)
	Cable resistance = 2·RL (if the maximum primary fault current belongs to a single phase fault). Cable resistance = RL (when the maximum primary fault current belongs to a 3 phase fault). RL = ρ · (L/S) ρ = resistivity (mm^2*Ω/m) S = cable section (m^2) L = cable length (m)	(ohms)
	Relay burden = (0.2 VA) / ($I2n^2$)	(ohms)
t	Required saturation free time (depends of the protection function – see Table 1.4-2)	(s)

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Table 1.4-2: Saturation Free Time and Fault Current Values				
Protection Function	**Fault Scenarios to be considered**	**t (s) = the time (seconds) from the fault start until the CT becomes saturated.**		**IF (fault current to calculate Kssc)**
		f = 50 Hz	f = 60 Hz	
87	External fault in the busbar (giving maximum fault current)	$3x10^{-3}$ (s)	$2.5x10^{-3}$ (s)	IF = $IF_{max_external}$ Maximum fault current for external fault
87N	External fault in the busbar (giving maximum fault current)	$4x10^{-3}$ (s)	$3.5x10^{-3}$ (s)	IF = $IF_{max_external}$ Maximum fault current for external fault
50	Internal fault giving a fault current equal to the pick-up value	It depends on the primary constant, however, it is always lower than $10x10^{-3}$ (s)	It depends on the primary constant, however, it is always lower than $8.3x10^{-3}$ (s)	IF = $IF_{pickup50}$ (instantaneous overcurrent unit pickup in primary value). **$IF_{pickup50}$ ≈** 0.7 · **(IF_2)** **IF_2**=the fault current to be detected by 50 overcurrent protection. It is normally the fault current at 50%-80% of the feeder. **Note 1**: The 0.7 factor is introduced to compensate CT errors, relay errors and short circuit calculation errors. **Note 2**: If the current IF_2 is not known, a first approximation could be done taking **IF_1 instead of IF_2**; Being **IF_1**= 80% of the fault current at 0% of the feeder (maximum short circuit current) = 80% (**$IF_{0\%}$**)
	Internal fault at 0% of the line	It depends on the primary constant, however, it is always lower than $7.4x10^{-3}$ (s)	It depends on the primary constant, however, it is always lower than $6 x10^{-3}$ (s)	IF = $IF_{0\%}$
21	Internal fault at 0% of the line	$8.4x10^{-3}$ (s)	$7 x10^{-3}$ (s)	IF = $IF_{0\%}$
	Internal fault at 100% of the line	$15x10^{-3}$ (s)	$12.5x10^{-3}$ (s)	IF = $IF_{100\%}$
	Internal fault at the limit of zone 1 reach (normally 80% of the line).	$25x10^{-3}$ (s)	$21x10^{-3}$ (s)	IF = $IF_{80\%}$

1.4.3.a Remanence Factor

Remanence factor is not considered for overcurrent and distance protection. For the mentioned functions Krem=1.

For the rest of the functions Kr=75%-->Krem=4.

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1.4.3.b Ktf Factor

The following tables include different ktf values calculated according to the formula (1.4.1). The saturation free times included in table 2 are considered together with the worst inception angles (θ). T2 is considered equal to 3 s.

Function	T1 (s)	K_{tf}
87T	0.01-0.3	0.43

Function	T1 (s)	K_{tf}
87N	0.01-0.3	0.58

Function	T1 (s)	K_{tf_pickup} 60 Hz	K_{tf_pickup} 50 Hz	$K_{tf_0\%}$ 60 Hz	$K_{tf_0\%}$ 50 Hz
50	0.01	1	1	1	1
	≤ 0.02	1	1	1	1
	≤ 0.03	1.15	1.15	1	1
	≤ 0.04	1.48	1.48	1	1
	≤ 0.05	1.6	1.6	1	1
	≤ 0.08	1.9	1.9	1	1
	≤ 0.1	2.1	2.1	1	1
	≤ 0.2	2.4	2.4	1	1
	≤ 0.3	2.5	2.5	1	1

Function	T1 (s)	$K_{tf\ zone1}$ 60 Hz	$K_{tf\ zone1}$ 50 Hz	$K_{tf\ 100\%}$ 60 Hz	$K_{tf\ 100\%}$ 50 Hz	$K_{tf\ 0\%}$ 60 Hz	$K_{tf\ 0\%}$ 50 Hz
21	0.01	4.3	3.9	3.8	3.6	2.3	2.3
	≤ 0.02	5.9	5.5	4.6	4.4	2.6	2.5
	≤ 0.03	6.6	6.3	4.9	4.8	2.7	2.6
	≤ 0.04	7.15	6.8	5.1	5	2.7	2.7
	≤ 0.05	7.46	7.2	5.3	5.2	2.7	2.7
	≤ 0.1	8.14	7.9	5.5	5.5	2.8	2.8
	≤ 0.2	8.5	8.4	5.6	5.6	2.8	2.8
	≤ 0.3	8.6	8.5	5.7	5.7	2.8	2.8

NOTE: For overcurrent and distance functions, Ktotal must be calculated for each of the cases considered (fault at 0% and fault with Ifault=Ipick-up for overcurrent; fault at 0%, 80% and 100% of the line for distance). The maximum value of Ktotal must be used to compare against ALF.

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Overcurrent

$$Ktotal_{0\%}=Kssc_{0\%}*Kburden*Ktf_{0\%}*Krem$$

$$Ktotal_{pick\text{-}up}=Kssc_{pick\text{-}up}*Kburden*Ktf_{pick\text{-}up}*Krem$$

$$Ktotal=max(Ktotal_{0\%}, Ktotal_{pick\text{-}up})$$

Distance

$$Ktotal_{0\%}=Kssc_{0\%}*Kburden*Ktf_{0\%}*Krem$$

$$Ktotal_{80\%}=Kssc_{80\%}*Kburden*Ktf_{80\%}*Krem$$

$$Ktotal_{100\%}=Kssc_{100\%}*Kburden*Ktf_{100\%}*Krem$$

$$Ktotal=max(Ktotal_{0\%}, Ktotal_{80\%}, Ktotal_{100\%})$$

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1.5 Physical Description

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1.5.1 General

The equipments are made up of the following modules:

- Processor module and HMI.
- Analog inputs module.
- Power Supply.
- Digital inputs, outputs and transducers inputs module.
- Communications module.
- Communications module 87L.

The modules are mounted vertically, constituting removable modules that do not require disassembling the front of the equipment. External connection is carried out by means of plug-in terminal blocks (supported on the bearing strip located at the back of each module) for ring lug connectors in case of analogical inputs, and pointed hubs for digital inputs and outputs and for transducer inputs. Depending on the terminal configuration, all the inputs / outputs contacts may be used or some may remain as spare signals.

Next figures represent the external appearance of the IEDs (for 1/3 and 1 rack of 19" and 6U standard height). The alphanumeric / graphic keypad and display, the local communication port (USB-B, USB-A), the local control buttons and the LED targets are mounted on the front part of the equipment.

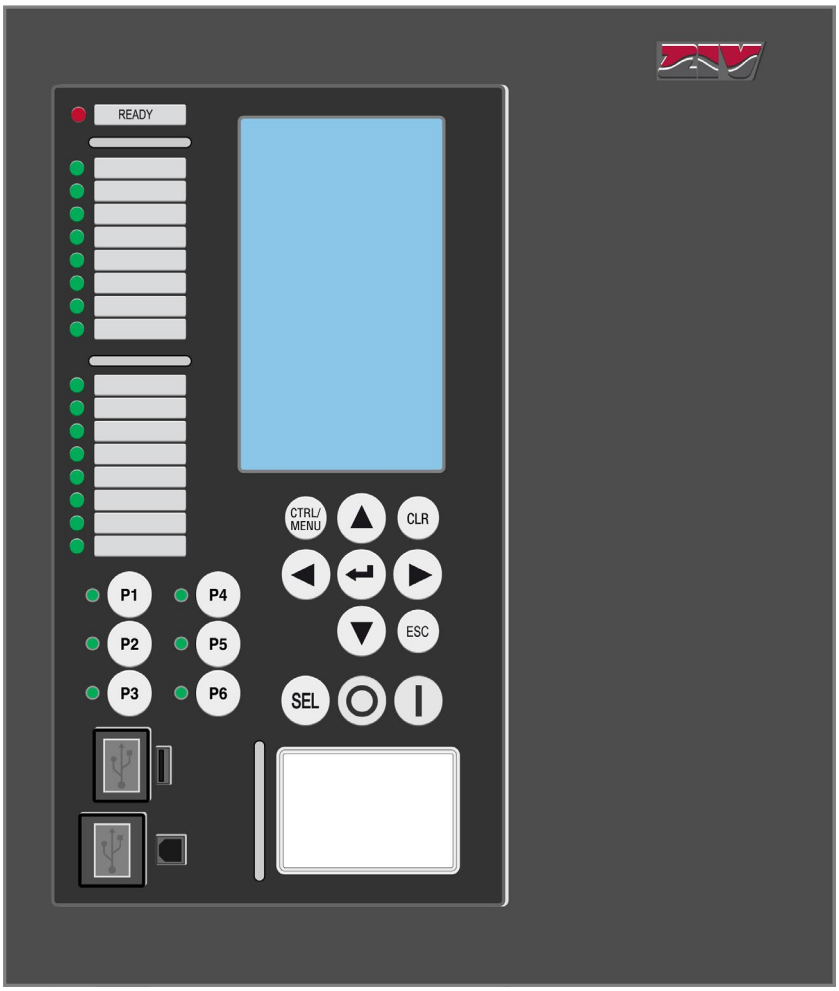


Figure 1.5.1 Front of a 6U x 19" 1/2 Rack DLF Model.

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Models with Standard Display (model digit 5 = 1 or 2) feature 6 configurable bicolor LEDs (green/red) associated with the command buttons P1-P6.

Models with Extended Buttons Display (model digit 5 = 4) feature 12 configurable bicolor LEDs (green/red) associated with the command buttons P1-P12, plus other 2 configurable LEDs (fixed red) associated with the Local/Remote (L/R) button. For this model, only the alphanumeric display option is available.

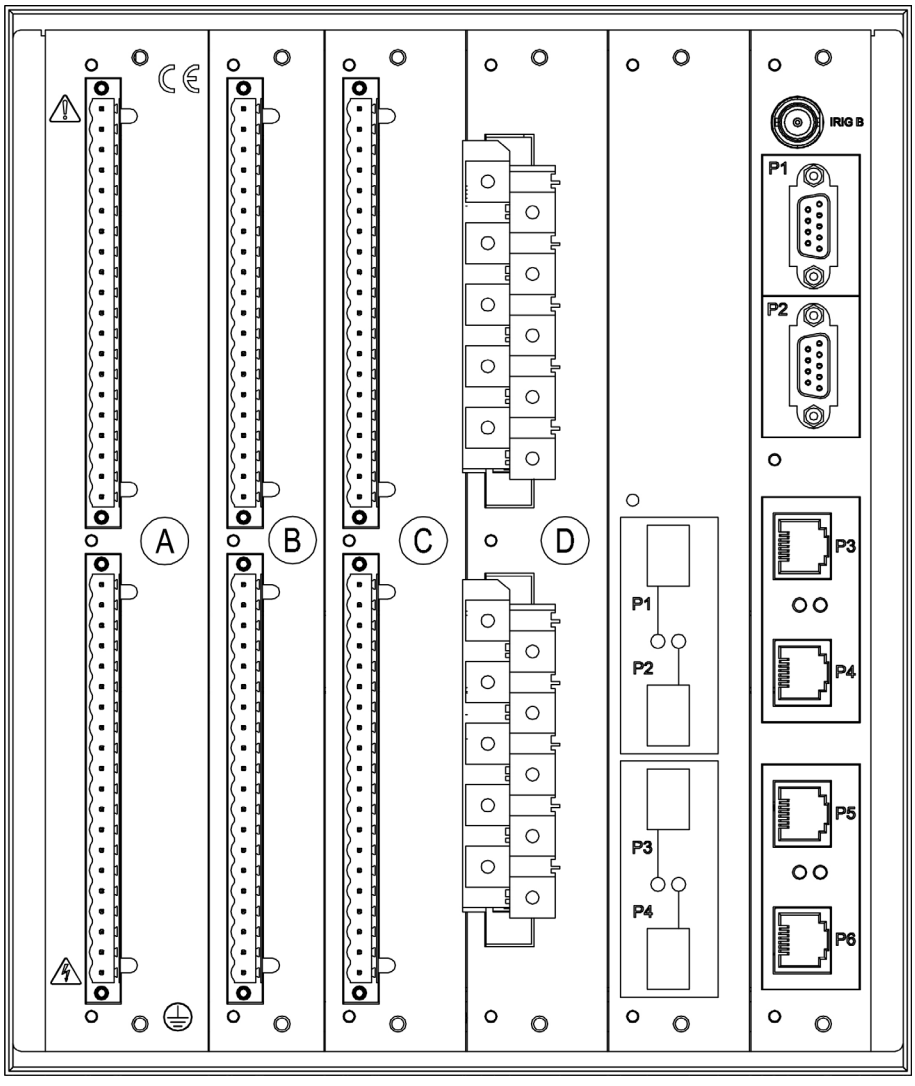


Figure 1.5.2 Rear of a 6U x 19" 1/2 Rack DLF-A Model.

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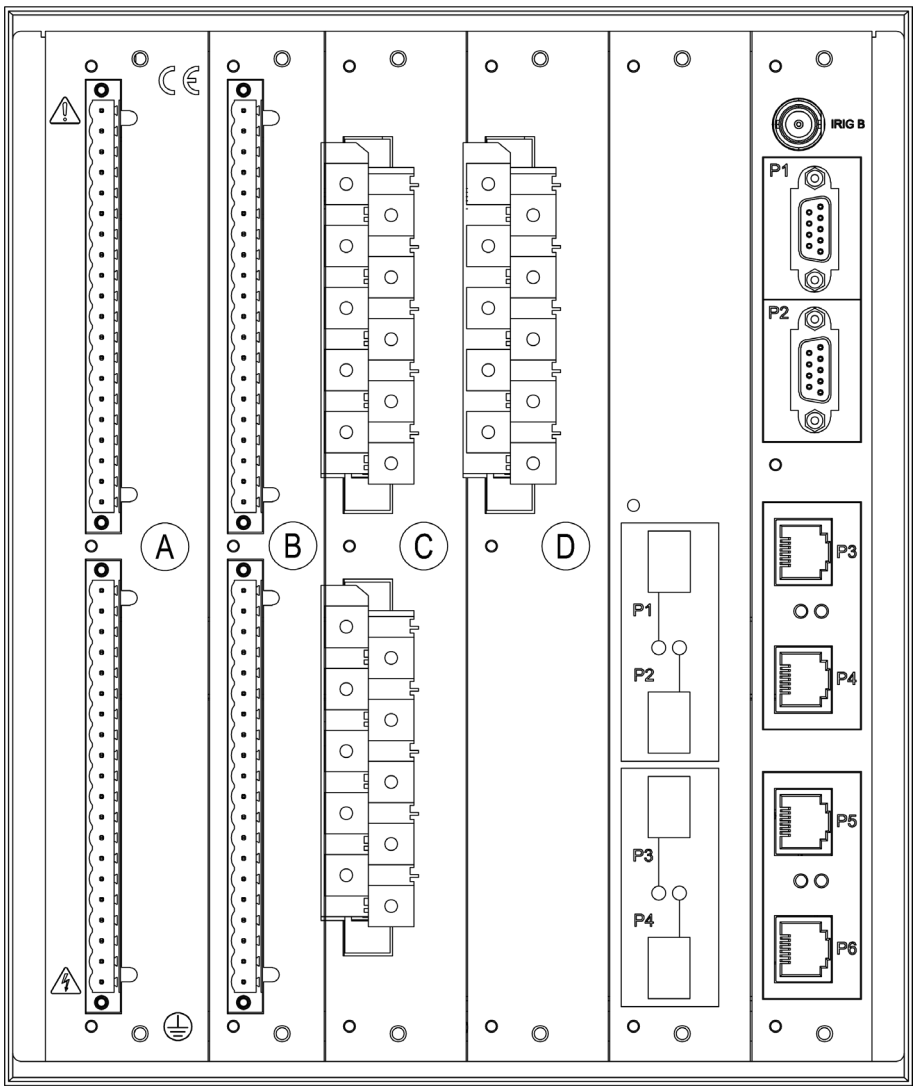


Figure 1.5.3 Rear of a 6U x 19" 1/2 Rack DLF-B Model.

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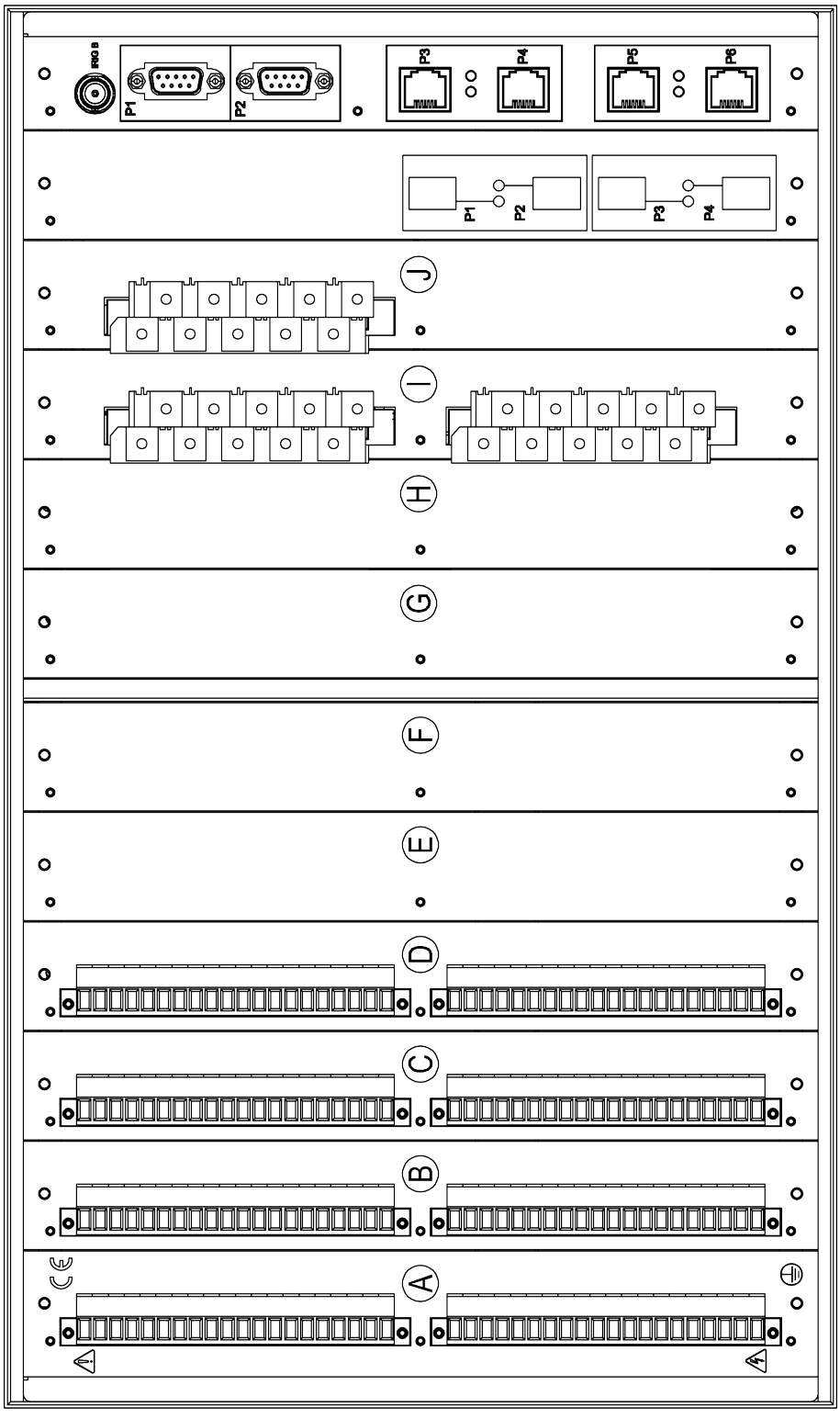


Figure 1.5.4 Rear of a 6U x 19" 1 Rack Model.

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1.5.2 Dimensions

Depending on the model, the IEDs are mounted as follows:

- Models in enclosures of 1/2 19"-, 6 standard units high.

Relays are designed for panel flush mounting or in cabinet racks. The box is graphite grey. Below are shown several combinations for mounting the equipments.

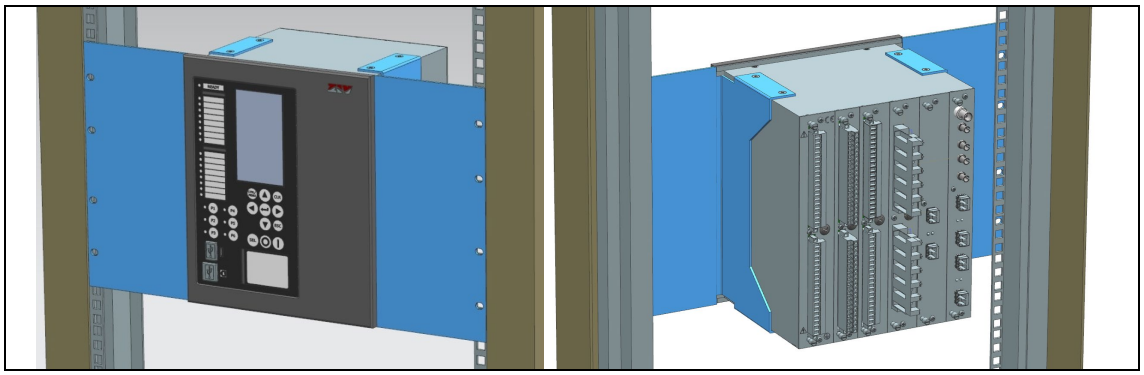


Figure 1.5.5 One 6U x 19" 1/2 Flex IEDs Rack Mounted.

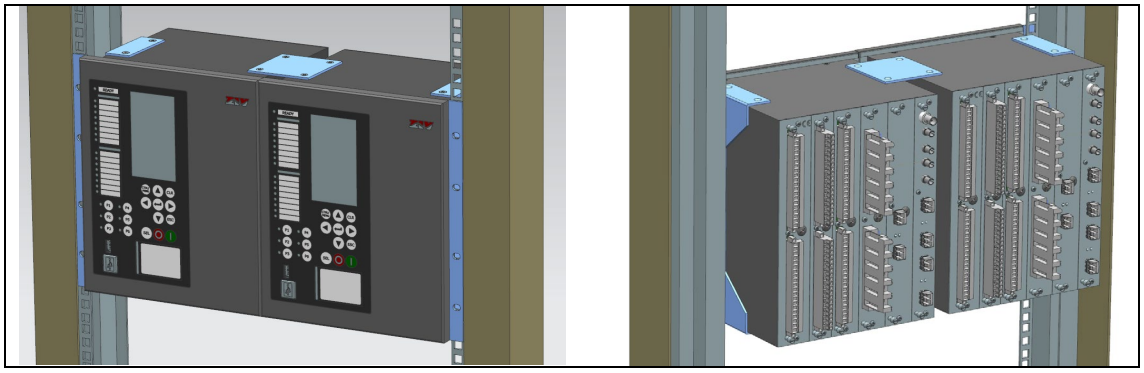


Figure 1.5.6 Two 6U x 19" 1/2 Flex IEDs Rack Mounted.

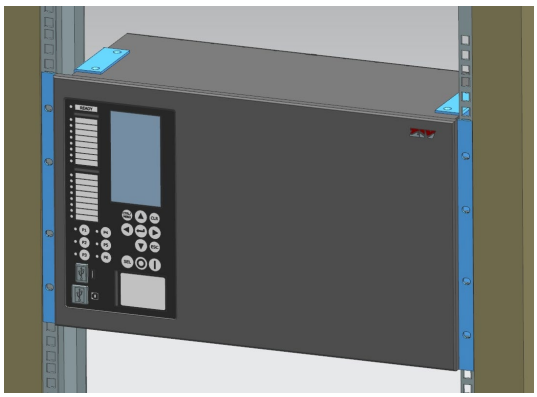


Figure 1.5.7 Mounting a 6U and 1 Rack Flex IED in Rack.

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1.5.3 Connection Elements

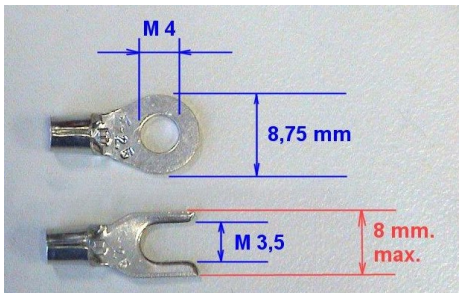
1.5.3.a Terminal Blocks

The number of connectors of the relay depends on the number of analogical inputs and the digital inputs / outputs of the specific model. Relays without connector will have a cover in its place. Strips are arranged vertically as shown in previous figures. Terminal arrangement by columns is as follows:

- **SLOT A**: 2 terminal blocks of 20 terminals for relay auxiliary power supply, digital inputs and outputs, including the internal relay in anomaly output.
- **SLOT B**: 2 terminal blocks of 20 terminals to connect digital inputs and outputs.
- **SLOT C**: 2 terminal blocks of 20 terminals to connect digital inputs and outputs.
- **SLOT D**: 1 terminal block of 10 terminals to connect 10 analog channels.
- **SLOT E**: 1 Communications board 87L.
- **SLOT CPU**: Communications ports and Synchronization (IRIG-B, 2 Serial Ports, up to 4 LAN Ports).

The ring lug terminals corresponding to the current analog inputs take wires up to #10-12 AWG (6 mm^2). We recommend ring lug terminals for these connections.

The connectors are plug-in and not self-shorting. They can be assigned to the current circuits supporting a current of 20 A continuously.



The terminals of the 20 terminals block admit a #28-14 AWG (2.5 mm^2) cable in the case of pin terminals and #12-22 AWG cables between 2.5 and 4 mm^2 in the case of the ring lug terminals. Use of pin terminals is recommended to connect to connectors.

1.5.3.b Removing Printed Circuit Boards (Non Self-shorting)



The IED's printed circuit board can be taken out. **WARNING: the current connector is non self-shorting. Consequently, the CT secondaries must be short-circuited externally before board removal.**

The back plate and the printed circuit board are attached to the case with self-tapping screws. These screws must be removed before the board is withdrawn. This operation always requires the protection to be **not in service**.

1.5.3.c Internal Wiring

The equipment uses traditional printed circuit board connections and internal buses to minimize internal wiring.

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1.5.4 Local Interface

1.5.4.a Display and Keypad

There are two display options (as per model selection): Alphanumeric display and alphanumeric and graphical display.

Alphanumeric Display has a screen resolution of 128x64 with capacity for 6 lines and 20 characters per line.

You can visualize alarms, settings, measurements, status, etc. from the display.

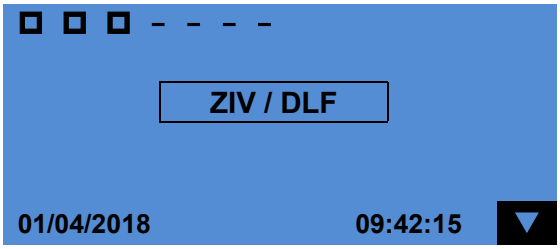


Figure 1.5.8 Alphanumeric Display.

The graphic display has a resolution of 272x480 to show the screens that have been configured in the relay user logic (single line, alarm screens, etc.), as well as the status of all digital inputs and outputs.

In the following chapters it will be explained how, by means of the CTRL/MENU button, the user can switch from the graphical display to the protection menu where it can be visualized all the information given by the alphanumeric display.

- **Default Display**

Default Alphanumeric Display: presents the model, the date and time and the status of the front communications port, serial remote port, LAN port and protocol instances through the LAN port.

Default Graphic Display: shows the single line diagram programmed in the user logic. If no single line diagram is available, the home screen will show the relay model, the date and time.

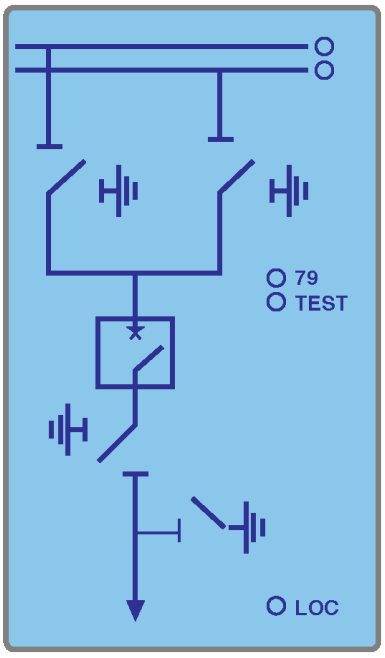


Figure 1.5.9 Graphic Display.

If no activity is detected by the relay during the time set in ***Display Time***, it will automatically return to the home screen.

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Below the display the scroll keys shown in Figure 1.5.9 are located. They explained in the following sections.

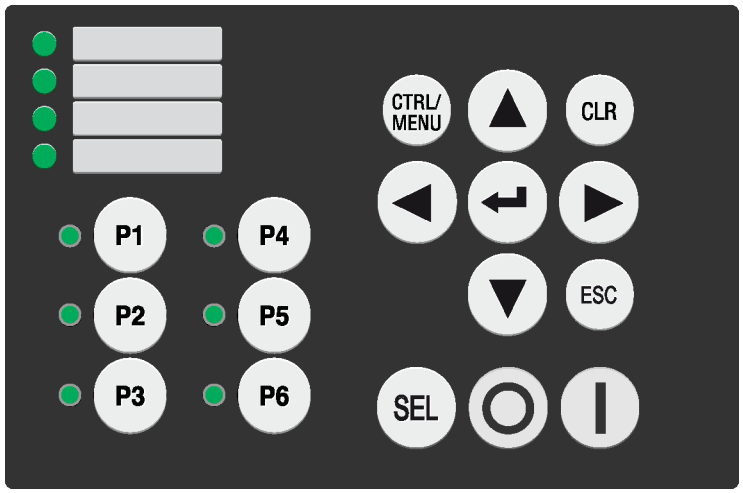


Figure 1.5.10 Keypad.

- **Command Panel Screen (associated with the alphanumeric display)**

The equipments are provided with a graphic screen for HMI commands, which can be accessed pressing **SEL** button, and where the status of different elements can be displayed and commands can be configured by ***ZIV e-NET tool***®. Once on the screen, the user can press again the **SEL** key to switch between different commands and controls that have been configured. In order to operate the command, it must be selected (blinking) and at that moment the close (I) or open (O) key will be pressed depending on ~~of~~ the action the user wants to operate over the selected command.

As commented before, access to the command panel is gained through the **SEL** key. The different commands can be scrolled using also the **SEL** key. The selected command blinks and the text configured for activation and deactivation of the command is displayed on the bottom part. In this blinking state, press the open or close keys to carry out the desired action.

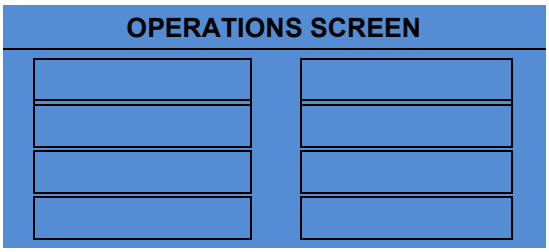


Figure 1.5.11 Command Panel Default Screen.

The command panel is configured from the ***ZIV e-NET tool***®, within the relay settings. The controls are distributed from 1 to 4, and there are two controls per number, A and B. The number indicates the row and the letter the corresponding column where the configured command will be placed on the relay screen.

Each command will have eight settings:

- **Command panel status signal**: signal linked to the command. When this signal is active, the corresponding square will be shown black whereas if the signal is deactivated, the square background will remain white.
- **Status Text Commands Panel**: Text that will appear inside the corresponding square.
- **Action Text Commands Panel**: texts that will appear in the bottom line of the screen when the command is selected. It is just a graphic presentation. The user can select the texts to be shown within a list available at the relay. Default texts are Activate / Deactivate.

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- **Sig Block Commands Panel**: signal the user can link to the command to block it. It can be any digital protection signal or signal generated in the control logic. When this blocking signal is active, the relay will prevent the command from being selected.
- **Action Button O Commands Panel**: O button signal activation mode. It can be a pulse, or step to 1 level (Activate) or 0 level (Deactivate). Default setting is to Disabled, which indicates that pressing the button will not effect any change to the associated signal.
- **Signal Button O Commands Panel**: command panel signal that will activate when the command is selected and the O button is pressed.
- **Action Button I Commands Panel**: I button signal activation mode It can be a pulse, or step to 1 level (Activate) or 0 level (Deactivate). Default setting is to Disabled, which indicates that pressing the button will not effect any change to the associated signal
- **Signal Button I Commands Panel**: command panel signal that will activate when the command is selected and the **I** button is pressed.

Button signals could be protection signals so that their activation or deactivation would trigger directly the desired action (enable or disable protection elements, element blocking, editing settings tables, etc.), or command signals so that their activation and deactivation can be taken into account in the relay logic.

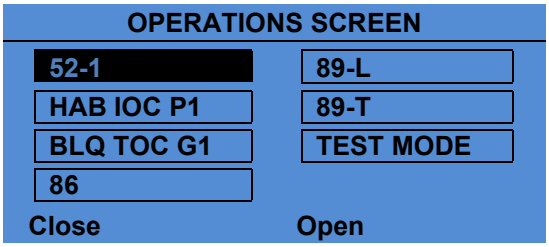


Figure 1.5.12 Example of configured command panel screen.

- **Autodimming**

Relays screen can be configured to keep the backlight permanently active or to switch the backlight off after a given time. The user can modify the ***Autodimming*** settings from the relay HMI by gaining access to the **Configuration** menu or else from the ***ZIV e-NET tool***®. By default, autodimming will be enabled for 2 minutes, so that the screen will turn off by itself 2 minutes after the last interaction with the relay or after booting. The *backlight* will never be permanently switched off through setting. The screen will always be lit up when the autodimming is disabled.

At the time a fault occurs, the relay backlight will automatically light up and will remain lit until the trip is reset.

The ***Display Time*** will also be used to return to the default screen.

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1.5.4.b Keypad associated to the Alphanumeric Display

The keypad has 11 keys, as follows.

CTRL / MENU: switches between graphic and alphanumerical screen. It has functionality just in models with graphical display.

▲	From the default screen, events and fault reports are displayed (only if they exist).
▶	From the default screen, measurements are visualized. Pressing again moves from one measurement screen to the next one.
▼	From the default screen you can see the status of the digital inputs and outputs.
◀	From the default screen it is accessed the screen where is displayed the information related to the last fault.

The keypad also provides an **Enter** key ↵ (in the center) **Escape** (**ESC**) and Clear (**CLR**):

Enter	Button used to Select or Accept.
ESC	Button whose purpose is to return to the previous screen. When being in the default screen, when pressed, the IED will show a screen with information regarding the configuration of the programmable buttons (P1 to P12). This screen will display the configured texts of each programmable button so that the user will now which function has been configured in each button.
CLR	Button to gain access to the memorized LED reset menu, last trip screen reset, event reset and fault reports reset. Both events and fault reports that can be reset are the ones showed in the HMI, all events and fault reports that can be downloaded by communications ports through ***ZIV e-NET tool***®) will be kept in the relay memory. Press the **CLR** button to switch between reset menus, and the relay will show them only if there are data subject to be erased. To proceed with the reset, from the corresponding menu, press **Enter** ↵ around two seconds until the prompt reset done is displayed on the screen. In case of resetting memorized LEDs, the relay will activate all LEDs and will reset the ones memorized without showing any message on the screen. If after the reset command and the activation of the 8 LEDs, any LED remains lit, it is because the signal associated to this LED is active.
ENT	When being in the protection default screen, when pressed, the IED will show during the time defined in ***Display Time*** a screen with information regarding the configuration of the programmable buttons (P1 to P12). This screen will display the configured texts of each programmable button so that the user will now which function has been configured in each button. In relays with alphanumeric display, the panel command screen can be accessed pressing again SEL button or pressing ENT button. For more information check the programmable buttons section.

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1.5.4.c Command Buttons

Pressing the **SEL** button once will open the command buttons screen, referring to the configuration of the programmable buttons, which can vary according to the IED model, P1 to P6 or P1 to P12. In models with alphanumeric display, pressing the button **ENT** or **SEL** again will open the Operation Screen, after user authentication.

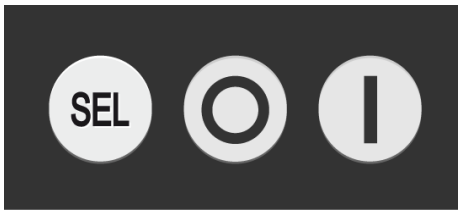


Figure 1.5.13 Command Buttons.

This **SEL** key is also used to scroll the command panel and to go to the required place. The controls configured in the protection settings are run through buttons (**I**) and (**O**).

In models with Graphic Display, the **SEL** key allows selecting, one by one, each single line diagram element until the no element selected situation is reached again. The selected element is represented graphically by a blinking symbol. Once the element has been selected, it is operated using the keys **O** – **I**. Being in the protection menu it will show the informative screen of the programmable buttons:

Open (O)	Open command after selecting the configured command on the Operation Screen or pressing buttons **P1** to **P6** or **P1** to **P12**, depending on the model. In graphic displays, the open command is issued through this key after selecting the configured component in the single-line diagram.
Close (I)	Close command after selecting the configured command on the Operation Screen or pressing buttons **P1** to **P6** or **P1** to **P12**, depending on the model. In graphic displays, the close command is issued through this key after selecting the configured component in the single-line diagram.

1.5.4.d Keys, Functions and Operation Modes

Below are the functions of the available keys, both the functions associated with the alphanumeric display and those of the keyboard.

- **Keypad**



Confirmation key
The confirmation key is used for confirming an action: after making a selection, or after editing a setting, or else to go on to visualize the totality of the registered data. After an operation is carried out (selection, change of settings, information, etc.), press ← again and return to the immediately previous level.



Escape key
The **ESC** key is used to exit the display if you do not wish to make any modification in the setting, or if you simply wish to exit the information display. In any case, when you press this key the system returns to the immediately previous level.

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Reset key
Press the **CLR** key to gain access to the memorized LED reset menu, last trip screen reset, event reset and reset of fault reports shown in the HMI. To proceed with the reset, from the corresponding menu, press **Enter** around two seconds until the prompt reset done is displayed on the screen. In case of resetting memorized LEDs, the relay will activate all LEDs and will reset the memories without showing any message on the screen. If after the reset command and the activation of the 8 LEDs, any LED remains lit, it is because the signal associated to this LED is active.



Selection keys on the display
You can go forward or backward in correlative order, using the selection keys, to any of the options available in a menu or submenu. When more than eight options are available in a menu, an arrow (⇓) will be visualized on the right-hand side of the display, indicating the existence of the same. These options will be accessed with key ▼ and the options that appear in the first place will cease to be visualized.

Then, a bar with an arrow (⇑) will appear on the right-hand side of the display, which will indicate, at the same time, the existence of these first options.

The key ◄ is also used for erasing digits within a setting when modifications are being carried out on the same. It only has this function when the setting is being introduced.

- **Auxiliary Function Keys**



When this key is pressed from the default display, it gives access to the information provided by the registration of control changes (events) and fault reports.



The key ► is used for consulting the unit as regards the data pertaining to current, voltage, power, etc.

The function key ► is used for rejecting the changes undertaken on the settings (when the unit requests the confirmation of these changes) and to reject the activation of a table of reserve settings (also when this confirmation is requested).



By pressing ▼ you can visualize the status of digital inputs and outputs from the unit.

Once the status of digital inputs is on screen, click the function key ► to visualize the status of digital outputs.



By pressing ◄ you confirm the changes of settings undertaken (when the unit requests that changes need to be confirmed) or the activation of a table of settings is confirmed (when the unit requests that changes need to be confirmed).

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- **Programmable Buttons**

The configurable buttons, **P1** to **P6** or **P1** to **P12** depending on the model, allow the operation of elements/units that can be selected by the user through the configuration program.

Models with Extended Buttons Display (model digit 5 = 3 or 4) feature a configurable **L/R** button, which can be used to change between Local/Remote hierarchical levels. This button has the same characteristics as the other user-configurable buttons (**P1**-**P12**), with the difference that the **L/R** Button has 2 associated LEDs (fixed color red). This button provides flexibility to implement the Local/Remote function.

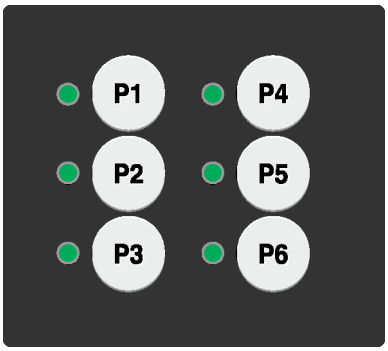


Figure 1.5.14 Programmable Command Buttons.

The programmable buttons are configured from the ***ZIV e-NET tool***®, within the relay settings. Each button will have ten (10) settings (6 for the button and 4 for the associated LED):

- **Text**: Text that will appear in the screen of the IED after pressing the button or ESC. Maximum of 15 characters are allowed.
- **Block Signal**: signal the user can link to the command to block it. It can be any digital protection signal or signal generated in the control logic. When this blocking signal is active, the relay will prevent the command from being selected.
- **Action Button O Command**: It indicates the operation mode over the associated signal when selecting the **O** button. It can be a pulse or a level signal (1/Activate or 0/Deactivate). The default setting is **Disabled**, which indicates that pressing the button will have no effect over the associated signal.
- **Signal Button O Command**: signal that will receive the operation mode (pulse, activation, deactivation) when the button is selected and the **O** button is pressed. It can be any signal of the relay (protection or control signal).
- **Action Button I Command**: It indicates the operation mode over the associated signal when selecting the **I** button. It can be a pulse or a level signal (1/Activate or 0/Deactivate). The default setting is **Disabled**, which indicates that pressing the button will have no effect over the associated signal.
- **Signal Button I Command**: signal that will receive the operation mode (pulse, activation, deactivation) when the button is selected and the **I** button is pressed. It can be any signal of the relay (protection or control signal).

Each programmable button has a double colored LED (red/green) associated. In order to configure them there are 4 settings available:

- **Red Activation:** Group of 16 settings where any digital signal of the relay can be configured (protection or control signal). The relay will activate the red LED colour of the corresponding button when any of the 16 signals activates.
- **Green Activation:** Group of 16 settings where any digital signal of the relay can be configured (protection or control signal). The relay will activate the green LED colour of the corresponding button when any of the 16 signals activates.
- **Blink:** when setting to yes, the LED will start flashing taking into account an internal pulse train when any of the colours in activated.
- **Memorized:** when setting to yes, the LED will remain in active status even after the deactivation of all the signals configured in the OR logics. The LED will deactivate after receiving a LED reset command.

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In order to know which is configured in each programmable button, pressing the **SEL** key when being in the protection default screen, it will be displayed during the time set in ***Display Time,*** a screen with the configured texts of each button.

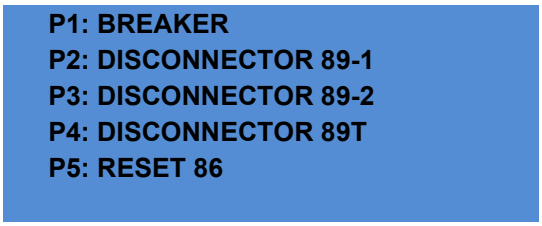


Figure 1.5.15 Example of programmable buttons screen.

When pressing any of the programmable buttons that screen will also appear. In this case, if the button can be selected (associated block signal deactivated or not configured) the text of the pressed push button will be shown blinking to indicate that it has been selected.

So, in models with graphical display, the information screen will appear just when being in the default screen of the "protection menu" (not in the graphical display), this is, after having pressed CTRL/MENU.

To show the information screen:

IEDs with **graphical display** (and being in the default screen of the protection menu):
- When pressing SEL button it will appear the screen in an informative way. This screen will be static and will be shown during the ***Display Time*** setting if the ESC button is not pressed earlier. - When pressing any of the buttons P1 to P6 or P1 to P12. In this case, and if the command is not blocked (corresponding block signal setting deactivated) the line which corresponds to the button which has been pressed will appear blinking and the corresponding LED will start also blinking in orange. When the command is executed (Button P1 to P6 + I/O button) the information screen will disappear. If the command is not executed, the screen will remain visible according to the ***Display Time*** setting. - If the information screen is being shown and any other P1 to P6 button or SEL button is pressed again, the counter will restart from zero (***Display Time***).
IEDs with **alphanumeric display** (and being in the default screen):
- When pressing SEL button it will appear the screen in an informative way. This screen will be static and will be shown during the ***Display Time***. After this time the IED will show the command panel screen. To avoid waiting that time to access the command panel screen the user can press again the SEL button or the ENT button and the IED will change the screen into the command panel one. In both screens (information and command panel) when pressing the ESC button, the IED will go to the default screen. - When pressing any of the buttons P1 to P6 or P1 to P12. In this case, and if the command is not blocked (corresponding block signal setting deactivated) the line which corresponds to the button which has been pressed will appear blinking and the corresponding LED will start also blinking in orange. When the command is executed (Button P1 to P6 + I/O button) the information screen will disappear. If the command is not executed, the screen will remain visible according to the Display Time setting. After directly pressing buttons P1 to P6 or P1 to P12 and showing the information screen it will never be access to the command panel screen, the IED will return after it to the default screen. The panel command screen can be accessed just after pressing SEL button. While one button is selected, pressing SEL button is not considered.

Both for models with graphic and alphanumeric display, buttons P1 to P6 or P1 to P12 will work normally even if the relay is not in the standard "protection menu/protection display", but in this case the information screen will not appear.

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If the signal configured in the button block is in active status, the button cannot be selected so when it is pressed:

- The information screen will appear (if we are in the default menu/protection screen) with all the texts in a static way.
- The corresponding LED will not blink.
- If after pressing the button P1 to P6 or P1 to P12 any of the I/O button is pressed, the IED will not perform any action. It would be like pressing I/O button without having pressed before P1 to P6 or P1 to P12 buttons.

If the signal configured in the button block is in inactive status, the button can be selected so when it is pressed:

- The information screen will appear (if we are in the default menu/protection screen) and the line which corresponds to the button which has been pressed will appear blinking.
- The corresponding LED will start also blinking in orange.
- If after pressing the P1 to P6 button any of the I/O button is pressed, the IED will activate the associated signal based on the selected mode (activation level, deactivation level, pulse).

1.5.4.e Access to Options

To access options, you must scroll around the menus using the selection keys and afterwards confirm the option selected by pressing **ENT**.

- **Operation**

Range Settings

Range settings are displayed as follows: the operational value of the setting is displayed next to **ACT** (Actual). The new value is introduced in the next line, next to **NEW**, where the cursor will display an intermittent flash.

Auxiliary function keys are used for editing the new value which must correspond with the range specified in the last line of the display. If there is an error when a value is introduced, you must use key ◄ to erase the same. Once the new value has been edited, press key ↵ to confirm the same and exit to the previous menu.

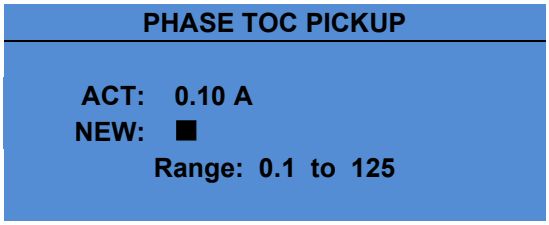


Figure 1.5.16 Range Settings.

YES / NO Type Settings

There is a type of setting whose range is limited to options **YES** and **NO**. Keys ▲ and ▼ correspond in this case to values **YES** and **NO**. After this, press key ↵ to confirm the setting and return to the previous screen. A similar case will be the numbered settings where the relay shows the various options. Scroll with the keys ▲ and ▼ to get the required option.

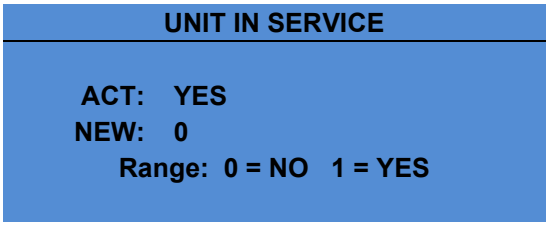


Figure 1.5.17 Numbered Settings.

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Settings for the Selection of an Option

These settings present the layout of an options menu. Select the required option through the selection keys and confirmation using ↵. Thus, the system returns to the previous screen.

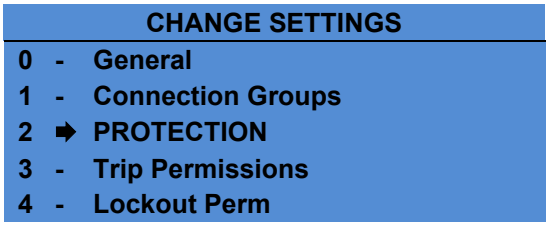


Figure 1.5.18 Selection Settings.

Masks Settings

As can be observed in the figure, the different options are presented in vertical order. Its current setting is: an empty square or a filled square which indicates enabled (■) or disabled (□) respectively.

The mask is modified (in the line indicated by brackets) using keys ◄ (1), enable, and ► (0), disabled.

- In the event that there are more options than those that can represented in one screen alone, an arrow (↓) will appear at the end of the last line, which will indicate the existence of that second screen. This second screen appears as soon as the last option on the first screen has been set.

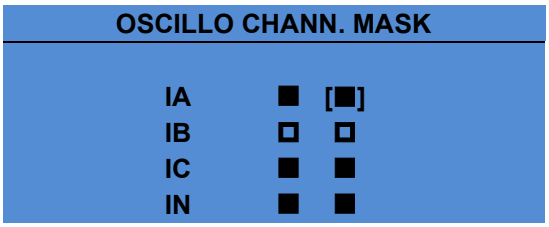


Figure 1.5.19 Mask Settings.

Exit Menus and Settings

In order to exit a menu or setting that you do not wish to modify, press **ESC** key. To exit a data display, you can either press the confirmation key ↵ or **ESC**. In all cases, you will return to the previous menu.

- **Last Trip Indication**

If any trip takes place, the terminal would present, on the default screen, the data related to it in a menu titled **TRIP**.

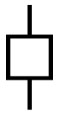
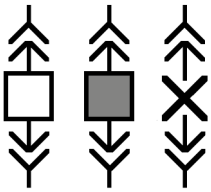
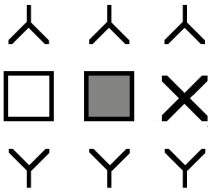
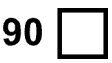
Additional screens will be created depending on the last types of units that trip. The format is always similar: a heading line that indicates the type of unit that has tripped (for example, Phase Undervoltage), and below this, all the elements and phases that have been involved (UV A1, UV B1,...). If various functions had tripped, and thus all of them do not fit into one screen, you can access all the functions involved through the selection keys.

The last trip screen will appear only if after a reset a trip has taken place.

This last trip screen will remain as default screen until it is removed through the reset menu accessed by the **CLR** key or until the device is switched off and booted again.

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1.5.4.f Symbols associated to the Graphic Display

Element	State 1	State 2
Breaker	 Open	 Closed
Breaker	 Unknown (0-0)*	 Unknown (1-1)*
Switch	 Open	 Closed
Position of the Breaker mechanism	 Plugged	 Unplugged
Position of the Breaker mechanism	 Pulled out closed	 Pulled out open
Recloser	 In Service	 Out of Service
Capacitor Bank Control	 Automatic	 Manual
Voltage Regulator	 Automatic	 Manual

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1.5.5 LEDs

Depending on the model, the IED may have 31 or 23 LEDs on the front, one with fixed function and the others configured.

- **Fixed function LED**

The LED on the upper right part of the relay with the greatest separation from the other LEDs is used to show the device status.

It is a tricolor LED that will indicate the following conditions:

- Relay in operation: steady green.
- Relay booting up: blinking green.
- Writing to flash memory: blinking orange.
- Relay in test mode: orange (future functionality).
- Relay in critical error (red).

- **Configurable LEDs**

The relay has 16 configurable monochrome LEDs. They can be configured to be activated in a fixed or blinking state and will always show the activation in red color.

These LEDs are configured through protection settings being able to assign up to 16 input signals to an OR gate so that when any of these 16 variables is activated, the corresponding LED is activated. Selected signals could be internal of the relay or user signals configured in the control logic configuration. Also, each LED will have two settings, ***Blinking*** and ***Memorizing*** so that they can be set separately for each LED in order that:

- ***Blink***: when the setting is set to **YES** and any of the OR logic signals is activated, the LED starts blinking, being activated and deactivated as a function of a pulse train of fixed duration.
- ***Memorized***: when the setting is set to **YES** and the signals assigned to the OR logic are deactivated after one activation, the LED remains lit or blinking until a LEDs reset command is received.The reset command may be carried out through the **CLR** key or through a digital input, command from the command panel or command through communications if so the relay has been configured by means of the control logic for that purpose.

The relay also has 6 to 12 bicolor LEDs (red/green), linked to 6 or 12 function buttons configured in the relay control logic through the ***ZIV e-NET tool***® configuration program. The number of buttons 1-6 or 1-12 is the defined according to the model.

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1.5.6 Inputs and Outputs

Inputs and outputs are grouped by SLOTs, being part of the power supply module or own digital input, output modules and transducer inputs.

The power supply module (**SLOT A** of the relay) will always be present while the input modules, digital outputs and input transducers (**SLOT B** and **SLOT C** of the relay) will vary depending on the model selection. This is why inputs and outputs are identified for each **SLOT** and not in a global way.

Both inputs and outputs will be configured through protection settings being able to assign up to 16 input signals to an OR gate for each input and output, so that when any of these 16 variables is activated, the corresponding physical input or physical output will be activated. Selected signals could be internal of the relay or user signals configured in the control logic configuration.

1.5.6.a Digital Inputs

The filtering and operation of the digital inputs is configurable according to the following options:

- ***Enable Digital Inputs***: When this setting is set to **NO** (inputs disabled), the inputs switch to disable or invalid status regardless the status of the signals assigned for activation in settings.
- ***Number of Changes to Disable*** (2-60): in order to prevent problems of a digital input under external or internal malfunction, a settable time window is established, in which the number of times the status of this digital input changes is monitored. If this number of changes exceeds a settable value, the digital input is disabled and the last status is frozen.
- ***Disable Window*** (1-30s): settable time window to disable a digital input for excessive number of changes.
- ***Number of Changes to Enable*** (2-60): once an input is disabled, it will be enabled again when complying with the enable conditions, this is, when the number of changes within the time window is less than the setting value, or through an enable command.
- ***Enable Window*** (1-30s): settable time window to enable a digital input that has previously been disabled for excessive number of changes.
- ***Digital Inputs Power Supply Supervision*** (NO / Digital Input). Allows enabling Digital Input validity control as a function of a given digital input supply voltage. When the setting is set to ***Digital Input***, the relay will supervise de voltage value of this input and if it is below the activation value, the validity of all digital inputs will be disabled and deactivated, which will remain in their last state. When the voltage exceeds the supervision input threshold, all inputs will be enabled showing their present state and active validity.
- ***Digital Inputs Voltage Supervisory Input*** (ED 1 to 6 of Slot B). Allows selecting the digital input that will be used as supply voltage reference. If the selected Digital Input is energized, the ***Digital Input Validity*** will remain active, otherwise, the ***Digital Input Validity*** will be deactivated.
- ***Digital Inputs Power Supply Voltage Level***. Setting used to determine the voltage value below which the equipment will disable the validity of the digital inputs.

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The relay includes 4 filters. Each filter is set through the settings below:

- ***Time between Samples*** (1-10 ms). To set up the sampling frequency of a digital input status.
- ***Number of Samples to Validate Changes*** (1-10): number of samples with the same value to validate an input. The number of samples to logic “0” or logic “1” consecutively to be detected in order to assume that the input is deactivated or activated respectively.

The filter for each input can be allocated through a setting:

- ***Filter Assignation*** (Filter 1 - Filter 2 – Filter 3 – Filter 4). Through this setting, “filter 1”, “filter 2”, “filter 3” or “filter 4” can be allocated to each configurable digital input. Filters 1, 2, 3, and 4 are made through the settings above allowing the creation of fast detection inputs or slow detection inputs.

A setting is also provided for each input to allow its automatic disabling:

- ***Automatic Disabling*** (YES / NO): There is a separate setting for each Digital Input. If set to YES, it allows the automatic disabling of the DI due to excessive number of changes.

The ***Activation Level*** of digital inputs can be allocated through a setting for each SLOT. Below is the input activation and deactivation value as a function of the according to the supply voltage used:

DI ON	Vdc ≥ Setting
DI ON/OFF	Setting - X < Vdc <Setting
DI OFF	≤ Setting - X

Where the hysteresis **X = 10 V** if the ***Activation Level*** setting is in the range of 15 V to 60 Vdc and where **X = 20 V** if the ***Activation Level*** setting is in the range of 60 V to 200 Vdc.

Vdc= Digital input supply voltage.
Setting= Activation threshold, range 15 - 200Vdc.

X = 10 Vdc if the setting Activation Threshold is within the range between **15 Vdc** and **60 Vdc**.
X = 20 Vdc if the setting Activation Threshold is within the range between **60 Vdc** and **200 Vdc**.

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The IED's metering elements and logic functions use **Logic Input Signals** in their operation. They are listed in the tables along with the description of each of them and can be assigned to the **Physical Digital Inputs** or to logic output signals of opcodes configured in the programmable logic. It must be taken into account that several logic inputs can be assigned to one physical input, but the same logic input signal cannot be assigned to more than one physical input.

The tables mentioned above only list the inputs available with the default configuration. The list of inputs can be expanded with those that are configured in the programmable logic (any logic input signal created in the programmable logic can be used with the description that the user generates).

Each protection element module of the relay has a special **Logic Input** signal to put it “into service” or “out of service” from the HMI (buttons on the front), with a digital input by level and with the communications protocol configured in each port (control command).

It is normal to do it either from the control logic through control functions or through a digital input. This logic input signal is called **Enable Input…**. It combines with the **In Service** setting in this algorithm.

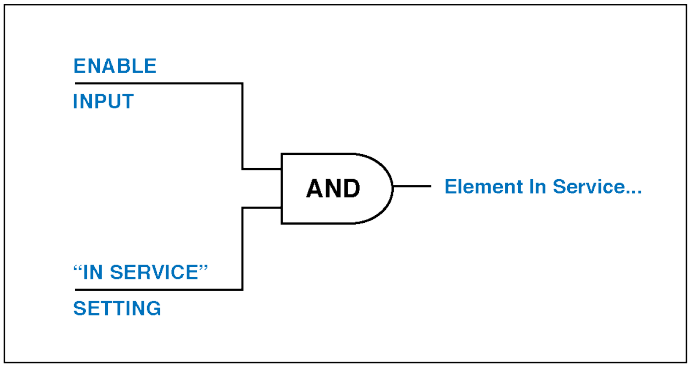


Figure 1.5.20 Element Enable Logic.

The default value of the logic input signal **Element Enable Input**... is a “1.” Therefore, when you do not configure the programmable logic at all, putting the protection elements into service depends only on the value of the **In Service** setting of each of them. The logic configuration to activate or switch off the enabling logic input signal will be as complicated or simple as you wish, from assigning it to a status contact input to building logical schemas with the various logic gates available (flip-flop’s) or allocate them to controls from the command panel or by communications.

Those protection functions that are put “out of service” by any of these methods will not generate or activate any of their associated logic signals, not even those that may be configured in the programmable logic and are directly related to these functions.

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Digital input related settings may only be configured from the communications program:

Table 1.5-1: Digital Inputs of the Inputs Module

Name	Group	IEC 61850	Description	Vis.	Function
SLOTX_DI01DISORD	Unit Enablement Control	-	Slot X Command to Disable Digital Input 1		Inputs to the module of digital inputs that activate and deactivate each of the digital inputs
SLOTX_DI02DISORD		-	Slot X Command to Disable Digital Input 2		
SLOTX_DI03DISORD		-	Slot X Command to Disable Digital Input 3		
SLOTX_DI04DISORD		-	Slot X Command to Disable Digital Input 4		
SLOTX_DI05DISORD		-	Slot B Command to Disable Digital Input 5		
SLOTX_DI06DISORD		-	Slot X Command to Disable Digital Input 6		
SLOTX_DI07DISORD		-	Slot X Command to Disable Digital Input 7		
SLOTX_DI08DISORD		-	Slot X Command to Disable Digital Input 8		
SLOTX_DI09DISORD		-	Slot X Command to Disable Digital Input 9		
SLOTX_DI010DISORD		-	Slot X Command to Disable Digital Input 10		
SLOTX_DI011DISORD		-	Slot B Command to Disable Digital Input 11		
SLOTX_DI012DISORD		-	Slot X Command to Disable Digital Input 12		
SLOTX_DI013DISORD		-	Slot X Command to Disable Digital Input 13		
SLOTX_DI014DISORD		-	Slot X Command to Disable Digital Input 14		
SLOTX_DI015DISORD		-	Slot B Command to Disable Digital Input 15		
SLOTX_DI016DISORD		-	Slot X Command to Disable Digital Input 16		
SLOTX_DI01ENAORD		-	Slot X Command to Enable Digital Input 1		
SLOTX_DI02ENAORD		-	Slot X Command to Enable Digital Input 2		
SLOTX_DI03ENAORD		-	Slot X Command to Enable Digital Input 3		

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Table 1.5-1: Digital Inputs of the Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
SLOTX_DI04ENAORD	Unit Enablement Control	-	Slot X Command to Enable Digital Input 4		Inputs to the module of digital inputs that activate and deactivate each of the digital inputs.
SLOTX_DI05ENAORD		-	Slot X Command to Enable Digital Input 5		
SLOTX_DI06ENAORD		-	Slot X Command to Enable Digital Input 6		
SLOTX_DI07ENAORD		-	Slot X Command to Enable Digital Input 7		
SLOTX_DI08ENAORD		-	Slot X Command to Enable Digital Input 8		
SLOTX_DI09ENAORD		-	Slot X Command to Enable Digital Input 9		
SLOTX_DI10ENAORD		-	Slot X Command to Enable Digital Input 10		
SLOTX_DI11ENAORD		-	Slot X Command to Enable Digital Input 11		
SLOTX_DI12ENAORD		-	Slot X Command to Enable Digital Input 12		
SLOTX_DI13ENAORD		-	Slot X Command to Enable Digital Input 13		
SLOTX_DI14ENAORD		-	Slot X Command to Enable Digital Input 14		
SLOTX_DI15ENAORD		-	Slot X Command to Enable Digital Input 15		
SLOTX_DI16ENAORD		-	Slot X Command to Enable Digital Input 16		

Table 1.5-2: Digital Outputs of the Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
SLOTX_DI01VALUE	Physical Digital Inputs	INSXGGIO1.Ind1	Slot X Digital Input 1		They indicate that the corresponding input has been activated.
SLOTX_DI02VALUE		INSXGGIO1.Ind2	Slot X Digital Input 2		
SLOTX_DI03VALUE		INSXGGIO1.Ind3	Slot X Digital Input 3		
SLOTX_DI04VALUE		INSXGGIO1.Ind4	Slot X Digital Input 4		
SLOTX_DI05VALUE		INSXGGIO1.Ind5	Slot X Digital Input 5		
SLOTX_DI06VALUE		INSXGGIO1.Ind6	Slot X Digital Input 6		
SLOTX_DI07VALUE		INSXGGIO1.Ind7	Slot X Digital Input 7		
SLOTX_DI08VALUE		INSXGGIO1.Ind8	Slot X Digital Input 8		
SLOTX_DI09VALUE		INSXGGIO1.Ind9	Slot X Digital Input 9		
SLOTX_DI10VALUE		INSXGGIO1.Ind10	Slot X Digital Input 10		
SLOTX_DI11VALUE		INSXGGIO1.Ind11	Slot X Digital Input 11		
SLOTX_DI12VALUE		INSXGGIO1.Ind12	Slot X Digital Input 12		
SLOTX_DI13VALUE		INSXGGIO1.Ind13	Slot X Digital Input 13		
SLOTX_DI14VALUE		INSXGGIO1.Ind14	Slot X Digital Input 14		
SLOTX_DI15VALUE		INSXGGIO1.Ind15	Slot X Digital Input 15		
SLOTX_DI16VALUE		INSXGGIO1.Ind16	Slot X Digital Input 16		

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Table 1.5-2: Digital Outputs of the Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
SLOTX_DI01VALIDITY	Validity of Digital Inputs		Slot X Validity of Digital Input 1		They indicate the valid status of the digital input.
SLOTX_DI02VALIDITY			Slot X Validity of Digital Input 2		
SLOTX_DI03VALIDITY			Slot X Validity of Digital Input 3		
SLOTX_DI04VALIDITY			Slot X Validity of Digital Input 4		
SLOTX_DI05VALIDITY			Slot X Validity of Digital Input 5		
SLOTX_DI06VALIDITY			Slot X Validity of Digital Input 6		
SLOTX_DI07VALIDITY			Slot X Validity of Digital Input 7		
SLOTX_DI08VALIDITY			Slot X Validity of Digital Input 8		
SLOTX_DI09VALIDITY			Slot X Validity of Digital Input 9		
SLOTX_DI10VALIDITY			Slot X Validity of Digital Input 10		
SLOTX_DI11VALIDITY			Slot X Validity of Digital Input 11		
SLOTX_DI12VALIDITY			Slot X Validity of Digital Input 12		
SLOTX_DI13VALIDITY			Slot X Validity of Digital Input 13		
SLOTX_DI14VALIDITY			Slot X Validity of Digital Input 14		
SLOTX_DI15VALIDITY			Slot X Validity of Digital Input 15		
SLOTX_DI16VALIDITY			Slot X Validity of Digital Input 16		
FALLOTALIMENTACIONENTRADASDIGITALES	Alarm and Error Signals		Digital Inputs Power Failure		Indication of voltage reference loss in Dis.
ENTRADASDIGITALESHABILITADAS	Others		Digital Inputs Enabled		Indication of DIs enabled by setting.

Slot X. There may be X A or B connectors depending on model.

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1.5.6.b Auxiliary Outputs

The number of digital outputs available will depend on each particular model. They can all be configured with any input or output signal of the pre-existing protection and control modules or defined by the user in the programmable logic.

Auxiliary outputs may use normally open, normally closed relays or quick solid state outputs. For details on the arrangement of contacts for each model, see the External Connections Scheme.

In operation, metering elements and logic elements generate several logic outputs. These signals or any other signal registered in the relay can be used to configure the activation of each digital output through the OR gate available in the protection settings. For more complex logic and to be able to allocate the resultant outputs to physical auxiliary outputs, the necessary opcodes must be programmed in the programmable logic to generate a user signal to be used in the setting of the corresponding output.

There is an additional, non-programmable auxiliary output contact (**SLOT A**) that corresponds to the relay **In Service**.

Table 1.5-3: Auxiliary Outputs of the Outputs Module

Name	Group	IEC 61850	Description	Vis.	Function
SLOTX_DO01	Physical Digital Outputs	OUTSXGGIO1.Ind1	Slot X Digital Output 1		They indicate that the corresponding input has been activated.
SLOTX_DO02		OUTSXGGIO1.Ind2	Slot X Digital Output 2		
SLOTX_DO03		OUTSXGGIO1.Ind3	Slot X Digital Output 3		
SLOTX_DO04		OUTSXGGIO1.Ind4	Slot X Digital Output 4		
SLOTX_DO05		OUTSXGGIO1.Ind5	Slot X Digital Output 5		
SLOTX_DO06		OUTSXGGIO1.Ind6	Slot X Digital Output 6		
SLOTX_DO07		OUTSXGGIO1.Ind7	Slot X Digital Output 7		

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1.5.6.c Digital Inputs, Auxiliary Outputs and LEDs Test

Apply rated voltage, appropriate for the model. At this time, the **In Service** LED should be lit.

- **Digital Inputs**

For the inputs test, exceed the rated voltage adjusted in ***Activation Level*** by SLOT between the terminals corresponding to the inputs (marked in the external connections diagram), always taking the polarity of the contacts into account and activation levels indicated in paragraph 1.5.6.a.

From the inputs screen of the menu check that the inputs are activated. Remove the voltage and check that the inputs are deactivated. The check may also be carried out through the relay events or communications program status section.

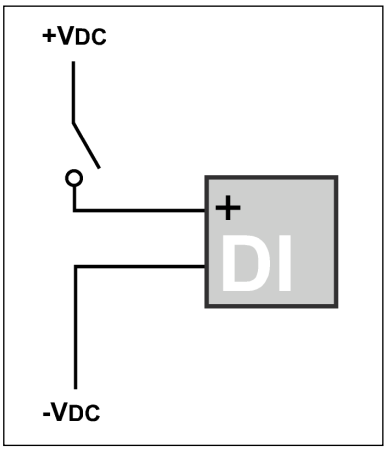


Figure 1.5.21 Digital Inputs Test.

- **Auxiliary Outputs**

To test the auxiliary contact outputs, their operation is provoked according to how they are configured. If they are not configured, they can be configured as activation of the status contact inputs or any other signal available on the equipment.

- **Selection and Command Buttons and Associated LEDs**

To test the configurable selection and command buttons on the front of the IED, they are assigned a configuration such that, once they have been selected and the command given, the corresponding auxiliary contact outputs are activated and deactivated.

Pressing the **P1** to **P6** keys after the configuration indicated above has been made, causes the LEDs corresponding to each of them to blink. Then, pressing the **I** key (which indicates closure) or the **O** key (which indicates opening), enables the contacts corresponding to the auxiliary contact outputs.

- **LED Targets**

In order to check the LED indicators, press the **CLR** key on the default screen until the LED reset screen appears. Keep **ENT** pressed until all LEDs light up and go off.

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1.5.7 Virtual Digital Inputs and Outputs

The equipment can manage up to 16 virtual inputs per remote unit connected through the communications card for the 87L line differential function. At the same time, it can send 16 virtual outputs by communications to all the remote units connected to it. These inputs and outputs will only work, that is, they will be considered valid, when there is a correct communication between units and when some communication channel with the corresponding remote unit is configured by settings.

The configuration of both inputs and outputs will be carried out by means of protection settings, being able to assign, per input and output, up to 16 signals connected to an OR door, in such a way that when any of these 16 signals is activated, the corresponding physical input or physical output will be activated. The signals to be selected may be internal to the equipment or user signals registered in the control configuration.

1.5.7.a Virtual Digital Inputs

The filtering and operation of the digital inputs is configurable according to the following options:

The equipment has 4 filters. Each filter is adjusted according to the following settings:

- ***Activation threshold*** (1-15 frames). It is possible to establish how many communication frames are necessary during an activation window for the signal to be considered active.
- ***Activation window*** (1-15 frames). Number of frames used to know if a certain signal is active or deactivated.

This threshold scheme of frames with active signal in a window of frames, or scheme *m over n*, allows to regulate the safety and obedience of the signal. Thus, the higher the threshold, the safer it will be before noises in the channel. However, it will delay signal activation and reduce obedience. By default, both values are set to 1. Therefore, only one frame with the virtual signal activated will be needed to consider it as active.

For each input, you can assign by setting which filter it will work with:

- ***Assignment of filters*** (Filter 1 - Filter 2 - Filter 3 - Filter 4). This setting is used to select "Filter 1", "Filter 2", "Filter 3" or "Filter 4" for each configurable virtual digital input. Using the settings explained above, filters 1, 2, 3 and 4 are built allowing you to create virtual inputs of fast and obedient detection and other virtual inputs of slow detection but more secure.

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Table 1.5-4: Settings of the Virtual Digital Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IAJSLDC_REMOTESIG_ACTWINDOWFILTER1	Virtual Digital Inputs	VIRINGGIO1.ActWindow1	Activation window for Filter 1		Number of frames used to know if a certain virtual digital input is active or not.
IAJSLDC_REMOTESIG_ACTWINDOWFILTER2		VIRINGGIO1.ActWindow2	Activation window for Filter 2		
IAJSLDC_REMOTESIG_ACTWINDOWFILTER3		VIRINGGIO1.ActWindow3	Activation window for Filter 3		
IAJSLDC_REMOTESIG_ACTWINDOWFILTER4		VIRINGGIO1.ActWindow4	Activation window for Filter 4		
IAJSLDC_REMOTESIG_ACTTHRESFILTER1		VIRINGGIO1.ActVal1	Activation threshold for Filter 1		Activated frames on the window to know if certain virtual digital input is active or not.
IAJSLDC_REMOTESIG_ACTTHRESFILTER2		VIRINGGIO1.ActVal2	Activation threshold for Filter 2		
IAJSLDC_REMOTESIG_ACTTHRESFILTER3		VIRINGGIO1.ActVal3	Activation threshold for Filter 3		
IAJSLDC_REMOTESIG_ACTTHRESFILTER4		VIRINGGIO1.ActVal4	Activation threshold for Filter 4		

Table 1.5-5: Settings of the E2 Remote Equipment Virtual Digital Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IAJSLDC_E2_DSREM1_ACTFILTER	Virtual Digital Inputs	VIRINE2GGIO.VInFil1	Filter for Virtual Digital Input 1		Apply a filter for Virtual Digital Inputs of the four available filters.
IAJSLDC_E2_DSREM2_ACTFILTER		VIRINE2GGIO.VInFil2	Filter for Virtual Digital Input 2		
IAJSLDC_E2_DSREM3_ACTFILTER		VIRINE2GGIO.VInFil3	Filter for Virtual Digital Input 3		
IAJSLDC_E2_DSREM4_ACTFILTER		VIRINE2GGIO.VInFil4	Filter for Virtual Digital Input 4		
IAJSLDC_E2_DSREM5_ACTFILTER		VIRINE2GGIO.VInFil5	Filter for Virtual Digital Input 5		
IAJSLDC_E2_DSREM6_ACTFILTER		VIRINE2GGIO.VInFil6	Filter for Virtual Digital Input 6		
IAJSLDC_E2_DSREM7_ACTFILTER		VIRINE2GGIO.VInFil7	Filter for Virtual Digital Input 7		
IAJSLDC_E2_DSREM8_ACTFILTER		VIRINE2GGIO.VInFil8	Filter for Virtual Digital Input 8		
IAJSLDC_E2_DSREM9_ACTFILTER		VIRINE2GGIO.VInFil9	Filter for Virtual Digital Input 9		
IAJSLDC_E2_DSREM10_ACTFILTER		VIRINE2GGIO.VInFil10	Filter for Virtual Digital Input 10		
IAJSLDC_E2_DSREM11_ACTFILTER		VIRINE2GGIO.VInFil11	Filter for Virtual Digital Input 11		
IAJSLDC_E2_DSREM12_ACTFILTER		VIRINE2GGIO.VInFil12	Filter for Virtual Digital Input 12		
IAJSLDC_E2_DSREM13_ACTFILTER		VIRINE2GGIO.VInFil13	Filter for Virtual Digital Input 13		
IAJSLDC_E2_DSREM14_ACTFILTER		VIRINE2GGIO.VInFil14	Filter for Virtual Digital Input 14		
IAJSLDC_E2_DSREM15_ACTFILTER		VIRINE2GGIO.VInFil15	Filter for Virtual Digital Input 15		
IAJSLDC_E2_DSREM16_ACTFILTER		VIRINE2GGIO.VInFil16	Filter for Virtual Digital Input 16		

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Table 1.5-6: Settings of the E3 Remote Equipment Virtual Digital Inputs Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IAJSLDC_E3_DSREM1_ACTFILTER	Virtual Digital Inputs	VIRINE3GGIO.VInFil1	Filter for Virtual Digital Input 1		Apply a filter for Virtual Digital Inputs of the four available filters.
IAJSLDC_E3_DSREM2_ACTFILTER		VIRINE3GGIO.VInFil2	Filter for Virtual Digital Input 2		
IAJSLDC_E3_DSREM3_ACTFILTER		VIRINE3GGIO.VInFil3	Filter for Virtual Digital Input 3		
IAJSLDC_E3_DSREM4_ACTFILTER		VIRINE3GGIO.VInFil4	Filter for Virtual Digital Input 4		
IAJSLDC_E3_DSREM5_ACTFILTER		VIRINE3GGIO.VInFil5	Filter for Virtual Digital Input 5		
IAJSLDC_E3_DSREM6_ACTFILTER		VIRINE3GGIO.VInFil6	Filter for Virtual Digital Input 6		
IAJSLDC_E3_DSREM7_ACTFILTER		VIRINE3GGIO.VInFil7	Filter for Virtual Digital Input 7		
IAJSLDC_E3_DSREM8_ACTFILTER		VIRINE3GGIO.VInFil8	Filter for Virtual Digital Input 8		
IAJSLDC_E3_DSREM9_ACTFILTER		VIRINE3GGIO.VInFil9	Filter for Virtual Digital Input 9		
IAJSLDC_E3_DSREM10_ACTFILTER		VIRINE3GGIO.VInFil10	Filter for Virtual Digital Input 10		
IAJSLDC_E3_DSREM11_ACTFILTER		VIRINE3GGIO.VInFil11	Filter for Virtual Digital Input 11		
IAJSLDC_E3_DSREM12_ACTFILTER		VIRINE3GGIO.VInFil12	Filter for Virtual Digital Input 12		
IAJSLDC_E3_DSREM13_ACTFILTER		VIRINE3GGIO.VInFil13	Filter for Virtual Digital Input 13		
IAJSLDC_E3_DSREM14_ACTFILTER		VIRINE3GGIO.VInFil14	Filter for Virtual Digital Input 14		
IAJSLDC_E3_DSREM15_ACTFILTER		VIRINE3GGIO.VInFil15	Filter for Virtual Digital Input 15		
IAJSLDC_E3_DSREM16_ACTFILTER		VIRINE3GGIO.VInFil16	Filter for Virtual Digital Input 16		

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The signal connection of the virtual digital inputs is similar to the physical digital inputs described above. These are divided according to the remote unit from which they come, starting with the remote unit E2 up to E3 (E1 is reserved for the local unit).

Table 1.5-7: Outputs of the E2 Remote Equipment Virtual Digital Inputs Module

Name	Group	IEC 61850	Description	Vis.	Function
LDC_E2_DI1VALUE	Virtual Digital Inputs	VIRINE2GGIO1.Ind1	Virtual Digital Input 1	I	Indication that this input has been activated.
LDC_E2_DI2VALUE		VIRINE2GGIO1.Ind2	Virtual Digital Input 2	I	
LDC_E2_DI3VALUE		VIRINE2GGIO1.Ind3	Virtual Digital Input 3	I	
LDC_E2_DI4VALUE		VIRINE2GGIO1.Ind4	Virtual Digital Input 4	I	
LDC_E2_DI5VALUE		VIRINE2GGIO1.Ind5	Virtual Digital Input 5	I	
LDC_E2_DI6VALUE		VIRINE2GGIO1.Ind6	Virtual Digital Input 6	I	
LDC_E2_DI7VALUE		VIRINE2GGIO1.Ind7	Virtual Digital Input 7	I	
LDC_E2_DI8VALUE		VIRINE2GGIO1.Ind8	Virtual Digital Input 8	I	
LDC_E2_DI9VALUE		VIRINE2GGIO1.Ind9	Virtual Digital Input 9	I	
LDC_E2_DI10VALUE		VIRINE2GGIO1.Ind10	Virtual Digital Input 10	I	
LDC_E2_DI11VALUE		VIRINE2GGIO1.Ind11	Virtual Digital Input 11	I	
LDC_E2_DI12VALUE		VIRINE2GGIO1.Ind12	Virtual Digital Input 12	I	
LDC_E2_DI13VALUE		VIRINE2GGIO1.Ind13	Virtual Digital Input 13	I	
LDC_E2_DI14VALUE		VIRINE2GGIO1.Ind14	Virtual Digital Input 14	I	
LDC_E2_DI15VALUE		VIRINE2GGIO1.Ind15	Virtual Digital Input 15	I	
LDC_E2_DI16VALUE		VIRINE2GGIO1.Ind16	Virtual Digital Input 16	I	
LDC_E2_DIVALIDITY		VIRINGGIO1.E2Valid	Validity Virtual Digital Inputs Remote Equipment E2	I	Indication that the virtual digital inputs are valid.

Table 1.5-8: Outputs of the E3 Remote Equipment Virtual Digital Inputs Module

Name	Group	IEC 61850	Description	Vis.	Function
LDC_E3_DI1VALUE	Virtual Digital Inputs	VIRINE3GGIO1.Ind1	Virtual Digital Input 1	I	Indication that this input has been activated.
LDC_E3_DI2VALUE		VIRINE3GGIO1.Ind2	Virtual Digital Input 2	I	
LDC_E3_DI3VALUE		VIRINE3GGIO1.Ind3	Virtual Digital Input 3	I	
LDC_E3_DI4VALUE		VIRINE3GGIO1.Ind4	Virtual Digital Input 4	I	
LDC_E3_DI5VALUE		VIRINE3GGIO1.Ind5	Virtual Digital Input 5	I	
LDC_E3_DI6VALUE		VIRINE3GGIO1.Ind6	Virtual Digital Input 6	I	
LDC_E3_DI7VALUE		VIRINE3GGIO1.Ind7	Virtual Digital Input 7	I	
LDC_E3_DI8VALUE		VIRINE3GGIO1.Ind8	Virtual Digital Input 8	I	
LDC_E3_DI9VALUE		VIRINE3GGIO1.Ind9	Virtual Digital Input 9	I	
LDC_E3_DI10VALUE		VIRINE3GGIO1.Ind10	Virtual Digital Input 10	I	
LDC_E3_DI11VALUE		VIRINE3GGIO1.Ind11	Virtual Digital Input 11	I	
LDC_E3_DI12VALUE		VIRINE3GGIO1.Ind12	Virtual Digital Input 12	I	
LDC_E3_DI13VALUE		VIRINE3GGIO1.Ind13	Virtual Digital Input 13	I	
LDC_E3_DI14VALUE		VIRINE3GGIO1.Ind14	Virtual Digital Input 14	I	
LDC_E3_DI15VALUE		VIRINE3GGIO1.Ind15	Virtual Digital Input 15	I	
LDC_E3_DI16VALUE		VIRINE3GGIO1.Ind16	Virtual Digital Input 16	I	
LDC_E3_DIVALIDITY		VIRINGGIO1.E3Valid	Validity Virtual Digital Inputs Remote Equipment E3	I	Indication that the virtual digital inputs are valid.

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1.5.7.b Virtual Digital Outputs

There are 16 virtual digital outputs that will be sent to all remotes without distinction. All of them are configurable with any input or output signal of the pre-existing protection and control modules or with user-defined signals in the programmable logic.

The measurement units and logic units generate, in their operation, a series of logic outputs. It is possible to use these signals or any signal registered inside the equipment to configure the activation of each digital output by means of the OR port available in the protection settings. In order to make more complex logics and be able to assign the resulting outputs to virtual digital outputs, it would be necessary to program the necessary opcodes in the programmable logic to generate a user signal to be used in the adjustment of the corresponding output.

Table 1.5-9: Outputs of the Virtual Digital Output Module

Name	Group	IEC 61850	Description	Vis.	Function
LDC_E1_DO1	Physical Digital Outputs	VIROUTGGIO.Ind1	Virtual Digital Output 1	I	Indication that this output has been activated.
LDC_E1_DO2		VIROUTGGIO.Ind2	Virtual Digital Output 2	I	
LDC_E1_DO3		VIROUTGGIO.Ind3	Virtual Digital Output 3	I	
LDC_E1_DO4		VIROUTGGIO.Ind4	Virtual Digital Output 4	I	
LDC_E1_DO5		VIROUTGGIO.Ind5	Virtual Digital Output 5	I	
LDC_E1_DO6		VIROUTGGIO.Ind6	Virtual Digital Output 6	I	
LDC_E1_DO7		VIROUTGGIO.Ind7	Virtual Digital Output 7	I	
LDC_E1_DO8		VIROUTGGIO.Ind8	Virtual Digital Output 8	I	
LDC_E1_DO9		VIROUTGGIO.Ind9	Virtual Digital Output 9	I	
LDC_E1_DO10		VIROUTGGIO.Ind10	Virtual Digital Output 10	I	
LDC_E1_DO11		VIROUTGGIO.Ind11	Virtual Digital Output 11	I	
LDC_E1_DO12		VIROUTGGIO.Ind12	Virtual Digital Output 12	I	
LDC_E1_DO13		VIROUTGGIO.Ind13	Virtual Digital Output 13	I	
LDC_E1_DO14		VIROUTGGIO.Ind14	Virtual Digital Output 14	I	
LDC_E1_DO15		VIROUTGGIO.Ind15	Virtual Digital Output 15	I	
LDC_E1_DO16		VIROUTGGIO.Ind16	Virtual Digital Output 16	I	

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1.5.8 Communications

1.5.8.a Communications Ports

The IEDs are provided with different types of communications ports depending on the selected model:

- **1 Front Local Port** USB-A host type for loading and downloading IEC 61850 files.
- **1 Front Local Port** USB-B type. Uses only PROCOME protocol for connection with the configuration tool.
- **2 Remote Ports** with the following characteristics:
  - Remote Port 1 (SP1): GFO (ST connector) interface or RS232 Full Modem electric interface.
  - Remote Ports 2 (SP2): GFO (ST connector) interface or RS232 / RS485 electric interface.
- **Up to 4 LAN Ports**. Two redundant interfaces with the following possible configurations (ETHERNET type communications).

Interface 1: LAN 1 and LAN 2	**LAN1**	**LAN2**
1st combination	RJ45	RJ45
2nd combination	GFO LC	GFO LC
3rd combination	GFO ST	GFO ST

Interface 2: LAN 3 and LAN 4	**LAN3**	**LAN4**
1st combination	Not available	Not available
2nd combination	RJ45	RJ45
3rd combination	GFO LC	GFO LC
4th combination	GFO ST	GFO ST

The relays include one controller per communications gate, so that communications can be established through all of them at the same time. On the other hand, Ethernet ports support up to 5 instances of protocols (PROCOME, DNP3 V3.0, MODBUS) simultaneously apart from MMS and GOOSE messages (IEC 61850) if an IEC 61850 relay is selected.

Technical data for these communications links can be found in Technical Data section. Information on model ports can be found in 1.2, Model Selection section.

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1.5.8.b Communications Ports for the Line Differential Function

The units have 2 or 4 communication ports (depending on the model) for the line differential function depending on the selected model:

- SFP (GFO LC) Ports. Rear for line differential function.
- GFO ST Multimode Ports. Rear for line differential function.

In addition, there is one led per port to indicate the status of the communication visually. These states and the corresponding LED indication are described in the following table:

LED Status	Communication Status
Off	Port disabled or without SFP connected
Fixed red	LOS or AIS
Fixed yellow	Incorrect address alarm
Blinking yellow	Yellow Bit
Blinking green	Port communicating correctly

Attention. Be careful when inserting SFP modules into the corresponding slot. If it is inserted upside down, difficulties may arise for later removal. Insert it in such a way that the safety flap closes towards the power supply unit.

1.5.8.c Communication with the Configuration Tool

Communication to set and download protection data (events, fault reports, disturbance recorder files, etc.) can be achieved through any communication ports set to PROCOME protocol. The local port is always assigned to this protocol, whereas remote ports must be assigned to protocol PROCOME for this purpose.

Communications are established through ***ZIV e-NET Tool***® program, which allows communicating whether locally (via a PC connected to front port) or remotely (via rear serial ports with PROCOME protocol), covering all needs regarding programming, settings, recording, reports, etc.

The configuration of the local communications gate may only be edited from the HMI, however, remote communications gate settings may also be edited through the communications program ***ZIV e-NET Tool***®, but only communicating with the relay through the local port.

The ***ZIV e-NET Tool***® program is protected against non-authorized users through access passwords. The ***ZIV e-NET Tool***®, which runs in WINDOWS™ environment, is easy to operate and uses buttons or keys to display the different submenus.

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1.5.8.d Communication Protocols

The following protocols are provided depending on the communications port:

- Front Local Port **USB-A** type (host). For loading and downloading IEC 61850 files using a pendrive.
- Front Local Port **USB-B** type. Uses only PROCOME protocol.
- Remote Ports **SP1** and **SP2**. Each port may be configured to be able to communicate through one protocol PROCOME, DNP V3.0 or MODBUS.
- **LAN** Ports. Two redundant interfaces. May communicate in MMS/GOOSE (IEC 61850) and simultaneously with one PROCOME instance with fixed port tcp 32001 and four configurable instances with configurable port TCP and configurable protocol (PROCOME, DNP3 V3.0 and MODBUS).

It is worth mentioning that communications through all ports can be maintained simultaneously.

PROCOME protocol complies with IEC-870-5 standards and is used, like IEC61850, for both protection and control information management. On the other hand, protocols DNP V3.0 and MODBUS can be used only for control information management.

For more details on protocols refer to the applicable protocol ANNEX.

1.5.8.e Control Change Recording

According to the signals that have been configured in the programmable logic through the ***ZIV e-NET Tool***®, the different events that occur in the system will generate the annotation of those signals that has changed their state.

Different signal lists for PROCOME 3.0, DNP V3.0 and MODBUS protocols can be configured through the programmable logic, saving the changes into different and separate relay files for each of the communications ports. This means that although the changes queue of one port is emptied after collecting said information, the same information is available at the other port for collection through the allocated protocol, whether it is the same as for the first port or not.

In the same way, from the signals configured in PROCOME, DNP 3.0 or both, user can select the ones to be displayed through the HMI. They are also saved into separate files, so that even if control changes queues of communications ports are emptied, the information is still available through HMI.

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Control change register data is displayed from the relay HMI, through the menu **Data/Registers/Events** or by pressing the **Up arrow** (which shows the options to **Display Events** or **Fault Reports)**. When entering into the display events option, the last generated event is always displayed (the most recent). Data is displayed as follows:

YY/MM/DD|HH:MM:SS
ms text1 □ or ■
ms text2 □ or ■

YY/MM/DD|HH:MM:SS
ms text3 □ or ■
ms text4 □ or ■

This is, events are grouped by “date” and “time”. Then, in the following line, the milliseconds corresponding to each control change and the label defined through the ***ZIV e-NET Tool***® (maximum of 13 characters) are shown. And at the end of the line, a filled or blank square indicates ACTIVATION-ON (■) or DEACTIVATION-OFF (□) respectively.

Default signal text labels are defined in input and output tables; in case of new signals generated into the programmable logic, said text must be defined. In any case, in order to use the names required by each user, the creation of a logic record card allocating a personalized name to every signal to be displayed is recommended.

The date and time stamp will be generated every time a new event occurs in it.

The MODBUS allows to display the actual value of the configured digital signals but do not record their changes.

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1.5.8.f Ethernet Redundancy

The equipment can have one or two redundant interfaces. Each redundant interface consists of two LAN ports. Depending on a setting, the operating mode can be defined: no redundancy, Bonding (Hot Stand By), RSTP, PRP or HSR.

- **No Redundancy**

The relay is provided with 2 separate network adapters with different MAC address and different IP address.

Both adapters are independent, it is possible to access the MMS data through both of them.

GOOSE messages will be sent and received only through one adapter, the one defined in the ***GOOSE Channel*** setting.

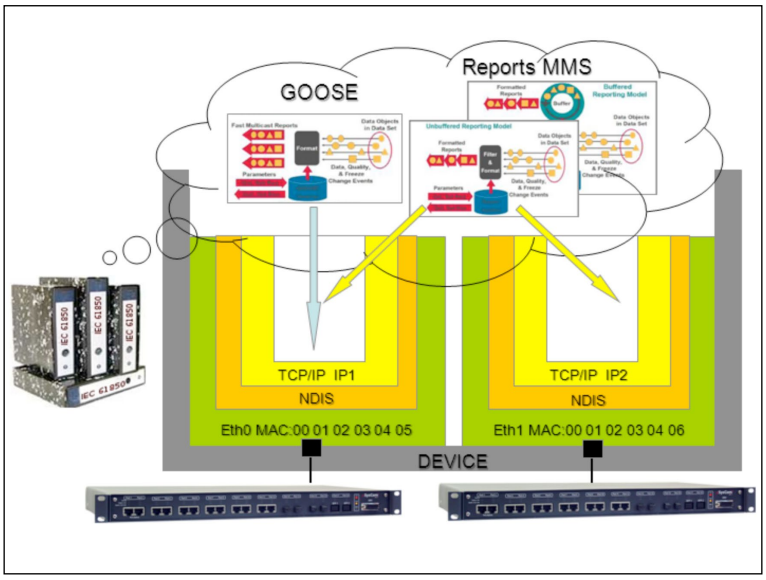


Figure 1.5.22 Configuration of Communications Ports for Relays without Ethernet Redundancy.

- **Bonding Type Redundancy (Hot Stand By)**

The relay is provided with 2 network adapters both operating with the same MAC address and the same IP address, only one of them being active as a function of the medium detection (a broken connection to the adapter results in switching to the other adapter that has a good connection). Both MMS data and GOOSE messages will be sent and received only by the active adapter.

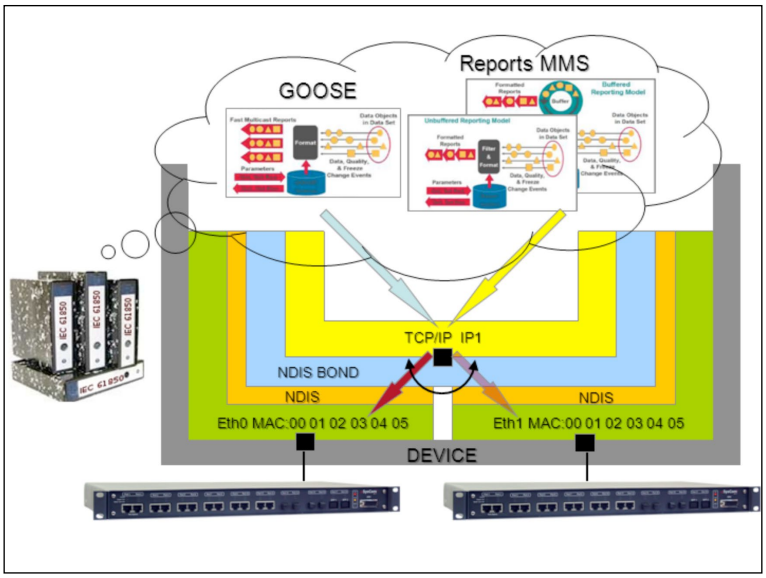


Figure 1.5.23 Configuration of Communications Ports for Relays with Bonding Type Redundancy (Hot Stand By).

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- **RSTP Type Redundancy**

The relay includes 2 network adapters, both operating with the same MAC address and the same IP address, and both adapters are active always. Relays define, together, the optimal path to send messages opening the ring to prevent loop formation. Also, they reconfigure the path when some type of relay or link failure occurs.

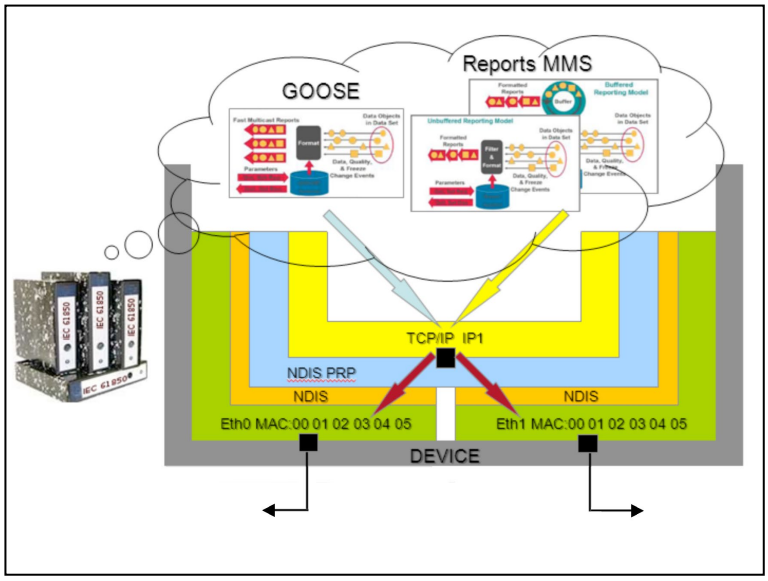


Figure 1.5.24 Configuration of Communications Ports for Relays with RSTP Type Redundancy.

RSTP type redundancy is based on connecting relays with each other with single ring, star or star-ring instead of using switches. The relays themselves are in charge of defining and opening the ring, as well as deleting messages from the same preventing their indefinite recirculation. All the equipments must support RSTP type Redundancy.

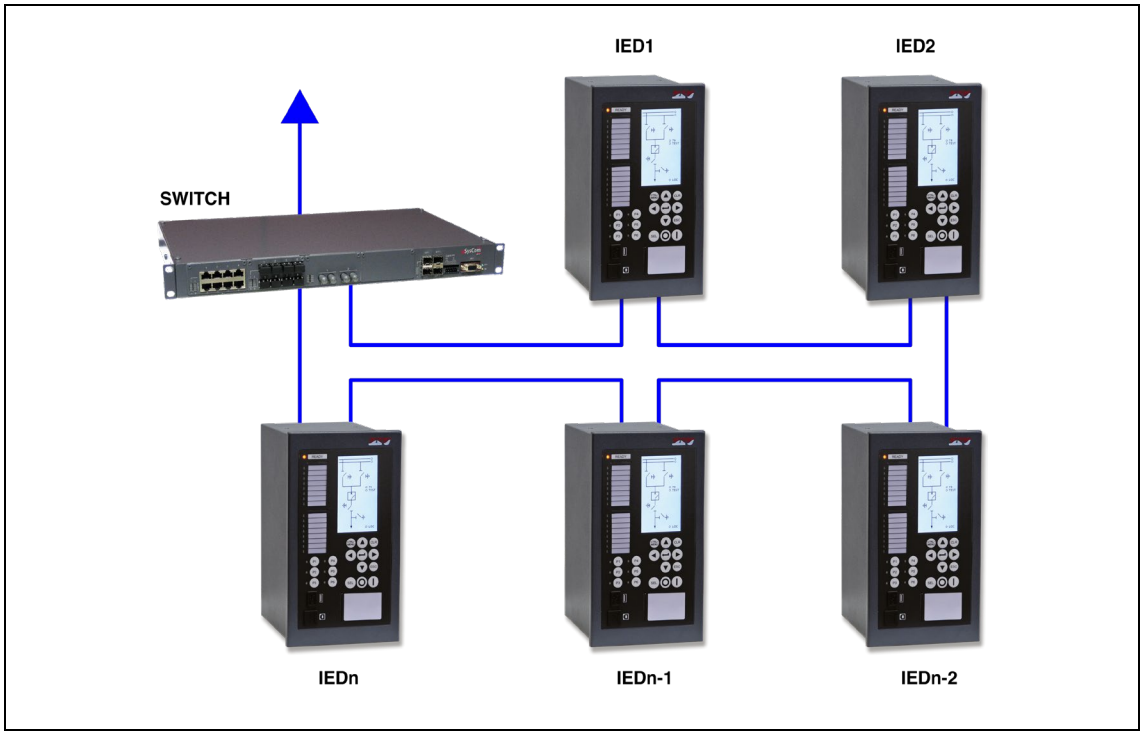


Figure 1.5.25 Example of Connecting Relays with RSTP Redundancy with Simple Ring.

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- **PRP Type Redundancy**

The relay is provided with 2 network adapters both operating with the same MAC address and the same IP address.

Both adapters are in active status all the time, sending the same data through both of them according to the IEC 62439-3 Parallel Redundancy Protocol (PRP).

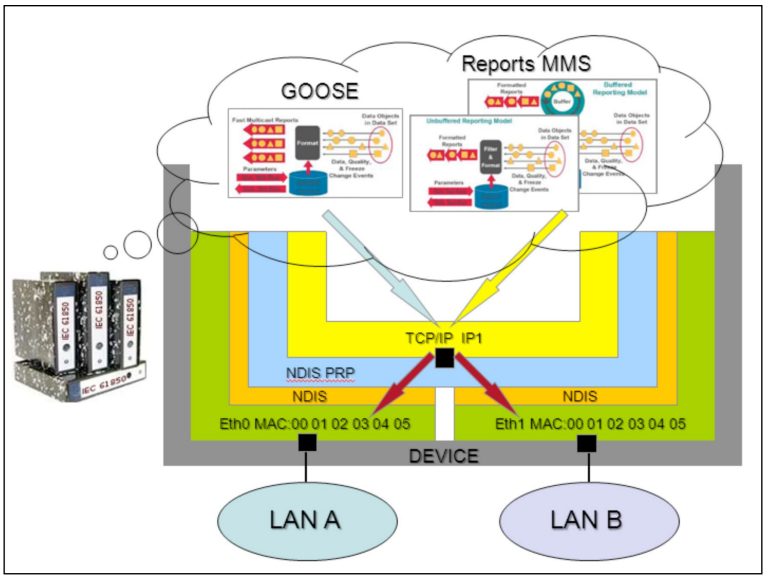


Figure 1.5.26 Configuration of Communications Ports for the Relay with PRP Type Redundancy.

This protocol is based on connecting the relays to two different Ethernet networks (LAN), not connected between them (independent LAN networks). The same data is sent through both adapters at the same time, adding 6 bytes to each Ethernet frame for the PRP protocol. These bytes enable discarding duplicate data, as the same data is received through both adapters and the idea is discarding the duplicate packet at the lowest possible level within the communications stack. Both MMS data and GOOSE messages will be sent through both adapters at the same time. In a PRP Redundancy system, both relays supporting PRP and relays not supporting RPR can operate, the latter being only connected to a single network.

LanID is fixed: 0x0A for LAN1 and LAN3 and 0x0B for LAN2 and LAN4.

- **HSR Type Redundancy**

The relay has 2 network adapters, both operating with the same MAC address and the same IP address, both adapters being active at all times and managing the traffic according to IEC 62439-3- High-availability Seamless Redundancy (HSR) protocol.

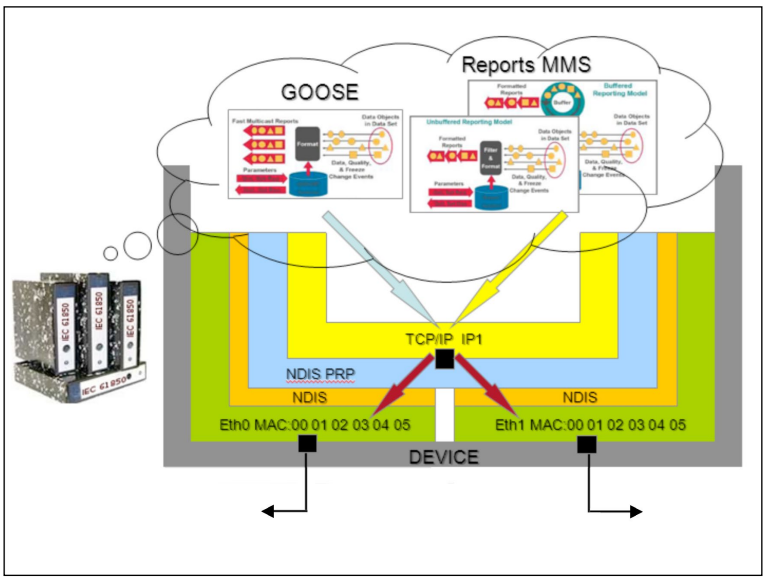


Figure 1.5.27 Configuration of Communications Ports for the Relay with HSR Type Redundancy.

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The HSR Redundancy is based on connecting the relays with each other in a ring structure. All relays connected to an HSR network must support HSR and the devices themselves carry out Ethernet frame management, operating as a bridge and resending traffic in case a relay is neither source nor target, receiving and deleting frames if they are target, discarding frames in case of emitter if they are returned through the same adapter as that used for sending or different adapter, sending supervision frames, etc.

LanID is fixed: 0x0A for LAN1 and LAN3 and 0x0B for LAN2 and LAN4.

- **Examples of Common Redundancies**

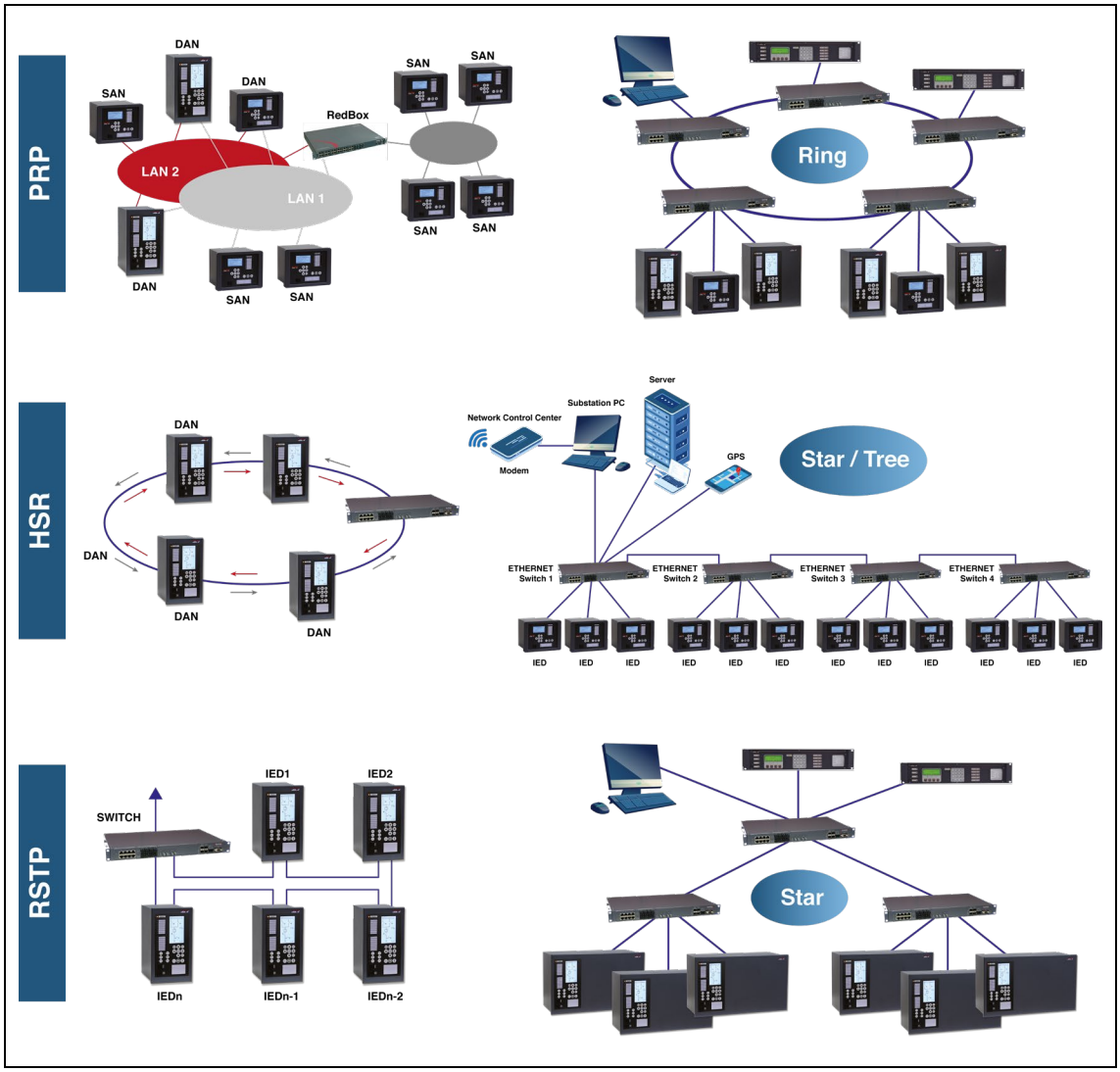


Figure 1.5.28 Examples of Common Redundancies.

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1.5.8.g Communications Settings

The settings described below are totally independent for each port and they are grouped as follows: ***Serial Port Settings (Local***, ***Remote Port 1*** **[SP1] or Remote Port 2 [SP2])**, ***LAN 1-2 Ports*** **(LAN1 or LAN2)**, ***LAN 3-4 Ports*** **(LAN3 or LAN4)**. Finally, specific settings for each protocol are described.

Every time a communications session is started through one of these ports, the relay communications port is displayed on the upper left corner of the relay alphanumeric screen (HMI). From left to right, local port, remote ports SP1 and SP2, fixed PROCOME instance to TCP 32001 port and configurable instances 1, 2, 3 and 4. On models with graphic display, this information is available in the protection menu.

That indication, in case of PROCOME 3.0 protocol, remains displayed during ***Communications Password TimeOut*** setting for the PROCOME Protocol after the last communication carried out; in case of MODBUS and DNP V3.0 protocols, the message remains displayed for one minute after the last communication.

There are different time settings for each physical communications ports (***Communications Fail Timer***), which, regardless of the protocol allocated, allow to configure the period of time with no communications activity after which the corresponding alarms (digital signals and events) of **Communications Fail Remote Port, Protocol 1, Protocol 2, Protocol 3, Protocol 4** and **Protocol PROCOME** are generated.

As stated above, the relay may include one or two redundant interfaces to make a total of 2 or 4 LAN ports. Settings are segregated by redundant interface, LAN1-2 and LAN3-4. Each interface includes the settings corresponding to each LAN port (LAN1, LAN2, LAN3 and LAN4), which will be used separately if the relay is set without redundancy, and the settings corresponding to the available interface redundancies (Bonding or Hot Stand By, RSTP, PRP and HSR).

When an interface is set with redundancy, its ports will work in pairs, LAN1 with LAN2 and LAN3 with LAN4. Each interface may be set with different type of redundancy. Regardless the selected type of redundancy, both adapters will work with the same MAC and IP address. The IP address used will be set in the LAN1 adapter for the LAN1-2 redundant interface or LAN3 in case of the LAN3-4 redundant interface.

The USB-B port allows the communication between 300 bits/s and 256000 bits/s automatically (it is not necessary to modify any setting on the port).

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Configuration / Communications / Ports / Local Port (HMI)					
Setting	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Communication Failure Indication Time	Comms Fail Time		0-600 s	0.1 s	60 s
Authenticated Protocol	Authenticated Prot		YES / NO		YES

Settings / Communications / Ports / Serial Ports / Remote Port 1					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Protocol Select	Protocol Select.		Procome 3.0 DNP3.0 MODBUS		Procome
Baudrate	Baudrate		2400-115200 Bauds		38400
Stop Bits	Stop Bits		1-2	1	1
Parity	Parity		None Odd Even		None
RX Time between characters	Rx Time btw. Char		1-60000 ms	0.5 ms	10 ms
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Authenticated Prot.	Authenticated Prot		YES / NO		YES
Advanced Settings	Advanced Settings				
Flow Control	Flow Control				
CTS Flow	CTS Flow		NO / YES		NO
DSR Flow	DSR Flow		NO / YES		NO
DSR Sensitive	DSR Sensitive		NO / YES		NO
DTR Control	DTR Control		Inactive Active Enable Send		Inactive
RTS Control	RTS Control		Inactive Active Enable Send Solicit Send		
Times	Time				
Tx Time Factor	Tx Time Factor		0-100	0.5	1
Tx Timeout Const.	Tx Timeout Const.		0-60000 ms	1 ms	0 ms
Message Modification	Message Modif.				
Number of Zeros	Number of Zeros		0-200	1	0
Collisions	Collisions				
Collision Type	Collision Type		No Echo DCD		No
Max Retries	Max Retries		0-3	1	0
Min Retry Time	Min Retry Time		0-60000 ms	1 ms	0 ms
Max Retry Time	Max Retry Time		0-60000 ms	1 ms	0 ms
Max Echo Delay	Max Eco Delay		0-60000 ms	0.5 ms	10 ms

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Settings / Communications / Ports / Serial Ports / Remote Port 2					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Protocol Select.	Protocol Select.		Procome 3.0 DNP3.0 MODBUS		Procome
Baudrate	Baudrate		2400-115200 Bauds		38400
Stop Bits	Stop Bits		1-2	1	1
Parity	Parity		None Odd Even		None
RX Time between characters	Rx Time btw. Char		1-60000 ms	0.5 ms	10 ms
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Authenticated Prot.	Authenticated Prot		YES / NO		YES
Advanced Settings	Advanced Settings				
Operating Mode	Operating Mode		RS-232 RS-485		RS-232
Times	Time				
Stop Bytes Number RS-485	Stop Bytes 485		0-4	1	0
Message Modification	Message Modif.				
Number of Zeros	Number of Zeros		0-200	1	0
Collisions	Collisions				
Collision Type	Collision Type		No Echo		No
Max Retries	Max Retries		0-3	1	0
Min Retry Time	Min Retry Time		0-60000 ms	1 ms	0 ms
Max Retry Time	Max Retry Time		0-60000 ms	1 ms	0 ms
Max Echo Delay	Max Eco Delay		0-60000 ms	0.5 ms	10 ms

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Settings / Communications / Ports / LAN Ports / Ports 1-2					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Redundancy Mode	Redundancy Mode	LCCH1.RedTyp	None Bonding PRP HSR RSTP		None
Channel Live Time	Channel Live Time	LCCH1.ChLivTms1	1-60 s	1 s	5 s
Link Live Time	Link Live Time	LCCH1.LnkLivTmms1	0-60 s	0.1 s	0 s
Bonding	Bonding				
Link Check Interval	Link Chk Interval	LCCH1.BndChkTmms	25-1000 ms	1 ms	100 ms
PRP					
Interval for Sending Supervision Frames	Superv TX Interval		0-30 s	0.5 s	2 s
LSB of Destination MAC for Supervision Frames	Sup LSB Dest MAC		0-255	1	0
HSR	HSR				
HSR Transmission	HSR transmission	LCCH1.HSRTxTyp	Store-Forward Cut-Through		Store-Forward
Interval for Sending Supervision Frames	Superv TX Interval		0-30 s	0.5 s	2 s
LSB of Destination MAC for Supervision Frames	Sup LSB Dest MAC		0-255	1	0
RSTP	RSTP				
Bridge Priority	Bridge Priority	LCCH1.STPPrio	0-61440	4096	32768
Hello Time	Hello Time	LCCH1.STPHello	1-10 s	1 s	2 s
Max Age	Max Age	LCCH1.STPMaxAge	6-40 s	1 s	20 s
Forward Delay	Forward Delay	LCCH1.STPFwdDl	4-30 s	1 s	15 s
Port 1	Port 1				
Priority	Priority	LCCH1.STPPrio1	0-240	16	128
Cost	Cost	LCCH1.STPCost1	0-200000000	1	200000
Edge	Edge	LCCH1.STPEdge1	On / Off		Off
Port 2	Port 2				
Priority	Priority	LCCH1.STPPrio2	0-240	16	128
Cost	Cost	LCCH1.STPCost2	0-200000000	1	200000
Edge	Edge	LCCH1.STPEdge2	On / Off		Off

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Settings / Communications / Ports / LAN Ports / Ports 1-2					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
LAN 1	LAN 1				
DHCP Enable	Enable DHCP		NO / YES		NO
IP Address	IP Address		ddd.ddd.ddd.ddd		192.168.1.81
Network Mask	Network Mask		ddd.ddd.ddd.ddd		255.255.255.0
Routing Tables	Routing tables				
Default Gateway	Default gateway				
Default route 1 IP address	IP default GW 1		ddd.ddd.ddd.ddd		0.0.0.0
Default route 1 metric	Metric def GW 1		0-65535	1	1
Default route 2 IP address	IP default GW 2		ddd.ddd.ddd.ddd		0.0.0.0
Default route 2 metric	Metric def GW 2		0-65535	1	1
Static routes	Static routes				
Destination address of route 1	Dest addr route 1		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 1	Netmask route 1		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 1	GW IP route 1		ddd.ddd.ddd.ddd		0.0.0.0
Destination address of route 2	Dest addr route 2		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 2	Netmask route 2		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 2	GW IP route 2		ddd.ddd.ddd.ddd		0.0.0.0
LAN 2	LAN 2				
DHCP Enable	Enable DHCP		NO / YES		NO
IP Address	IP Address		ddd.ddd.ddd.ddd		192.168.1.81
Network Mask	Network Mask		ddd.ddd.ddd.ddd		255.255.255.0
Routing Tables	Routing tables				
Default Gateway	Default gateway				
Default route 1 IP address	IP default GW 1		ddd.ddd.ddd.ddd		0.0.0.0
Default route 1 metric	Metric def GW 1		0-65535	1	1
Default route 2 IP address	IP default GW 2		ddd.ddd.ddd.ddd		0.0.0.0
Default route 2 metric	Metric def GW 2		0-65535	1	1
Static routes	Static routes				
Destination address of route 1	Dest addr route 1		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 1	Netmask route 1		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 1	GW IP route 1		ddd.ddd.ddd.ddd		0.0.0.0
Destination address of route 2	Dest addr route 2		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 2	Netmask route 2		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 2	GW IP route 2		ddd.ddd.ddd.ddd		0.0.0.0

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Settings / Communications / Ports / LAN Ports / Ports 3-4					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Redundancy Mode	Redundancy Mode	LCCH1.RedTyp	None Bonding PRP HSR RSTP		None
Channel Live Time	Channel Live Time	LCCH1.ChLivTms1	1-60 s	1 s	5 s
Link Live Time	Link Live Time	LCCH1.LnkLivTmms1	0-60 s	0.1 s	0 s
Bonding	Bonding				
Link Check Interval	Link Chk Interval	LCCH1.BndChkTmms	25-1000 ms	1 ms	100 ms
PRP					
Interval for Sending Supervision Frames	Superv TX Interval		0-30 s	0.5 s	2 s
LSB of Destination MAC for Supervision Frames	Sup LSB Dest MAC		0-255	1	0
HSR	HSR				
HSR Transmission	HSR transmission	LCCH1.HSRTxTyp	Store-Forward Cut-Through		Store-Forward
Interval for Sending Supervision Frames	Superv TX Interval		0-30 s	0.5 s	2 s
LSB of Destination MAC for Supervision Frames	Sup LSB Dest MAC		0-255	1	0
RSTP	RSTP				
Bridge Priority	Bridge Priority	LCCH1.STPPrio	0-61440	4096	32768
Hello Time	Hello Time	LCCH1.STPHello	1-10 s	1 s	2 s
Max Age	Max Age	LCCH1.STPMaxAge	6-40 s	1 s	20 s
Forward Delay	Forward Delay	LCCH1.STPFwdDl	4-30 s	1 s	15 s
Port 1	Port 1				
Priority	Priority	LCCH1.STPPrio1	0-240	16	128
Cost	Cost	LCCH1.STPCost1	0-200000000	1	200000
Edge	Edge	LCCH1.STPEdge1	On / Off		Off
Port 2	Port 2				
Priority	Priority	LCCH1.STPPrio2	0-240	16	128
Cost	Cost	LCCH1.STPCost2	0-200000000	1	200000
Edge	Edge	LCCH1.STPEdge2	On / Off		Off

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Settings / Communications / Ports / LAN Ports / Ports 3-4					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
LAN 3	LAN 3				
DHCP Enable	Enable DHCP		NO / YES		NO
IP Address	IP Address		ddd.ddd.ddd.ddd		192.168.1.81
Network Mask	Network Mask		ddd.ddd.ddd.ddd		255.255.255.0
Routing Tables	Routing tables				
Default Gateway	Default gateway				
Default route 1 IP address	IP default GW 1		ddd.ddd.ddd.ddd		0.0.0.0
Default route 1 metric	Metric def GW 1		0-65535	1	1
Default route 2 IP address	IP default GW 2		ddd.ddd.ddd.ddd		0.0.0.0
Default route 2 metric	Metric def GW 2		0-65535	1	1
Static routes	Static routes				
Destination address of route 1	Dest addr route 1		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 1	Netmask route 1		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 1	GW IP route 1		ddd.ddd.ddd.ddd		0.0.0.0
Destination address of route 2	Dest addr route 2		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 2	Netmask route 2		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 2	GW IP route 2		ddd.ddd.ddd.ddd		0.0.0.0
LAN 4	LAN 4				
DHCP Enable	Enable DHCP		NO / YES		NO
IP Address	IP Address		ddd.ddd.ddd.ddd		192.168.1.81
Network Mask	Network Mask		ddd.ddd.ddd.ddd		255.255.255.0
Routing Tables	Routing tables				
Default Gateway	Default gateway				
Default route 1 IP address	IP default GW 1		ddd.ddd.ddd.ddd		0.0.0.0
Default route 1 metric	Metric def GW 1		0-65535	1	1
Default route 2 IP address	IP default GW 2		ddd.ddd.ddd.ddd		0.0.0.0
Default route 2 metric	Metric def GW 2		0-65535	1	1
Static routes	Static routes				
Destination address of route 1	Dest addr route 1		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 1	Netmask route 1		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 1	GW IP route 1		ddd.ddd.ddd.ddd		0.0.0.0
Destination address of route 2	Dest addr route 2		ddd.ddd.ddd.ddd		0.0.0.0
Network mask of route 2	Netmask route 2		ddd.ddd.ddd.ddd		255.255.255.0
IP Gateway address of route 2	GW IP route 2		ddd.ddd.ddd.ddd		0.0.0.0

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Settings / Communications / Ports / LAN Protocols					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Procome Protocol	PROCOME Protocol				
Port Number	Port Number		1-65535	1	32001
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Encrypted Prot.	Encrypted Prot.		NO / YES		YES
Authenticated Prot.	Authenticated Prot		NO / YES		SYES
Advanced Settings	Advanced Settings				
TCP KeepAlive Time	Tcp KeepAlive Time		0-32767	1	20
TCP KeepAlive Probes	Tcp KeepAlive Prob		1-127	1	2
TCP KeepAlive Interval	Tcp KeepAlive Int		0-32767	1	10
Protocol 1	Protocol 1				
Ethernet Protocol	Ethernet Protocol		None Procome Dnp 3.0 Modbus		None
Port Number	Port Number		1-65535	1	20000
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Encrypted Prot.	Encrypted Prot.		NO / YES		YES
Authenticated Prot.	Authenticated Prot		NO / YES		SYES
Advanced Settings	Advanced Settings				
TCP KeepAlive Time	Tcp KeepAlive Time		0-32767	1	20
TCP KeepAlive Probes	Tcp KeepAlive Prob		1-127	1	2
TCP KeepAlive Interval	Tcp KeepAlive Int		0-32767	1	10
Protocol 2	Protocol 2				
Ethernet Protocol	Ethernet Protocol		None Procome Dnp 3.0 Modbus		None
Port Number	Port Number		1-65535	1	20001
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Encrypted Prot.	Encrypted Prot.		NO / YES		YES
Authenticated Prot.	Authenticated Prot		NO / YES		SYES
Advanced Settings	Advanced Settings				
TCP KeepAlive Time	Tcp KeepAlive Time		0-32767	1	20
TCP KeepAlive Probes	Tcp KeepAlive Prob		1-127	1	2
TCP KeepAlive Interval	Tcp KeepAlive Int		0-32767	1	10

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Settings / Communications / Ports / LAN Protocols					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Protocol 3	Protocol 3				
Ethernet Protocol	Ethernet Protocol		None Procome Dnp 3.0 Modbus		None
Port Number	Port Number		1-65535	1	20002
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Encrypted Prot.	Encrypted Prot.		NO / YES		YES
Authenticated Prot.	Authenticated Prot		NO / YES		SYES
Advanced Settings	Advanced Settings				
TCP KeepAlive Time	Tcp KeepAlive Time		0-32767	1	20
TCP KeepAlive Probes	Tcp KeepAlive Prob		1-127	1	2
TCP KeepAlive Interval	Tcp KeepAlive Int		0-32767	1	10
Protocol 4	Protocol 4				
Ethernet Protocol	Ethernet Protocol		None Procome Dnp 3.0 Modbus		None
Port Number	Port Number		1-65535	1	20003
Comms Fail Timer	Comms Fail Time		0-600 s	0.1 s	60 s
Encrypted Prot.	Encrypted Prot.		NO / YES		YES
Authenticated Prot.	Authenticated Prot		NO / YES		SYES
Advanced Settings	Advanced Settings				
TCP KeepAlive Time	Tcp KeepAlive Time		0-32767	1	20
TCP KeepAlive Probes	Tcp KeepAlive Prob		1-127	1	2
TCP KeepAlive Interval	Tcp KeepAlive Int		0-32767	1	10

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Settings / Communications / Protocols					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
PROCOME 3.0	Procome Protocol				
IED Address	Unit Number		0-254	1	0
DNP 3.0 Protocol	DNP 3.0 Protocol				
IED Address	Relay Number		0-65519	1	1
T. Confirm Timeout	T. Confirm Timeout		100-65535 ms	1	1000 ms
Max Retries	Max Retries		0-65535	1	0
Enable Unsolicited	Enab. Unsolicited		NO / YES		NO
Unsolicited Master No.	Unsol. Master No.		0-65519	1	1
Unsolicited Grouping Time	Uns. Grouping Time		100-65535 ms	1	1000 ms
Sync Interval	Syncr. Interval		0-120 min	1	0 min
Binary Changes Class	Binary Class		None Class 1 Class 2 Class 3		Class 1
Analog Changes Class	Analog Class		None Class 1 Class 2 Class 3		Class 2
Counter Changes Class	Counter Class		None Class 1 Class 2 Class 3		Class 3
Binary Status	Binary Status		NO / YES		YES
32 Bits Analog Inputs	32 Bit Analog Inp.		NO / YES		YES
Metering (16 Dead Bands)	Measures		0.0001-100	0.0001	100
Counters (20 Counter Dead Bands)	Counters		1-32767	1	1
MODBUS Protocol	MODBUS Protocol				
IED Address	Unit Number		0-247	1	1

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Settings / Communications / Protocols					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
IEC 61850					
GOOSE Channel			LAN1 LAN2 LAN3 LAN4		LAN1
Goose	Goose				
Simulation	Simulation				
Publications	Publication				
GCB 01 Simulated	GCB 01 Simulated		NO / YES		NO
GCB 02 Simulated	GCB 02 Simulated		NO / YES		NO
GCB 03 Simulated	GCB 03 Simulated		NO / YES		NO
GCB 04 Simulated	GCB 04 Simulated		NO / YES		NO
GCB 05 Simulated	GCB 05 Simulated		NO / YES		NO
GCB 06 Simulated	GCB 06 Simulated		NO / YES		NO
GCB 07 Simulated	GCB 07 Simulated		NO / YES		NO
GCB 08 Simulated	GCB 08 Simulated		NO / YES		NO
GCB 09 Simulated	GCB 09 Simulated		NO / YES		NO
GCB 10 Simulated	GCB 10 Simulated		NO / YES		NO
Subscription	Subscription		NO / YES		NO

The configuration settings of the PROCOME 3.0 protocol are:

- ***IED Address*** (0-254): it specifies the address of the relay (acting as RTU or Remote Terminal Unit) in relation to the rest of equipment that communicate with the same master station (MTU or Master Terminal Unit).

The DNP 3.0 protocol configuration settings include the definition of:

- ***Relay Number*** (0-65519): it specifies the address of the relay (acting as RTU or Remote Terminal Unit) in relation to the rest of equipment that communicate with the same master station (MTU or Master Terminal Unit). The 0xFFF0 to 0xFFFF addresses are reserved for the Broadcast addresses.
- ***T. Confirm TimeOut*** (100-65535): it specifies the time lapse (in milliseconds) from the time the IED sends a message requesting the master to confirm the Application layer (Level 7), until this confirmation is considered lost. The IED requests confirmation of the Application Layer when it sends spontaneous (Unsolicited) messages or in response to requests for Class 1 or Class 2 Data. When this time expires, the message is retransmitted the number of times specified in the N. Retries parameter.
- ***N. Retries*** (0-65535): number of retries of the Application Layer (N7). The default value is 0 (zero), indicating that no retransmission will be attempted.
- ***Enable Unsolicited*** (YES/NO): enables (YES) or disables (NO) sending spontaneous messages (Unsolicited); it is used in combination with the ***MTU Number*** parameter. For the relay to begin sending spontaneous messages the master must also enable them with the Function Code FC = 20.
- ***Master Number Unsolicited*** (0-65535): it specifies the address of the master station (MTU or Master Terminal Unit) to which the relay will send spontaneous (Unsolicited) messages. It is used in combination with Enable Unsolicited parameter. Addresses 0xFFF0 to 0xFFFF are reserved for Broadcast addresses.

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- ***Time Grouping Unsolicited*** (100-65535): it specifies the time interval between the generation of a first event for an unsolicited message and the transmission of the message, with the purpose of grouping several events that may occur within this time interval in a single transmission message, in order not to saturate the communications line with multiple messages.
- ***Sync. Interval*** (0-120 minutes): it specifies the maximum time interval between two synchronizations. If no synchronization occurs within the interval, the need for synchronization is set in Internal Indication (IIN1-4 NEED TIME). This setting has no effect if the Sync. Interval is 0.

Up to 64 measurements or analog magnitudes can be set for DNP3 transmission. Among them, up to 16 measurements can be set for transmission upon a change request. To select the measurements to transmit upon a change request, enable the ***DNP3 Measurement Change*** control configuration option using ***ZIV e-NET Tool***®.

The measurement change transmission is set through two parameters for each measurement: ***Upper Limit*** (in profile I relays) or ***Maximum Value*** (in profile II relays) setting values and the ***Band*** setting value set for that measurement. Up to 16 band values may be configured through ***ZIVercomPlus***®, which will be associated to the measurements enabled for change transmission in the same sequence as they are ordered in ***ZIV e-NET Tool***®. This is: band value 000 will be assigned to the first measurement enabled for change transmission, 001 to the second, and so on up to the last measurement enabled, with the limit of 16. The band represents a percentage of the ***Maximum Value***, so that when a measurement change exceeds that band, the measurement value is annotated to be sent as change. When the relay receives a measurement change request, it will send all changes annotated.

Analog changes will not be annotated for measurements with option ***DNP3 Measurement Change*** enabled but with the band set to 100%, or measurements with option ***DNP3 Measurement Change*** not enabled, they being deemed disabled for change transmission. Additionally, these are other settings defined for the DNP3.0 Profile II and DNP 3.0 Profile II ETHERNET Protocols:

- ***Class for Binary Changes*** (CLASS 1, CLASS 2, CLASS 3, NONE). Assigns the class to the binary changes.
- ***Class for Analog Changes*** (CLASS 1, CLASS 2, CLASS 3, NONE). Assigns the class to the analog changes.
- ***Class for Counter Changes*** (CLASS 1, CLASS 2, CLASS 3, NONE). Assigns the class to the counter changes.
- ***"Status" Type Binary Inputs*** (YES-NO). Binary inputs used are according to "status" type inputs (YES) or binary inputs used are not sent according to "status" type inputs (NO).
- ***32 bits Analog Inputs*** (YES-NO). Analog inputs used are 32 bits resolution (YES) or analog inputs used are 16 bits resolution (NO).

In order for the relay to accept commands received through DNP3, the internal Remote Control signal must be active, for this, it must be activated through control logic.

The only configuration setting of the MODBUS protocol is the ***Relay Number*** (0-254), which specifies the relay address (acting as RTU or Remote Terminal Unit) with reference to the rest of relays communicating with the same master station (MTU or Master Terminal Unit).

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1.5.8.h Output Signals of the Communications Module

Table 1.5-10: Output Signals of the Communications Module

Name	Group	IEC 61850	Description	Vis.	Function
FALLO_LINK1	Errors and Alarms	LCCH1.LnkLiv	LAN1 Link Failure	I	Signal indicating link failure after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_COMS1		LCCH1.ChLiv	LAN1 Communications Failure	I	Signal indicating that no traffic exists after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_LINK2		LCCH1.RedLnkLiv	LAN2 Link Failure	I	Signal indicating link failure after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_COMS2		LCCH1.RedChLiv	LAN2 Communications Failure	I	Signal indicating that no traffic exists after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_LINK3		LCCH2.LnkLiv	LAN3 Link Failure	I	Signal indicating link failure after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_COMS3		LCCH2.ChLiv	LAN3 Communications Failure	I	Signal indicating that no traffic exists after the timer set time times out. IEC 61850 signal indicates otherwise.

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Table 1.5-10: Output Signals of the Communications Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
FALLO_LINK4	Errors and Alarms	LCCH2.RedLnkLiv	LAN4 Link Failure	I	Signal indicating link failure after the timer set time times out. IEC 61850 signal indicates otherwise.
FALLO_COMS4		LCCH2.RedChLiv	LAN4 Communications Failure	I	Signal indicating that no traffic exists after the timer set time times out. IEC 61850 signal indicates otherwise.
AVALANCHAENLAN1		LCCH1.InOv	Network Congestion Detected on LAN1		The number of frames received exceeds the limit supported and the relay discards incoming traffic through this port.
AVALANCHAENLAN2		LCCH1.RedInOv	Network Congestion Detected on LAN2		The number of frames received exceeds the limit supported and the relay discards incoming traffic through this port.
AVALANCHAENLAN3		LCCH2.InOv	Network Congestion Detected on LAN3		The number of frames received exceeds the limit supported and the relay discards incoming traffic through this port.
AVALANCHAENLAN4		LCCH2.RedInOv	Network Congestion Detected on LAN4		The number of frames received exceeds the limit supported and the relay discards incoming traffic through this port.
BONDINGACT1	Others	LCCH1.BndActCh	Bonding LAN1 active		Indicates active Bonding port. In IEC 61850, FALSE stands for LAN1 port and TRUE for LAN2 port.
BONDINGACT2			Bonding LAN2 active		
BONDINGACT3		LCCH2.BndActCh	Bonding LAN3 active		Indicates active Bonding port. In IEC 61850, FALSE stands for LAN3 port and TRUE for LAN4 port.
BONDINGACT4			Bonding LAN4 active		

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1.5.9 Time Synchronization

1.5.9.a Manual Time Synchronization

If synchronization is not detected from any source, the relay will accept manual synchronization through the HMI.

1.5.9.b Time Synchronization by Protocol

Relays may be synchronized as follows:

- **Protocol PROCOME**: the relay can receive the date and time through protocol PROCOME either from a central unit or from the communications program, which will send the PC local time. The relay will synchronize if IRIG-B or SNTP synchronization is not detected.
- **Protocol DNP3**: the relay may receive the date and time through protocol DNP3 from a server. The relay will synchronize if IRIG-B, SNTP or PROCOME synchronization is not detected.

1.5.9.c Synchronization by SNTP

IEC 61850 relays can be synchronized through protocol SNTP by means of broadcast or unicast and with one or two servers. The relay will be synchronized through SNTP if IRIG-B synchronization is not detected. For this, there is a Synchronization section within the settings menu, where the following settings can be found: See Annex D.

1.5.9.d Synchronization by IRIG-B 123 and 003

Relays are provided (depending on the model) with a BNC type input for IRIG-B 123 or 003 standard time synchronization signals. Said input is located at the relay rear panel. Synchronization accuracy is ±1ms.

In case the relay is receiving an IRIG-B synchronization signal, access from HMI to **Date and Time** settings is denied.

An output can be configured to show IRIG-B signal received status. This output remains active while the relay receives correctly said signal. This relays are also prepared for indication of both the loss and recovery of IRIG-B signal by generating events associated to each of these circumstances.

Discerning whether the time received through BNC connector corresponds to **UTC Time** or a given **Time Zone (Local)** is possible through ***IRIG-B Time Type*** setting.

In the first case, a correction must be introduced to adapt the UTC time to the time zone of the relay site. The ***Local Time Zone*** setting within the ***Date and Time*** settings group is used for this purpose, which allows putting UTC time forward or back as required.

In the second case, the relay receives the time signal already adapted to the local time zone and no correction is needed. In this case local ***Local Time Zone*** has no effect.

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1.5.9.e PTP Synchronization

The precision time protocol also known by the acronym PTP is originally defined by the IEEE 1588 standard and is used for relay synchronization through a local area network, reaching a microsecond accuracy, namely, it is a protocol far more accurate than SNTP, IRIG-B or serial protocol.

In order to reach this accuracy, the synchronization system uses protocol messages sent between PTP nodes to determine the clock phase difference and the delays inherent to the network, such that propagation and latency times are taken into account.

1.5.9.f Synchronization Settings

Settings / Synchronization					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
IRIG-B	IRIG-B				
Domain Number	Domain Number	LPTP1.DomainNum	0-127&254	1	254
LAN1					
Enable PTP	Enable	LPTP1.PTPEna1	NO / YES		NO
Log ch calc interv	Log ch calc interv	LPTP1.DlClcPer1	0.125s 0.25s 0.5s 1s 2s 4s 8s 16s 32s		1s
Delay	Delay	LPTP1.DlAdjTm1	0–1000000 ns	1ns	0ns
Asymmetry	Asymmetry	LPTP1.AsymAdjTm1	-10000 to 10000	1ns	0ns
VLAN LAN1					
Enabled		LPTP1.VlanEna1	NO / YES		NO
VLAN Identifier		LPTP1.VlanId1	0-4094	1	0
Priority		LPTP1.VlanPrio1	0-7	1	4
LAN2					
Enable PTP	Enable	LPTP1.PTPEna2	NO / YES		NO
Delay Mechanism	Delay Mechanism	LPTP1.DlClcPer2	0.125s 0.25s 0.5s 1s 2s 4s 8s 16s 32s		1s
Delay	Delay	LPTP1.DlAdjTm2	0–1000000 ns	1ns	0ns
Asymmetry	Asymmetry	LPTP1.AsymAdjTm2	-10000 to 10000	1ns	0ns
VLAN LAN2					
Enabled		LPTP1.VlanEna2	NO / YES		NO
VLAN Identifier		LPTP1.VlanId2	0-4094	1	0
Priority		LPTP1.VlanPrio2	0-7	1	4

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Settings / Synchronization					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
LAN3					
Enable PTP	Enable	LPTP1.PTPEna3	NO / YES		NO
Delay Mechanism	Delay Mechanism	LPTP1.DlClcPer3	0.125s 0.25s 0.5s 1s 2s 4s 8s 16s 32s		1s
Delay	Delay	LPTP1.DlAdjTm3	0–1000000 ns	1ns	0ns
Asymmetry	Asymmetry	LPTP1.AsymAdjTm3	-10000 to 10000	1ns	0ns
VLAN LAN3					
Enabled		LPTP1.VlanEna3	NO / YES		NO
VLAN Identifier		LPTP1.VlanId3	0-4094	1	0
Priority		LPTP1.VlanPrio3	0-7	1	4
LAN4					
Enable PTP	Enable	LPTP1.PTPEna4	NO / YES		NO
Delay Mechanism	Delay Mechanism	LPTP1.DlClcPer4	0,125s 0,25s 0,5s 1s 2s 4s 8s 16s 32s		1s
Delay	Delay	LPTP1.DlAdjTm4	0–1000000 ns	1ns	0ns
Asymmetry	Asymmetry	LPTP1.AsymAdjTm4	-10000 to 10000	1ns	0ns
VLAN LAN4					
Enabled		LPTP1.VlanEna4	NO / YES		NO
VLAN Identifier		LPTP1.VlanId4	0-4094	1	0
Priority		LPTP1.VlanPrio4	0-7	1	4

1.5.9.g Output Signals of the Synchronization Module

Table 1.5-11: Output Signals of the Synchronization Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
SIGNAL_IRIGB	Others	LTIM1.SynSt	IRIGB Active	I	Signal indicating that IRIG-B signal is being received.
SNTP_SINCRONIZADO			Synchronization by SNTP	I	Signal indicating that SNTP signal is being received.
PTP_SINCRONIZADO			Synchronization by PTP	I	Signal indicating that PTP signal is being received.
SICRONIZACIONRELOJ		-	Clock Synchronization		Signal indicating that the clock has been synchronized.

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1.6 Installation and Commissioning

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1.6.5.c	Metering Tests	1.6-6

1.6.1 General

Improper handling of electrical equipment is extremely dangerous; therefore, only skilled and qualified personnel familiar with appropriate safety procedures and precautions should work with this equipment. Damage to equipment and injury to personnel can result when proper safety precautions are not followed.

The following general safety precautions are provided as a reminder:

- **High magnitude voltages are present in Power Supply and metering circuits even after equipment has been disconnected.**
- **Equipment should be solidly grounded before handling or operating.**
- **Under no circumstances should the operating limits of the equipment be exceeded (voltage, current, etc.).**
- **The power supply voltage should be disconnected from the equipment before extracting or inserting any module; otherwise damage may result.**

The tests defined next are those indicated for the start-up of an IED. They do not necessarily coincide with the final manufacturing tests to which each manufactured equipment is subjected. The number, the type and the specific characteristics of the acceptance tests are model dependent.

1.6.2 Accuracy

The accuracy of the measuring instruments and test source signals (auxiliary power supply voltage, AC currents and AC voltages) is key in electrical testing. Therefore, the information specified in the Technical Data section (2.1) of this manual can only be reasonably verified with test equipment under normal reference conditions and with the tolerances indicated in the UNE 21-136 and IEC 255 standards in addition to using precision instruments.

It is extremely important that there be little or no distortion (<2%) in the test source signals as harmonics can affect internal measuring of the equipment. For example, distortions will affect this IED, made up of non-linear elements, differently from an AC ammeter, because the measurement is made differently in both cases.

It must be emphasized that the accuracy of the test will depend on the instruments used for measuring as well as the source signals used. Therefore, tests performed with secondary equipment should focus on operation verification and not on measuring accuracy.

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1.6.3 Installation

- **Location**

The place where the equipment is installed must fulfill some minimum requirements, not only to guarantee correct operation and the maximum duration of useful life, but also to facilitate placing the unit in service and performing necessary maintenance. These minimum requirements are the following:

- Absence of dust.
- Absence of humidity.
- Absence of vibration.
- Good lighting.
- Easy access.
- Horizontal or vertical mounting.

Installation should be accomplished in accordance with the dimension diagrams.

- **Connections**

The first terminal of the terminal block corresponding to the auxiliary power supply must be connected to ground so that the filter circuits can operate. The cable used for this connection should be 14 AWG stranded wire, with a minimum cross section of 2 mm^2. The length of the connection to ground should be as short as possible, but not more than 75 inches (30 cm). In addition, the ground terminal of the case, located on the rear of the unit, should be connected to ground.

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1.6.4 Preliminary Inspection

The following equipment aspects should be examined:

- The unit is in good physical condition, mechanical parts are securely attached and no assembly screws are missing.
- The unit model number and specifications agree with the equipment order.

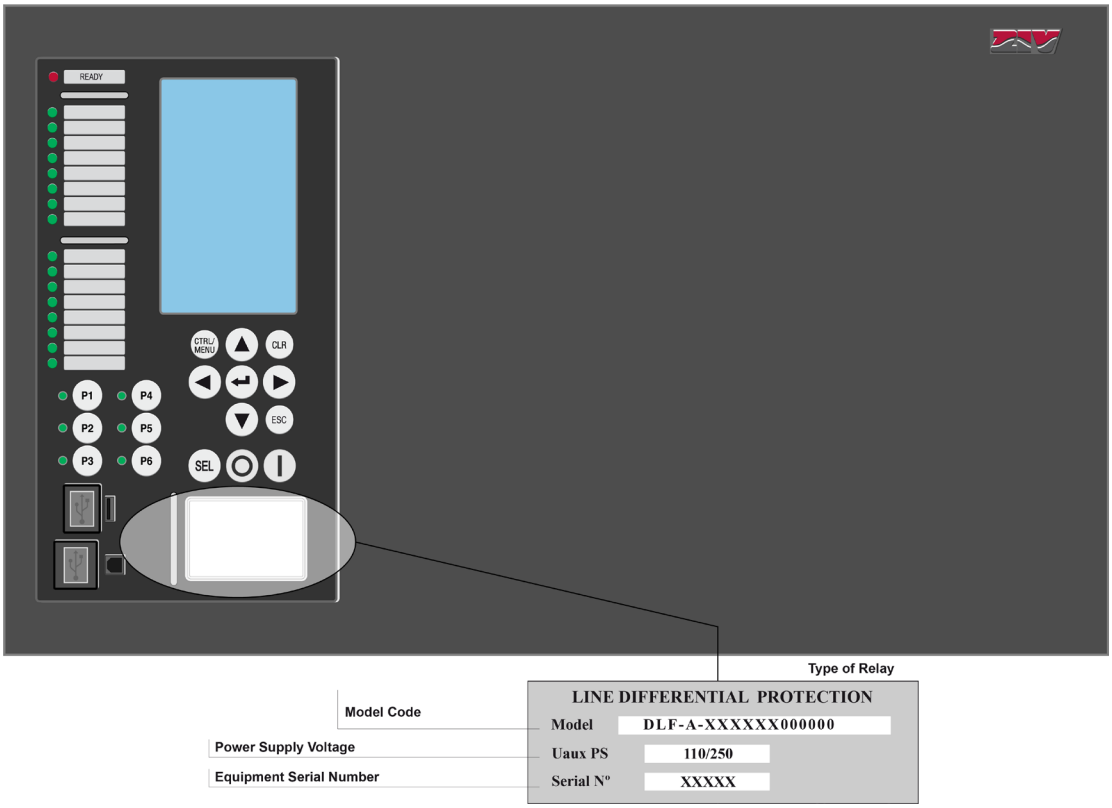


Figure 1.6.1: Name Plate (DLF).

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1.6.5 Tests

1.6.5.a Isolation Test

While testing for isolation of switchgear and external wiring, the IED must be disconnected to avoid damage in case the test is not performed properly or if there are shorts in the harness, since the manufacturer has performed isolation testing on 100% of the units.

- **Common Mode**

All the terminals of the IED must be short-circuited, except those that relate to the power supply. The enclosure ground terminal must also be disconnected. Then 2000 Vac are applied between the interconnected terminals and the metal case for 1 min or 2500 Vac during 1s between the terminal group and the metal enclosure. When the IED has the inputs, outputs and converters expansion card, terminals of the transducers do not need to be short-circuited (See External Connection Schemes).

- **Between groups**

The isolation groups are made up of the current and voltage inputs (independent channels), digital inputs, auxiliary outputs, trip and close contacts and power supply. Refer to the connection's schematic to identify the terminals to group for performing the test. Then 2500 VAC are applied during 1 sec. between each pair of groups. For the transducers test 1000 VAC are applied during one second between this group and all the rest.



There are internal capacitors that can generate high voltage if the test points are removed for the insulation test without reducing the test voltage.

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1.6.5.b Power Supply Test

Connect the power supply as indicated in following table.

VDC PROT	CON1P	CON2P
Slot A pin 3(+) - 2(-)	Slot A pin 6 - 5	Slot A pin 6 - 4

It is important to verify that, when the IED is not energized, the contacts designated CON2P in the table mentioned previously are closed, and those designated CON1P are open. Then it is fed its rated voltage and the contacts designated CON1P and CON2P must change state and the “In Service” LED must light up.

1.6.5.c Metering Tests

For this test it should be considered that, if it is required to avoid trips while this is being carried out, the elements should be disabled and the cutoff of the injection of current and/or voltage by the breaker avoided. Subsequently, the currents and voltages which, as an example, are indicated in the following table, will be applied to each of the channels and the following measures will be verified:

Applied Current or Voltage	Measured Current or Voltage	Phase of I or V applied	Phase of I or V measured	Frequency Applied (V > 20 Vac)	Frequency Measured (V > 20 Vac)
X	X ±1%	Y	Y ±1º	Z	Z ±5 mHz

If high current values are to be checked, they will be applied the shortest possible time; for example, less than 8 seconds for 20A. For angle display, phase A voltage must be applied or inject current into the phase A as a function of the reference angle setting value and the injected values must exceed the setting values set for this purpose. In order to be able to measure the frequency, voltage must be injected into any phase, taking into account that the instantaneous value of the Clarke alfa voltage considers a value above the Inhibit Voltage disable setting.

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1.7 Onload Test

1.7.1 Introduction 1.7-2
1.7.2 Voltage Connections 1.7-2
1.7.3 Current Connections 1.7-2

1.7.1 Introduction

The objectives of Onload Test are the following ones:

- Confirm that the external wiring of the voltage and current analog input channels is correct.
- Check the polarity of the current transformers.
- Check the voltage and current measurements (module and angle).

In order to proceed with the test, primary injections will be done to check the polarity and transformation ratios. These tests can only be carried out if there are no restrictions related to the energization of the bay and all the other devices of the bay where the protection relay is located have already been commissioned.

Before starting the tests, check that all the test leads have been removed and ensure that the external wiring is properly connected (it is possible that during the commissioning tests external wirings have been disconnected).

1.7.2 Voltage Connections

Using a multimeter check that the secondary voltage measurements are correctly rated, and by means of a phase rotation meter confirm that the system phase rotation is the correct one.

Compare the secondary multimeter values with the measurements the relay shows in the measurement screen when the transformation ratio is set to 1. Check not only the module but also the angle. Modify the setting in order to show the measurements in primary values. The measurements that are displays in the HMI of the device or in the communication program should comply with the values which are specified in the Measurement Accuracy paragraph in Chapter 1.3, Technical Data.

1.7.3 Current Connections

Place a multimeter in series with each of the analog current inputs of the relay in order to test the secondary values of each phase. This test will be carried out comparing the value of the multimeter with the value displayed in the HMI of the relay when the transformation ratio is set to 1. Check not only the module but also the angle. Modify the setting in order to show the measurements in primary values. The measurements that are displays in the HMI of the device or in the communication program should comply with the values which are specified in the Measurement Accuracy paragraph in Chapter 1.3, Technical Data.

Check that when injecting a balanced system, the current which is flowing through the neutral circuit of the transformer is negligible.

Ensure the current polarity is the correct one measuring the phase angle between the current and the voltage which are being injected.

Check that for load current flowing outside the bay (forward direction) the active power measurement is positive while for load current flowing inside the bay (reverse direction) the active power measurement is negative.

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In those models with ground differential current measurement, check that the current polarity of the polarization channels is the correct one. Inject the same current value in the ground channel and just in one phase analog input lagging 180º (from the same winding) and check that the ground differential current (IGN) is zero or almost zero. In case of having ground differential current, modify the wiring of the ground channel.

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1.8 Standards and Type Tests

1.8.1 Insulation 1.8-2
1.8.2 Electromagnetic Compatibility 1.8-3
1.8.3 Environmental Test 1.8-4
1.8.4 Power Supply 1.8-5
1.8.5 Mechanical Test 1.8-5

The equipment satisfies the standards indicated below. When not specified, the standard is IEC-60255.

1.8.1 Insulation

Insulation Test (Dielectric Strength)	*IEC-60255-5 / 60255-27*
Between all circuit terminals and ground	
Analog Inputs, DIs, DOs and PS	**2 kV**, **50/60 Hz**, for 1min
Communications Ports	**1 kV**, **50/60 Hz**, for 1min
Between all circuit terminals	
Analog Inputs, DIs, DOs and PS	**2 kV**, **50/60 Hz**, for 1min
Measurement of Insulation Resistance	*IEC-60255-5 / 60255-27*
Common mode	**R ≥ 100 MΩ** or **5μA**
Differential mode	**R ≥ 100 kΩ** or **5mA**
Voltage Impulse Test	*IEC-60255-5 (UNED21-136-83/5) / 60255-27*
Common mode	
Analog Inputs, DIs, DOs and PS	**5 kV**; **1.2/50 μs**; **0.5 J**
Communications Ports	**1 kV**; **1.2/50 μs**; **0.5 J**
Differential mode	
DOs	**1 kV**; **1.2/50 μs**
Power Supply	**3 kV**; **1.2/50 μs**

Note: IEC60255-27 standard tests for altitude up to 2 000 m.

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1.8.2 Electromagnetic Compatibility

100khz and 1 MHz Burst Test	*IEC-60255-22-1 / 61000-4-18*
Common mode	**2.5 kV**
Differential mode	**1 kV**
Damped Oscillatory Magnetic Field Immunity Test	*IEC-61000-4-10*
100KHz and 40 Transients/s	**±100 A/m**
1MHz and 400 Transient/s	**±100 A/m**
Fast Transient Disturbance Test	*IEC-60255-22-4 Class IV (IEC 61000-4-4)* **4 kV (5kz)**
Radiated Electromagnetic Field Disturbance	*IEC 61000-4-3 Class III*
AM 80% 1KHz, range 80MHz-3GHz	**10 V/m**
Amplitude modulated (*EN 50140*)	**10 V/m**
Conducted Electromagnetic Field Disturbance	*IEC 61000-4-6 Class III (IEC 50141)*
Frequency band from 0.15 to 80Mhz	**10 Vrms**
Electrostatic Discharge	*IEC-60255-22-2 Class IV (IEC 61000-4-2)*
Contact Mode	**±8 kV ±10 %**
In Air Mode	**±15 kV ±10 %**

Surge Immunity Test	*IEC-61000-4-5 (UNE 61000-4-5)* **(1.2/50µs - 8/20µs)**
Differential mode	**±2 kV**
Common mode	**±4 kV**

Radiated Electromagnetic Field Disturbance at Industrial Frequency (50/60 Hz)	*IEC-61000-4-8*

Radio Frequency Emissivity	*EN55022* (Conducted) *EN55011* (Radiated)

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1.8.3 Environmental Test

Temperature	*IEC-60068-2*
Cold work limit conditions	*IEC-60068-2-1* **-40º C**, **96 hours**
Dry heat limit conditions	*IEC-60068-2-2* **+85º C**, **96 hours**
Humid heat	*IEC-60068-2-78* **+40º C, 93% relative humidity, 96h**,
Quick temperature changes	*IEC-60068-2-14 / IEC-61131-2* IED disconnected **-25º C** for **3h** and **+70º C** for **3h** (**5 cycles**)
Changes in humidity	*IEC-60068-2-30 / IEC-61131-2*
Temperature change according to norm	**+55º C** for **12h** and **+25º C** for **12h** (**6 cycles**)
Humidity variable according to norm	
Operating range	From **-25º C** to **+70º C**
Storage range	From **-40º C** to **+85º C**

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1.8.4 Power Supply

DC Alimentation Ripple Immunity	*61000-4-17*
Ripple	**15%**
Dips, Interruptions and Gradual On / Off Immunity	*61000-4-29 / 61000-4-11*
Dip 100%	**100ms**
Dip 60%	**200ms**
Dip 30%	**500ms**
Inverse Polarity of the Power Supply	*IEC-61131-2*
Resistance of Ground Connection	*IEC-61131-2*
Surge Capacity	*IEC-60044-1*

1.8.5 Mechanical Test

Vibration (sinusoidal)	*IEC-60255-21-1*
a) Response: (Equipment running). Class II	
b) Endurance: (Equipment off). Class I	
Mechanical Shock and Bump Test	*IEC-60255-21-2 Class I*
Earthquakes	*IEC-60255-21-3 Class I*
External Protection Levels	*IEC-60529 / IEC-60068-2-75*
Front	*IP54* (Mounting into cell with gasket)
Rear Protection	*IP20*
	IP10 in Analog Terminals
Side	*IP30*
Mechanical Protection	*IK07*

CEEIEC: International Electrotechnical Commission / CEI: Comisión Electrotécnica Internacional.

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1.9 Schemes and Drawings

Dimension and Drill Hole Schemes

6U x 1/2 19” rack (extended display included)	>>	4BF0105/0017
6U x 1/2 19” rack (*) (extended display included)	>>	4BF0105/0019
6U x 1 19” rack (extended display included)	>>	4BF0105/0020

(*) Only for Models with Breaker and a Half Bay configuration with line CT.

External Connection Schemes

CPU	>>	3RX0206/0001
Power Supply and Digital I/O (card type digit 2/4)	>>	3RX0206/0002
Digital I/O (card type digit 7)	>>	3RX0206/0004
Digital I/O (card type digit 3)	>>	3RX0206/0009
Digital I/O (card type digit 2)	>>	3RX0206/0003
Digital I/O (card type digit 6)	>>	3RX0206/0011
20 DI all independent (card type digit 5)	>>	3RX0206/0015
Analog Inputs (card type digit B)	>>	3RX0206/0007
Analog Inputs (card type digit H)	>>	3RX0206/0016
Analog Inputs (card type digit J)	>>	3RX0206/0017
Digital I/O	>>	3RX0206/0015
Communications 87L (card type digit Z)	>>	3RX0206/0014

- **Analog Channels DLF-A for models without Short-Circuitable connectors**

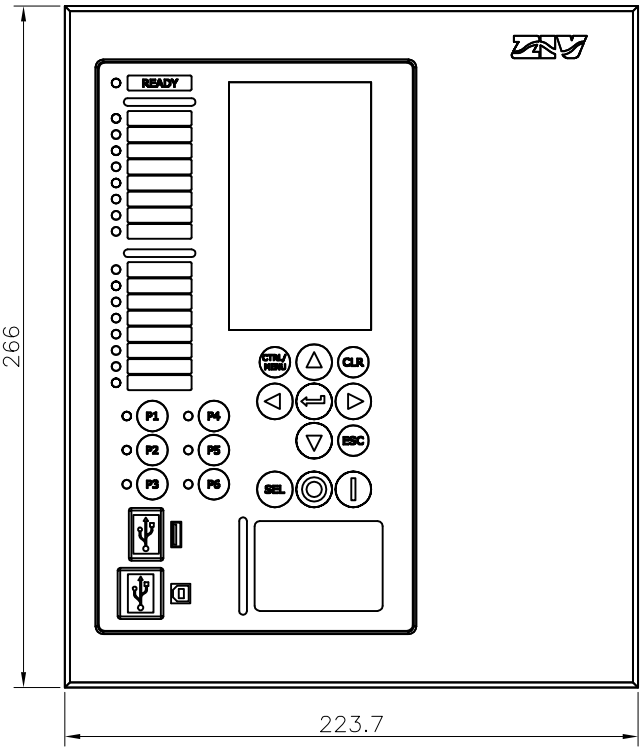
Magnitude	Analog Channels	Analog Channels description	SLOT (1/2 rack)	SLOT (1 rack)	PINS
PHASE AG VOLTAGE	VA	VOLTAGE INPUT 1	D	J	1-2
PHASE BG VOLTAGE	VB	VOLTAGE INPUT 2	D	J	3-4
PHASE CG VOLTAGE	VC	VOLTAGE INPUT 3	D	J	5-6
SYNCHRONISM VOLTAGE	VSYNC	VOLTAGE INPUT 4	D	J	7-8
NEUTRAL VOLTAGE	VG	VOLTAGE INPUT 5	D	J	9-10
PHASE A CURRENT	IA	CURRENT INPUT 1	D	J	11-12
PHASE B CURRENT	IB	CURRENT INPUT 2	D	J	13-14
PHASE C CURRENT	IC	CURRENT INPUT 3	D	J	15-16
PARALLEL LINE NEUTRAL CURRENT	IPAR	CURRENT INPUT 4	D	J	17-18
GROUNDING CURRENT	IG	CURRENT INPUT 5	D	J	19-20

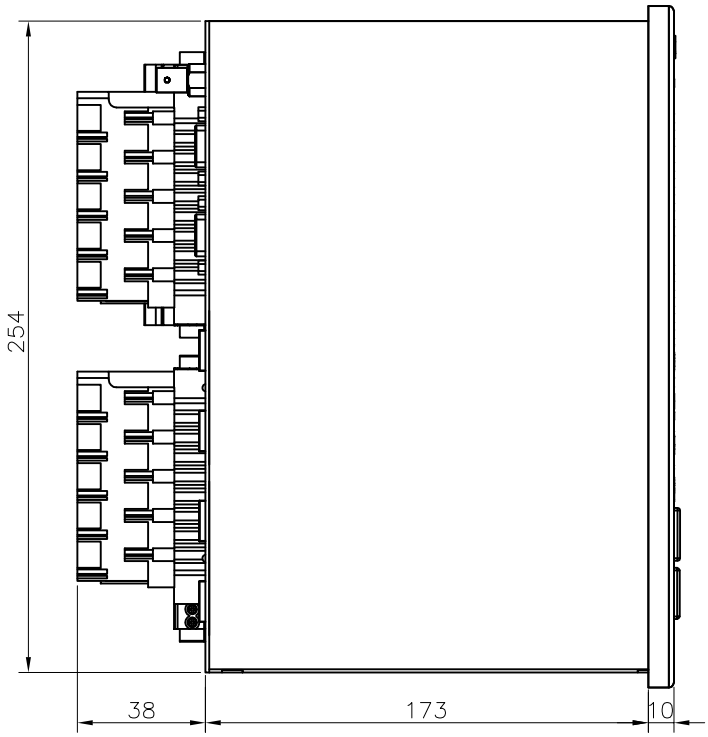
- **Analog Channels DLF-B for models without Short-Circuitable connectors**

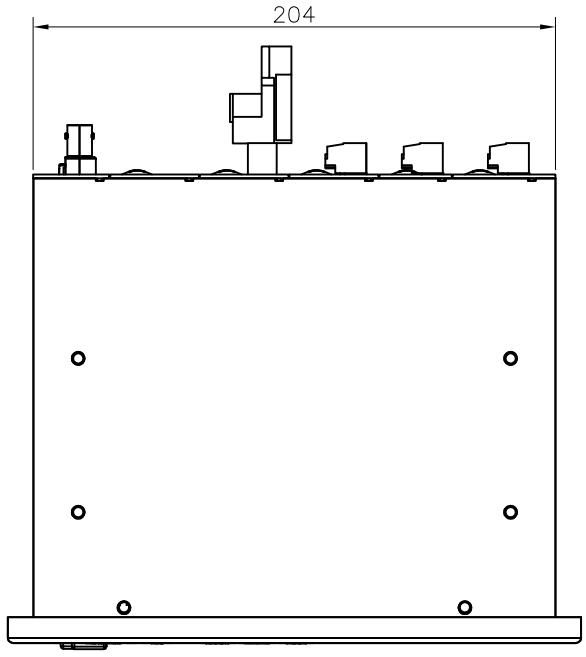
Magnitude	Analog Channels	Analog Channels description	SLOT (1/2 rack)	SLOT (1 rack)	PINS
PHASE VOLTAGE AG	VA	VOLTAGE INPUT 1	C	I	1-2
PHASE VOLTAGE BG	VB	VOLTAGE INPUT 2	C	I	3-4
PHASE VOLTAGE CG	VC	VOLTAGE INPUT 3	C	I	5-6
SYNCHRONISM VOLTAGE 1	V1	VOLTAGE INPUT 4	C	I	7-8
NEUTRAL VOLTAGE	VG	VOLTAGE INPUT 5	C	I	9-10
PHASE A CURRENT, CB1	IA	CURRENT INPUT 1	C	I	11-12
PHASE B CURRENT, CB 1	IB	CURRENT INPUT 2	C	I	13-14
PHASE C CURRENT, CB 1	IC	CURRENT INPUT 3	C	I	15-16
PARALLEL LINE NEUTRAL CURRENT	IPAR	CURRENT INPUT 4	C	I	17-18
GROUNDING CURRENT	IG	CURRENT INPUT 5	C	I	19-20
SYNCHRONISM VOLTAGE 2	V2	VOLTAGE INPUT 6	D	J	1-2
SYNCHRONISM VOLTAGE 3	V3	VOLTAGE INPUT 7	D	J	3-4

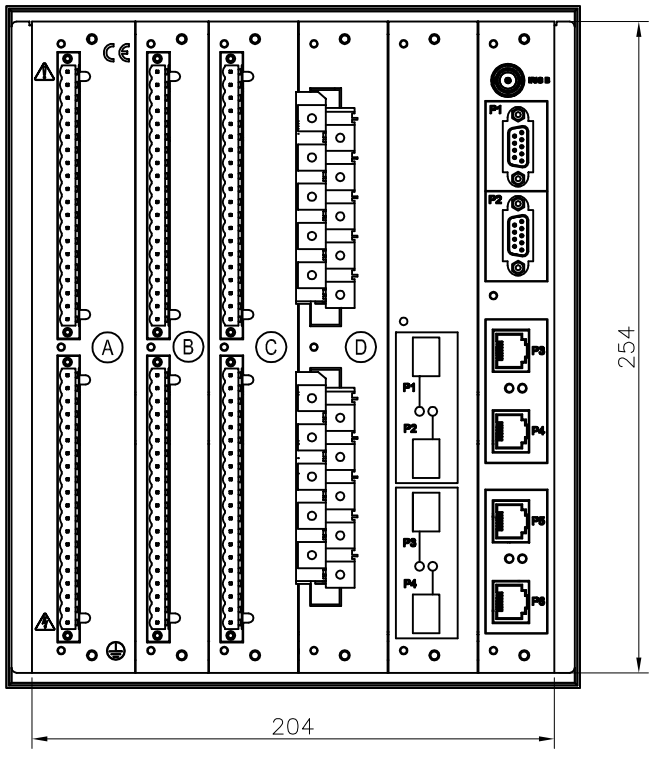
- **Analog Channels DLF-A for models with Short-Circuitable connectors**

Magnitude	Analog Channels	Analog Channels description	SLOT (1/2 rack)	SLOT (1 rack)	PINS
PHASE AG VOLTAGE	VA	VOLTAGE INPUT 1	C	I	1-2
PHASE BG VOLTAGE	VB	VOLTAGE INPUT 2	C	I	3-4
PHASE CG VOLTAGE	VC	VOLTAGE INPUT 3	C	I	5-6
SYNCHRONISM VOLTAGE	VSYNC	VOLTAGE INPUT 4	C	I	7-8
NEUTRAL VOLTAGE	VG	VOLTAGE INPUT 5	C	I	9-10
PHASE A CURRENT	IA	CURRENT INPUT 1	C	I	11-12
PHASE B CURRENT	IB	CURRENT INPUT 2	C	I	13-14
PHASE C CURRENT	IC	CURRENT INPUT 3	C	I	15-16
PARALLEL LINE NEUTRAL CURRENT	IPAR	CURRENT INPUT 4	C	I	17-18
GROUNDING CURRENT	IG	CURRENT INPUT 5	C	I	19-20









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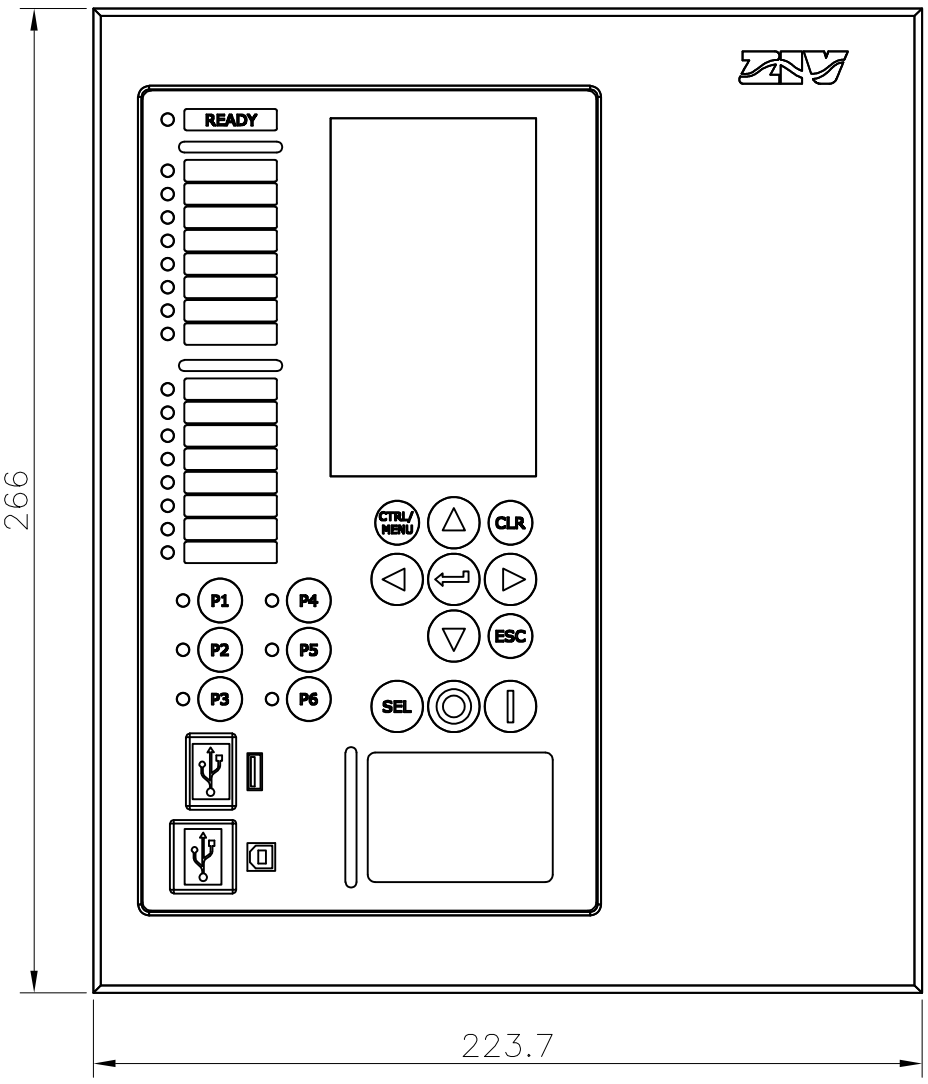
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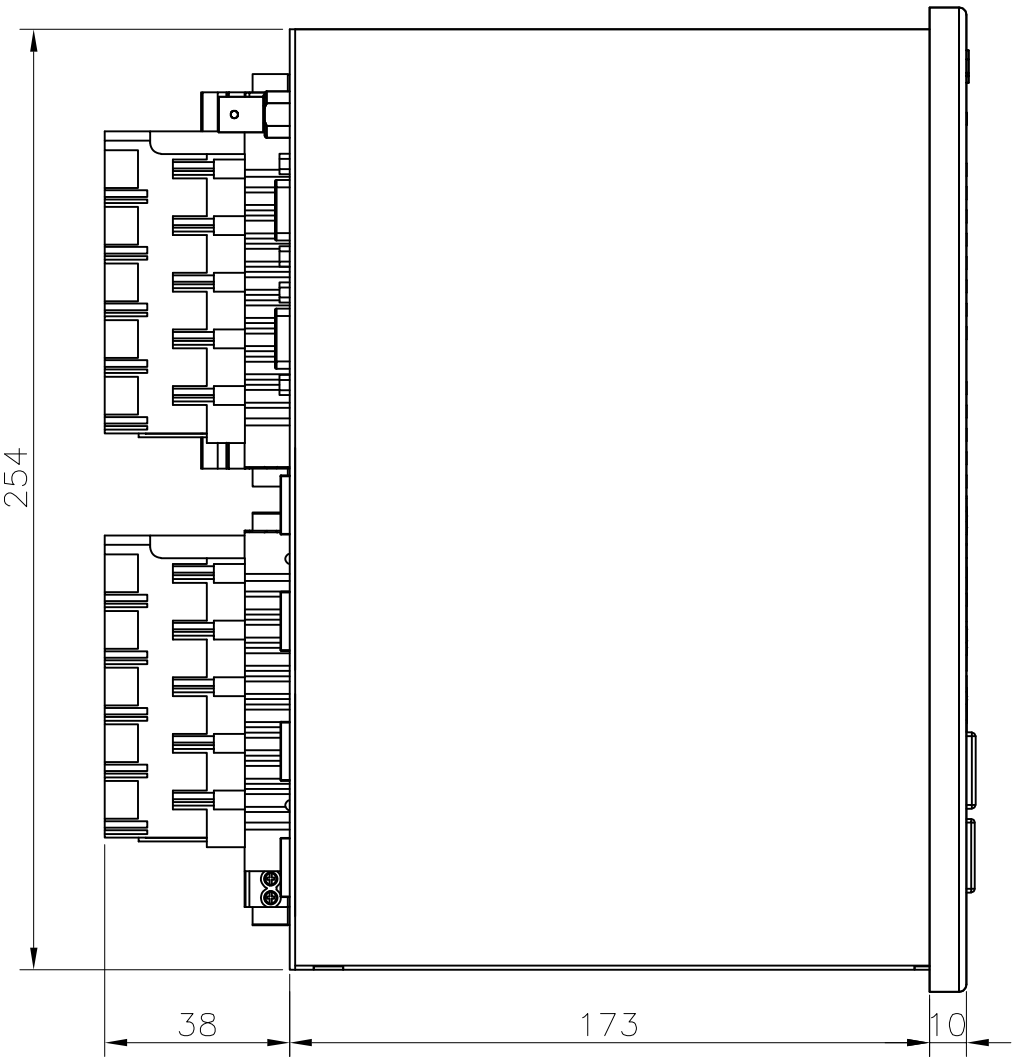
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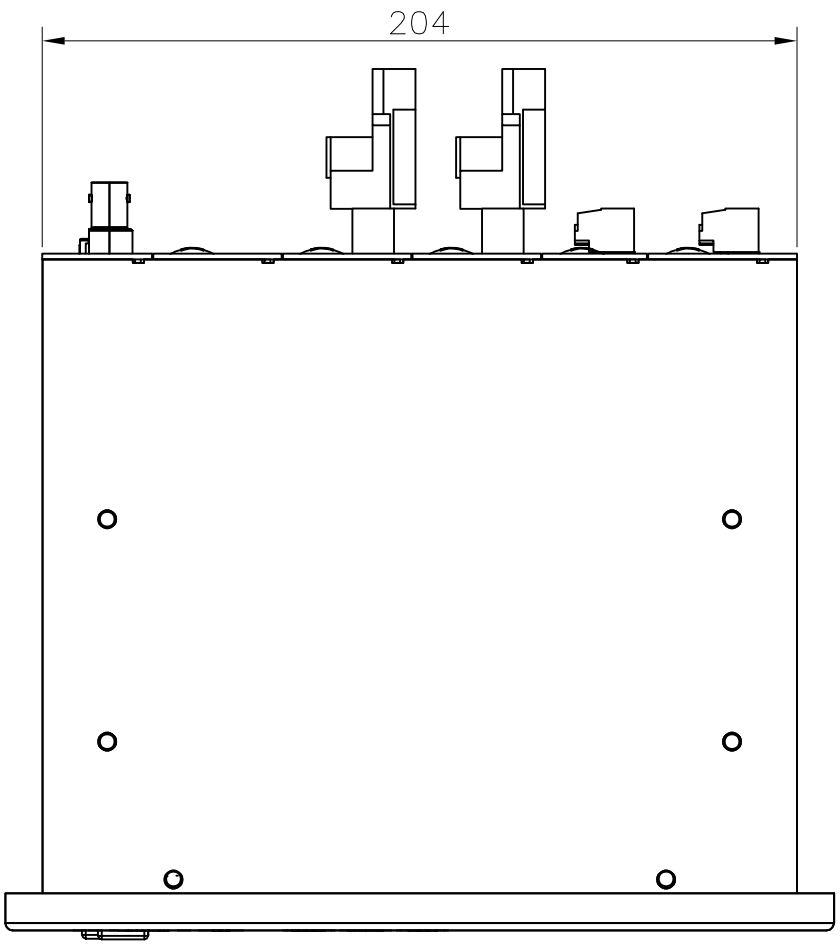
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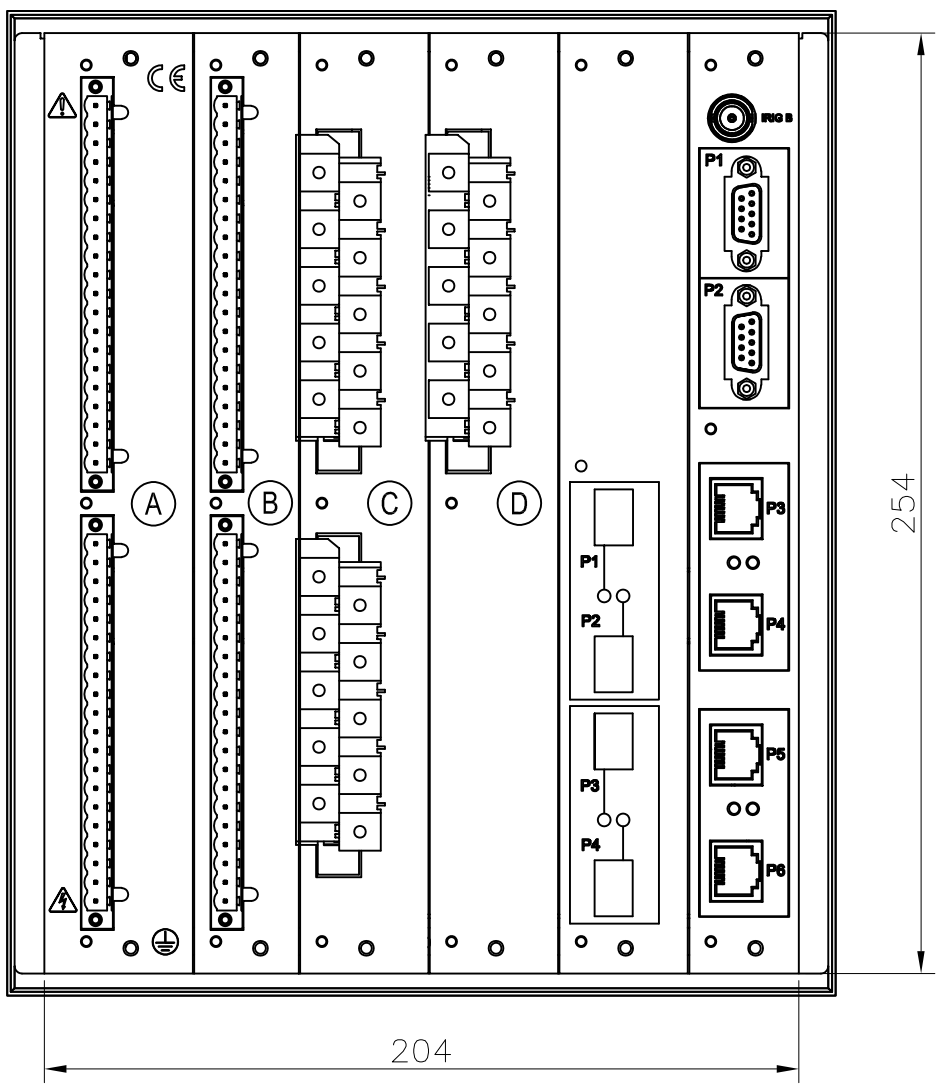
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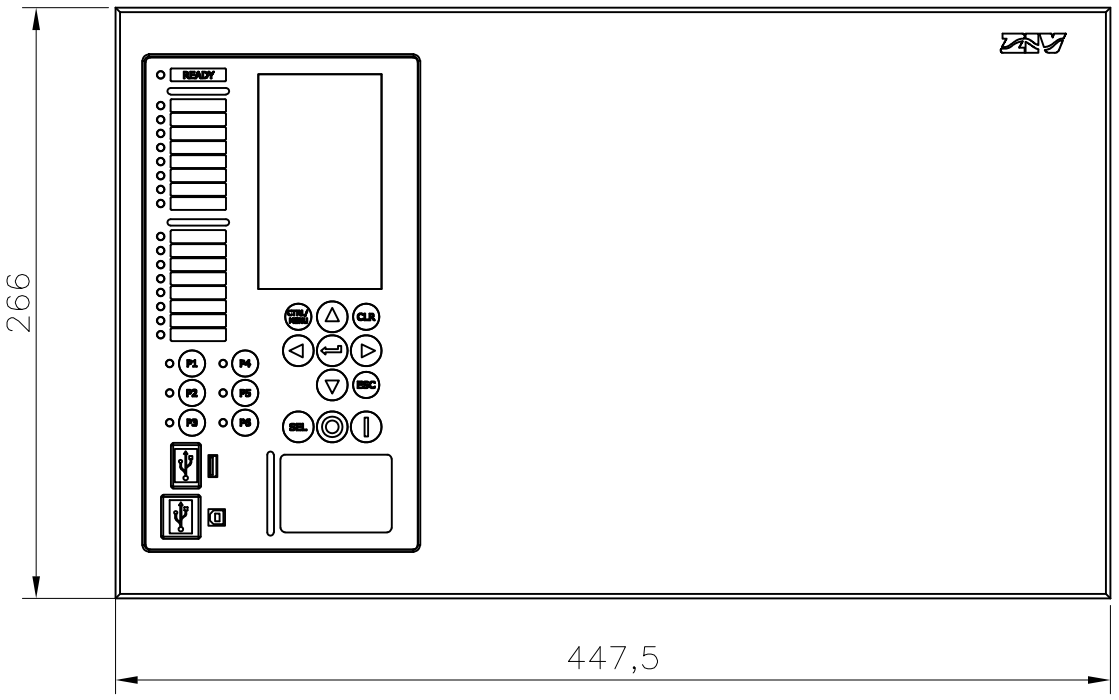
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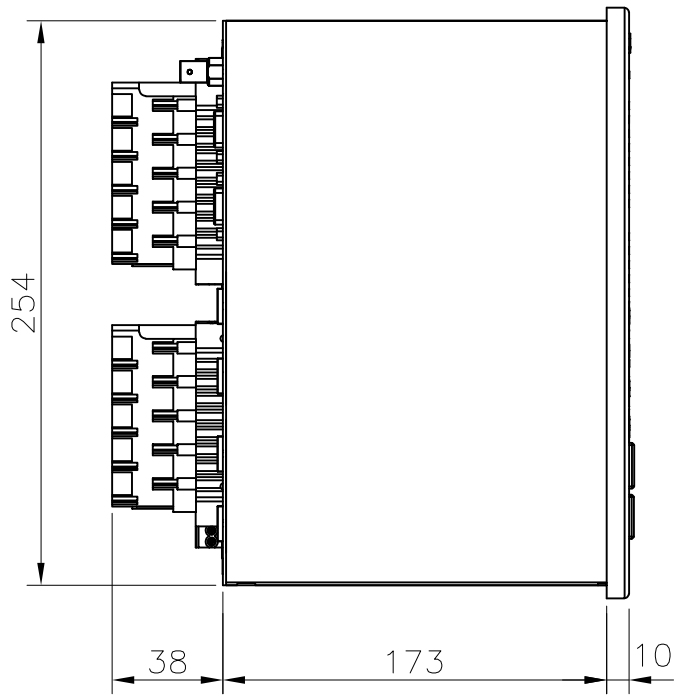
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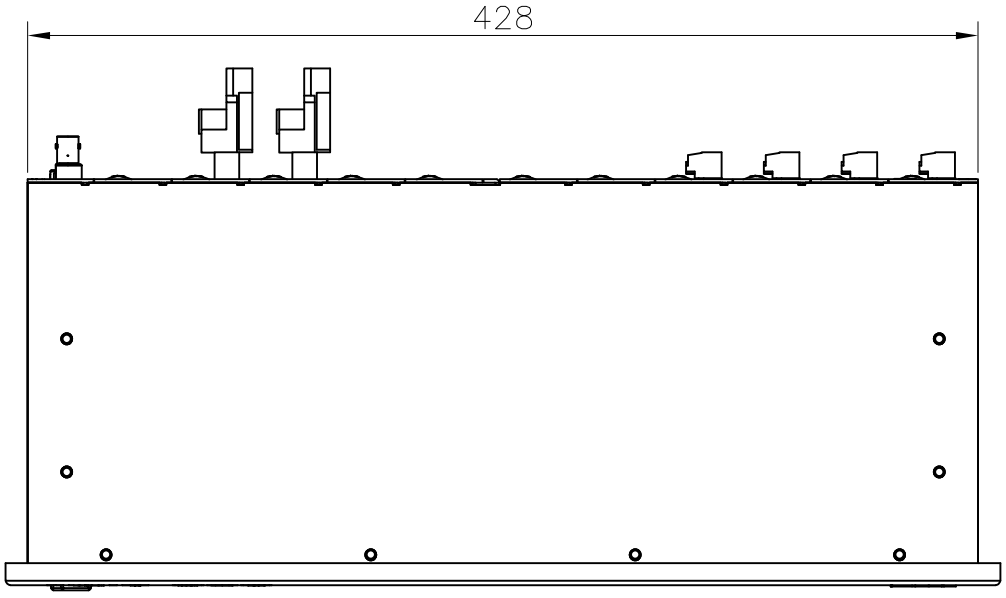
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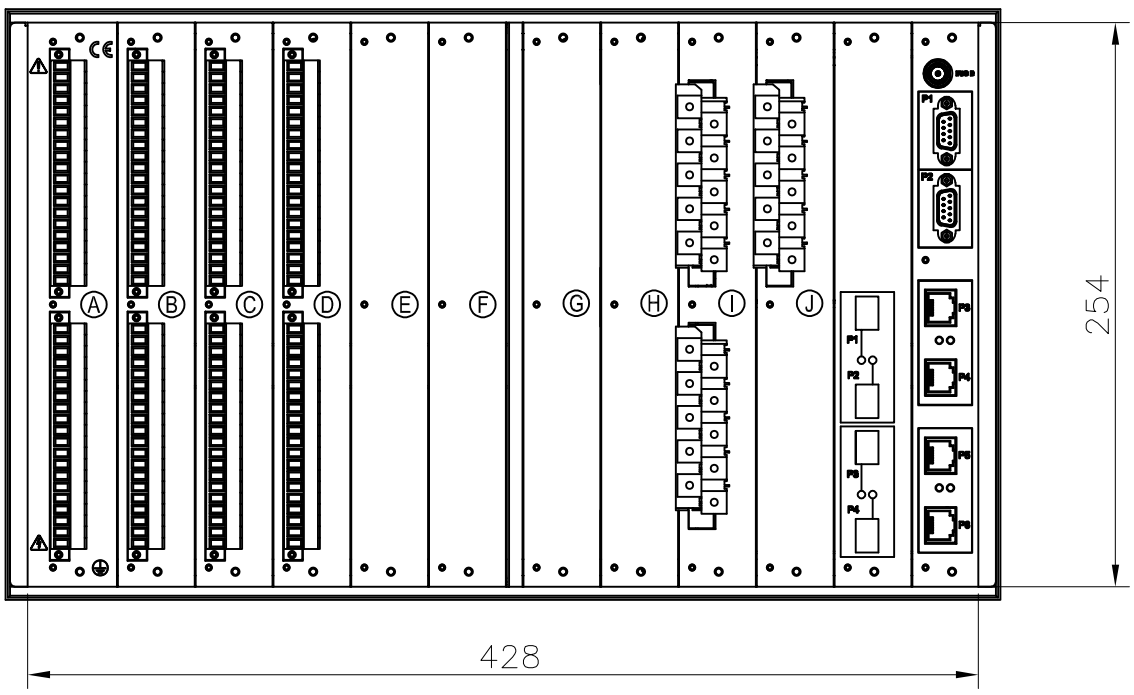
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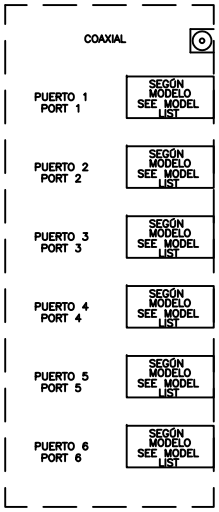
NUM: 4BF0105/0020

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Dibujado / *Drawn*	20/06/23	J.M.S.
Aprobado / *Approved*	20/06/23	P.A.

Hoja / *Sheet:* 1

Continua en Hoja: *Continued on sheet:* –

COMMUNICATION MODULE
MÓDULO COMUNICACIONES



SERIAL PORT
PUERTO SERIE
RS-232 FULL MODEM

PIN	SEÑAL
1	DCD
2	RX
3	TX
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	RI



SERIAL PORT
PUERTO SERIE
RS-232 / RS-485

PIN	SEÑAL
1	LIBRE / *FREE*
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	LIBRE / *FREE*
8	LIBRE / *FREE*
9	LIBRE / *FREE*



SERIAL PORT RJ45
PUERTO SERIE RJ45

PIN	SEÑAL
1	TX+
2	TX-
3	RX+
4	N/C
5	N/C
6	RX-
7	N/C
8	N/C

RACK	1/3			
SLOT	A	B	C	
				CPU
MODEL I#F#-###	#	#	#	XYZW

RACK	1/2					
SLOT	A	B	C	D	E	
						CPU
MODEL I#F#-###	#	#	#	#	#	XYZW

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
												CPU
MODEL I#F#-###	#	#	#	#	#	#	#	#	#	#	#	XYZW

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REV.	0	CD500004568	1		2		3		4	
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11		12		13		14		15		16

Z I V Aplicaciones y Tecnología

TITULO: CONEXIONES EXTERNAS CPU
TITLE: EXTERNAL CONNECTIONS CPU

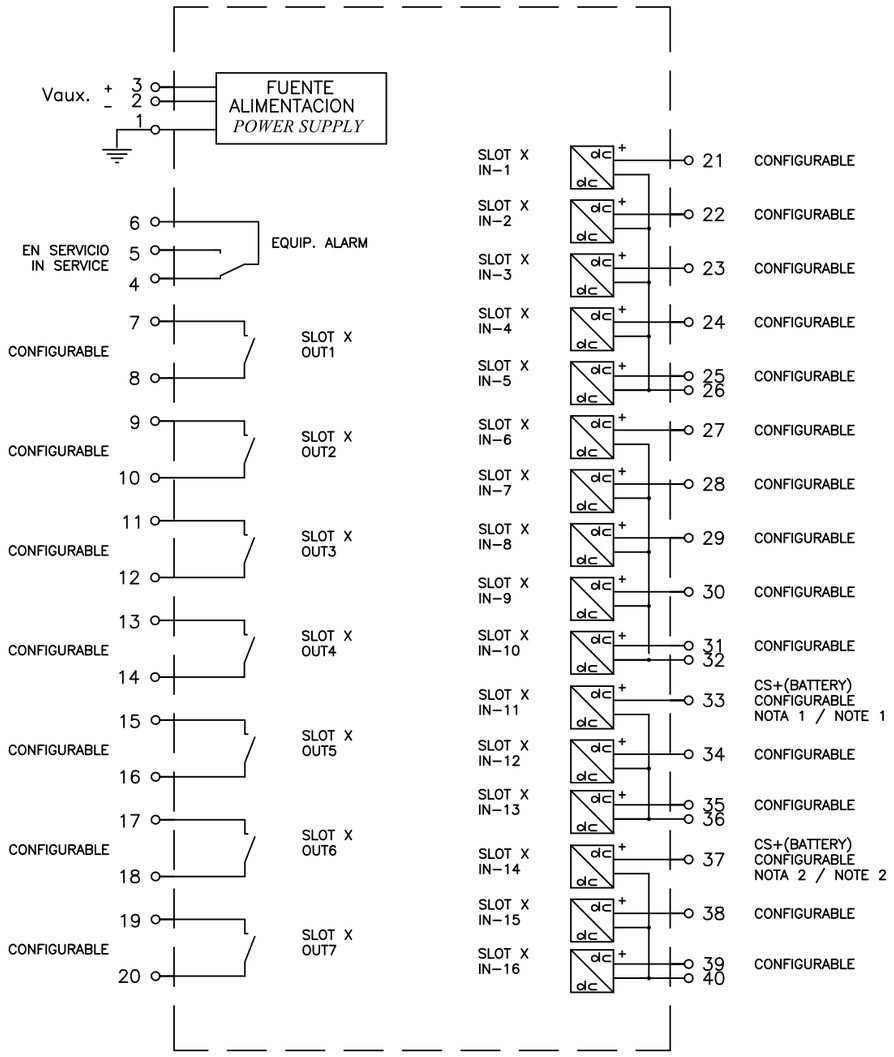
PROYECTO / *PROJECT:* IRF#-###############XYZW

Rev.0

NUM.: 3RX0206/0001

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	17/03/17	J.M.S.
Aprobado / *Approved*	17/03/17	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: –
Continued on sheet:



RACK	1/3			
SLOT	A	B	C	
	X			
MODEL I#F#-###	2	#	#	####
	4	#	#	####

RACK	1/2					
SLOT	A	B	C	D	E	
	X					CPU
MODEL I#F#-###	2	#	#	#	#	####
	4	#	#	#	#	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
	X											CPU
MODEL I#F#-###	2	#	#	#	#	#	#	#	#	#	#	####
	4	#	#	#	#	#	#	#	#	#	#	####

NOTA 1: LA BORNA 33 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN12, IN13 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.
NOTA 2: LA BORNA 37 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN15, IN16 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.

NOTE 1: TERMINAL 33 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN12, IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.
NOTE 2: TERMINAL 37 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN15 OR IN16 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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REV.	0	CD500004568	1		2		3		4	
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11		12		13		14		15		16

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES FUENTE ALIMENTACION Y E/S DIGITALES
TITLE: EXTERNAL CONNECTIONS POWER SUPPLY &DIGITAL I/O

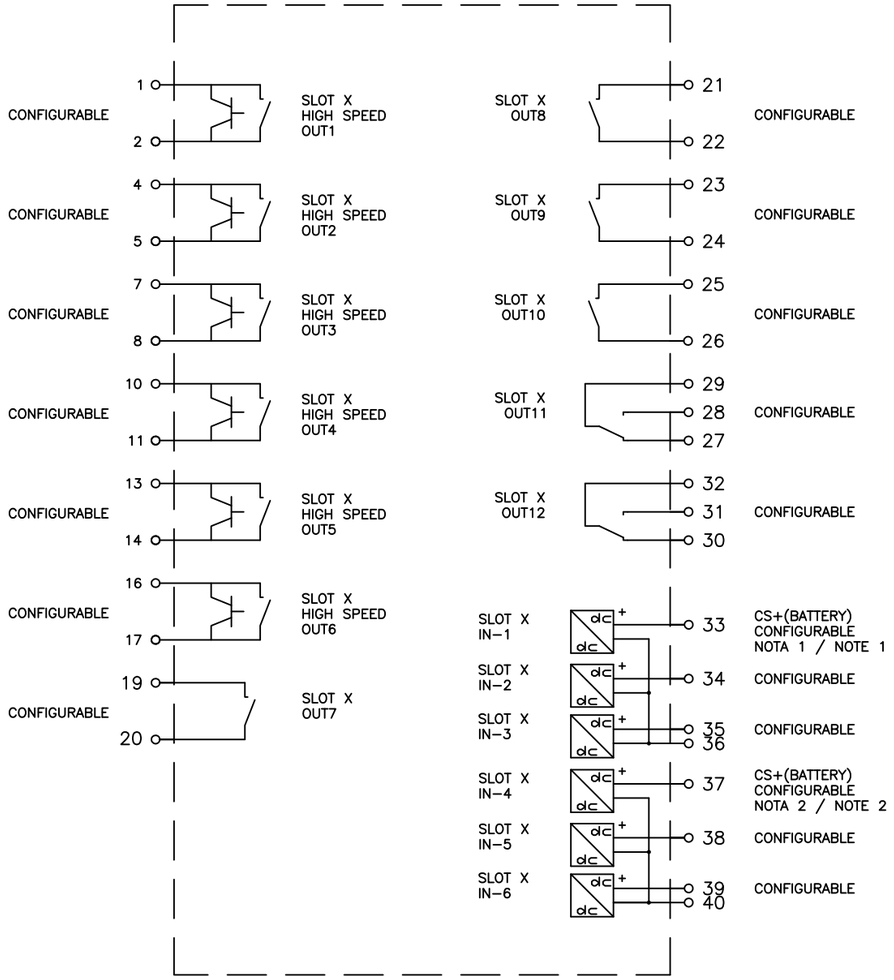
PROYECTO / *PROJECT:* IRF#-###2############## / IRF#-###4##############

Rev.0

NUM.: 3RX0206/0002

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	17/03/17	J.M.S.
Aprobado / *Approved*	17/03/17	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: –
Continued on sheet:



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#–###	#	7	7	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#–###	#	7	7	7	7	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#–###	#	7	7	7	7	7	7	7	7	7	7	####

NOTA 1: LA BORNA 33 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN2, IN3 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.

NOTA 2: LA BORNA 37 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN5, IN6 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.

NOTE 1: TERMINAL 33 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2, IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

NOTE 2: TERMINAL 37 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN5 OR IN6 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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REV.	0	CD500004568	1		2		3		4	
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11		12		13		14		15		16	

Z I V Aplicaciones y Tecnología

TITULO: CONEXIONES EXTERNAS ENTRADAS/SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL INPUT/OUTPUTS

PROYECTO / *PROJECT:* IRF#–####7777777777####

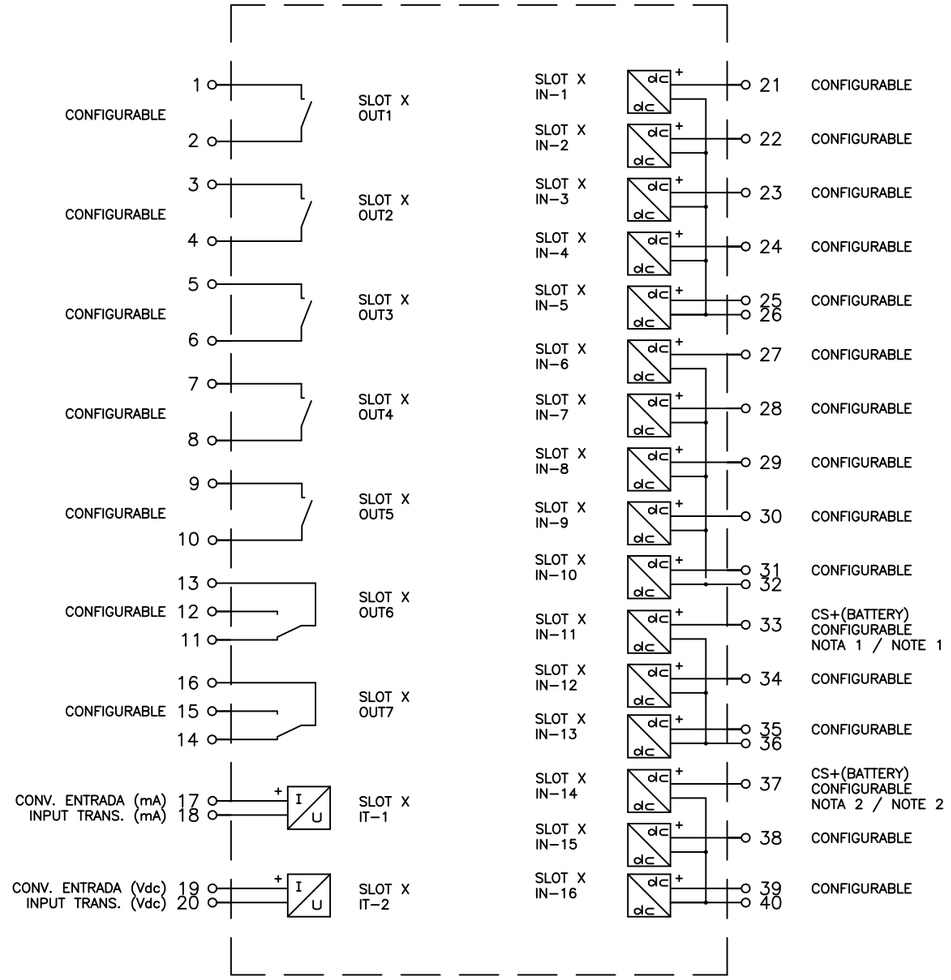
Rev.0

NUM.: 3RX0206/0004

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	17/03/17	J.M.S.
Aprobado / *Approved*	17/03/17	P.A.

Hoja / *Sheet:* 1

Continua en Hoja: – *Continued on sheet:*



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#-###	#	3	3	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#-###	#	3	3	3	3	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#-###	#	3	3	3	3	3	3	3	3	3	3	####

NOTA 1: LA BORNA 33 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN12, IN13 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.
NOTA 2: LA BORNA 37 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN15, IN16 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.

NOTE 1: TERMINAL 33 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN12, IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.
NOTE 2: TERMINAL 37 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN15 OR IN16 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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Z I V Aplicaciones y Tecnología

TITULO: CONEXIONES EXTERNAS ENTRADAS/SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL INPUT/OUTPUTS

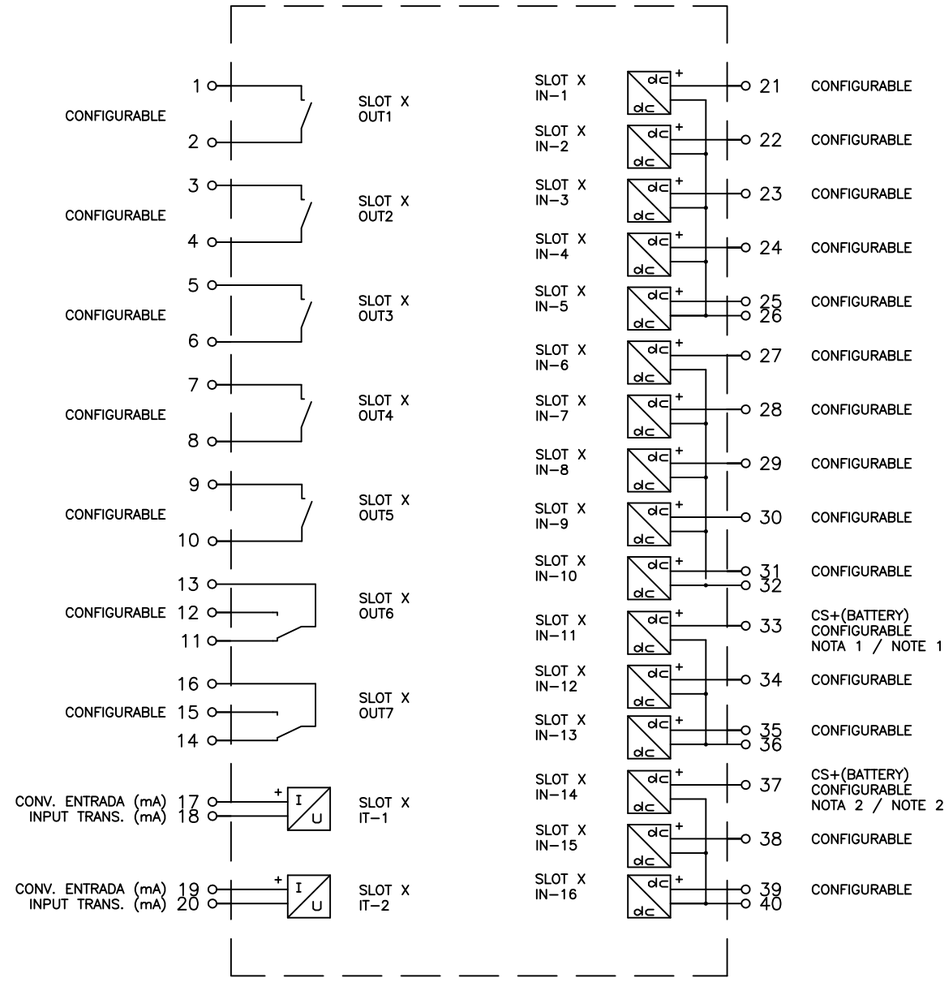
PROYECTO / *PROJECT:* IRF#-####3333333333####

Rev.0

NUM.: 3RX0206/0009

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	12/07/18	J.M.S.
Aprobado / *Approved*	12/07/18	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: – *Continued on sheet:*



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#-###	#	2	2	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#-###	#	2	2	2	2	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#-###	#	2	2	2	2	2	2	2	2	2	2	####

NOTA 1: LA BORNA 33 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN12, IN13 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.
NOTA 2: LA BORNA 37 DEBERÁ CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS IN15, IN16 PARA LA FUNCIÓN DE VIGILANCIA DE BOBINAS DE INTERRUPTOR.

NOTE 1: TERMINAL 33 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN12, IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.
NOTE 2: TERMINAL 37 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN15 OR IN16 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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Z I V Aplicaciones y Tecnología

TITULO: CONEXIONES EXTERNAS ENTRADAS/SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL INPUT/OUTPUTS

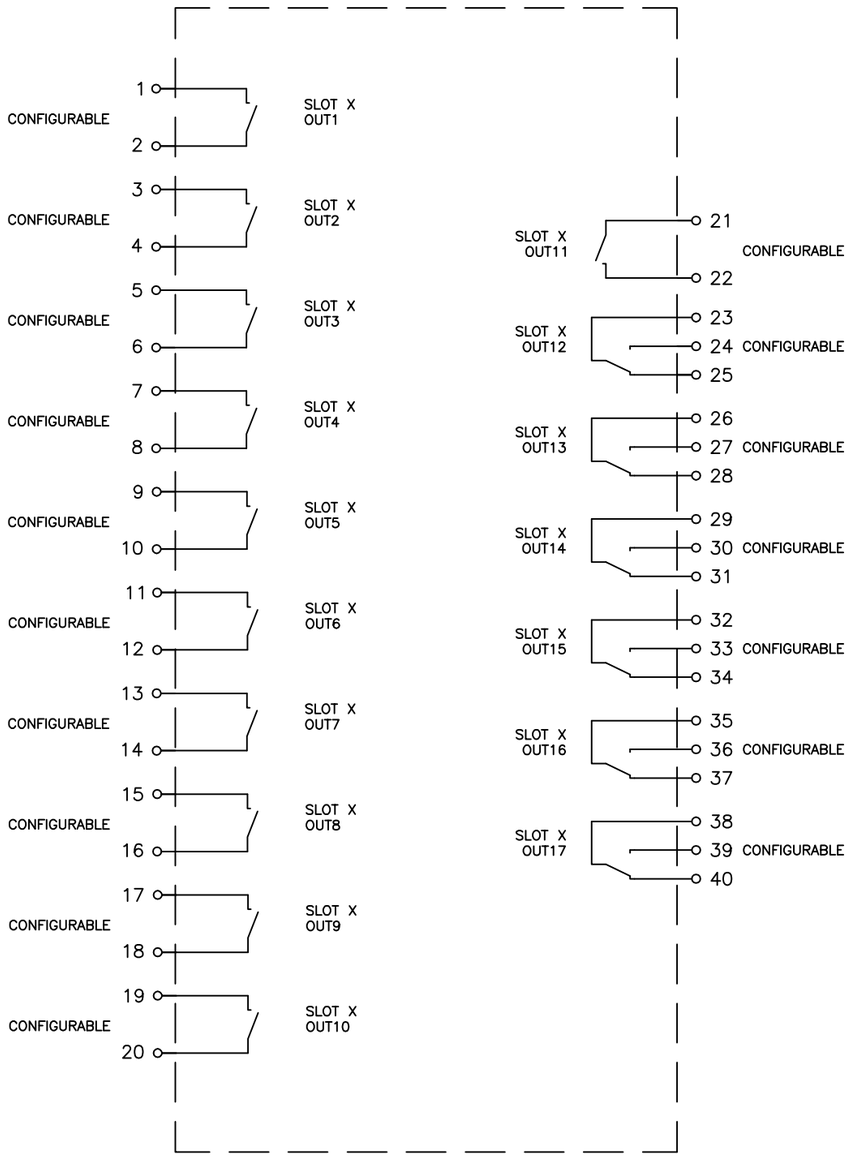
PROYECTO / *PROJECT:* IRF#-####2222222222####

Rev.0

NUM.: 3RX0206/0003

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	17/03/17	J.M.S.
Aprobado / *Approved*	17/03/17	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: – *Continued on sheet:*



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#-###	#	6	6	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#-###	#	6	6	6	6	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#-###	#	6	6	6	6	6	6	6	6	6	6	####

"ATENCION" *"WARNING"*
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REV.	0	CD	1		2		3		4	
5		6		7		8		9		10	
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TITULO: CONEXIONES EXTERNAS SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL OUTPUTS

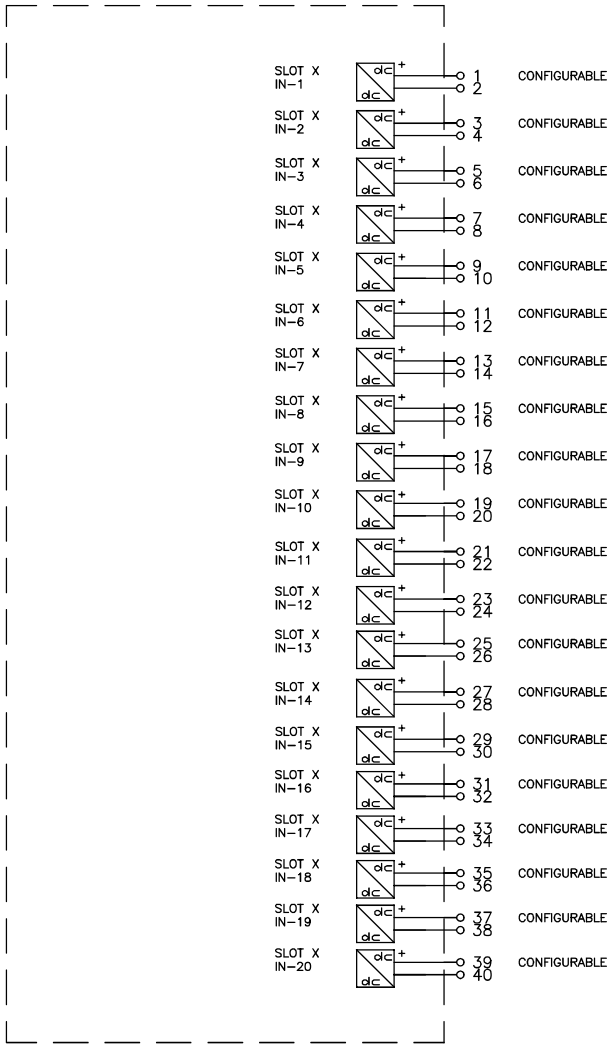
PROYECTO / *PROJECT:* IRF#-####6666666666####

Rev.0

NUM.: 3RX0206/0011

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	27/05/19	J.M.S.
Aprobado / *Approved*	27/05/19	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: *Continued on sheet:* –



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#-###	#	5	5	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#-###	#	5	5	5	5	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#-###	#	5	5	5	5	5	5	5	5	5	5	####

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REV.	0	CD–	1	2	3	4
5		6	7	8	9	10
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Z I V Aplicaciones y Tecnología

TITULO: CONEXIONES EXTERNAS ENTRADAS/SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL INPUT/OUTPUTS

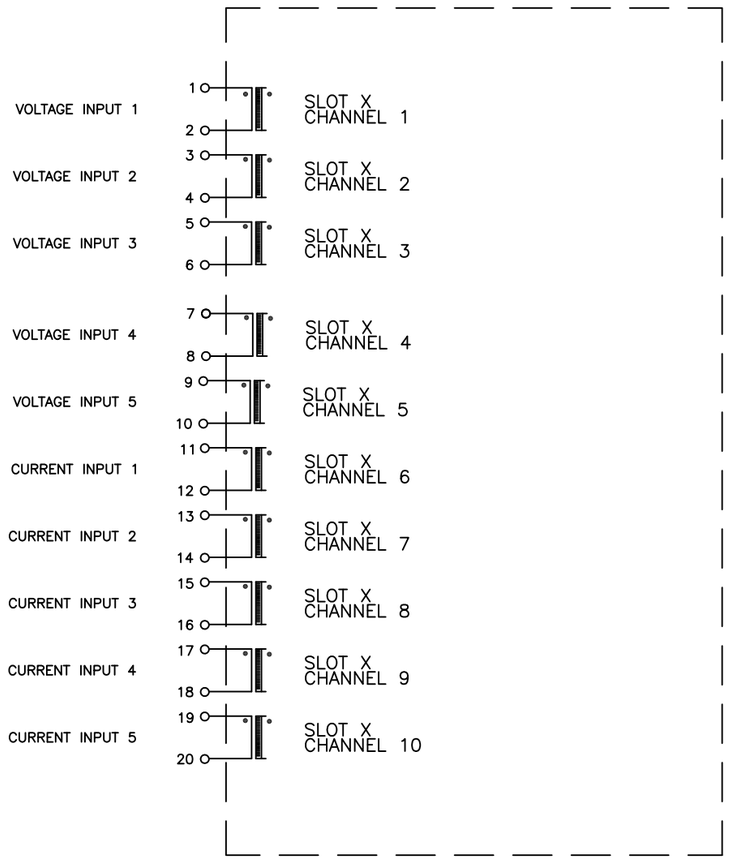
PROYECTO / *PROJECT:* IRF#-####5555555555####

Rev.0

NUM.: 3RX0206/0015

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	06/09/21	J.M.S.
Aprobado / *Approved*	06/09/21	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: –
Continued on sheet:



RACK	1/3			
SLOT	A	B	C	
			X	
MODEL \#F#-###	#	#	B	####

RACK	1/2					
SLOT	A	B	C	D	E	
			X	X	X	
MODEL \#F#-###	#	#	B	B	B	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
								X	X	X	X	
MODEL \#F#-###	#	#	#	#	#	#	#	B	B	B	B	####

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11		12		13		14		15		16	

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS ENTRADAS ANALOGICAS
TITLE: EXTERNAL CONNECTIONS ANALOGUE INPUTS

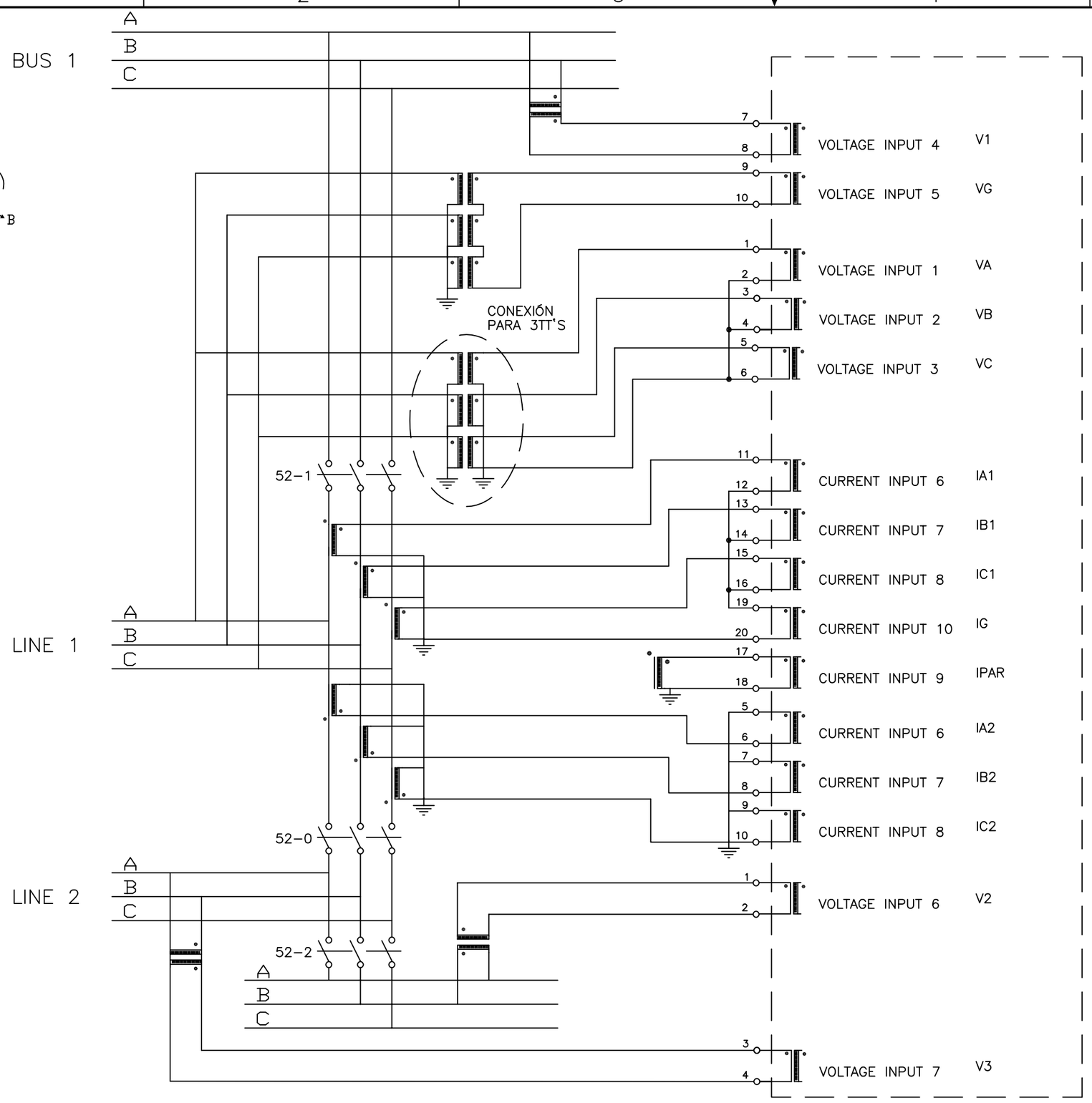
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Rev.0

NUM.: 3RX0206/0007

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	12/07/18	J.M.S.
Aprobado / *Approved*	12/07/18	P.A.

Hoja / *Sheet:* 1
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REV.	0	CD-	1		2		3		4	
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11		12		13		14		15		16

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS ENTRADAS ANALOGICAS
TITLE: EXTERNAL CONNECTIONS ANALOGUE INPUTS

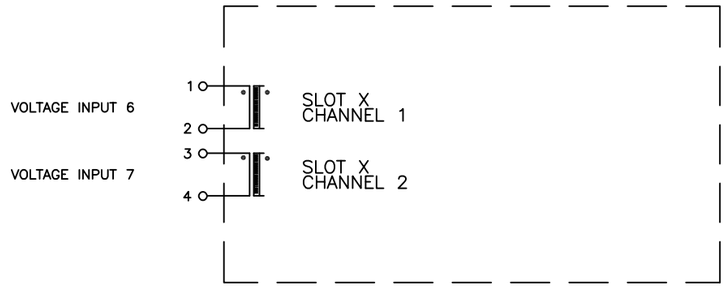
PROYECTO / *PROJECT:* ZLFC

Rev.0

NUM.: 3RX0206/0016

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	01/02/23	J.M.S.
Aprobado / *Approved*	01/02/23	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: –
Continued on sheet:



RACK	1/2					
SLOT	A	B	C	D	E	
			X	X	X	
MODEL I#F#-###	#	#	H	H	H	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
								X	X	X	X	
MODEL I#F#-###	#	#	#	#	#	#	#	H	H	H	H	####

"ATENCION" *"WARNING"*
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REV.	0	CD500007352	1		2		3		4	
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11		12		13		14		15		16	

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS ENTRADAS ANALOGICAS
TITLE: EXTERNAL CONNECTIONS ANALOGUE INPUTS

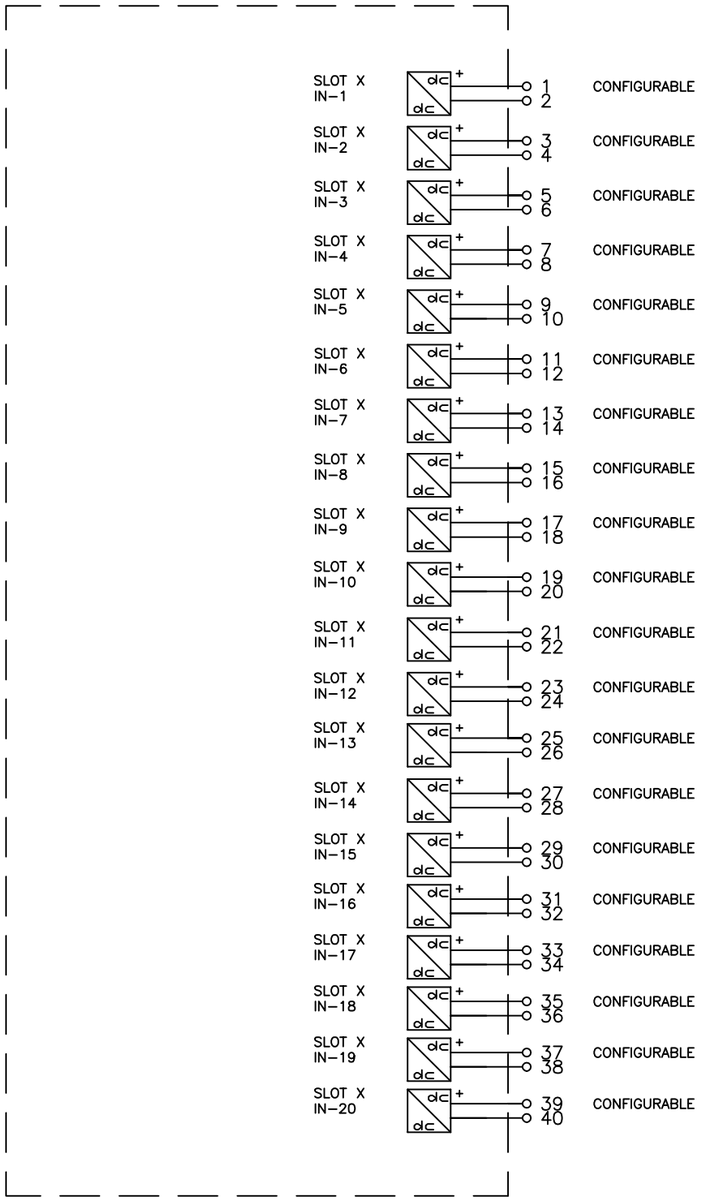
PROYECTO / *PROJECT:* DLF-KSA (DLFB)

Rev.0

NUM.: 3RX0206/0017

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	20/06/23	J.M.S.
Aprobado / *Approved*	20/06/23	P.A.

Hoja / *Sheet:* 1
Continua en Hoja: –
Continued on sheet:



RACK	1/3			
SLOT	A	B	C	
		X	X	
MODEL I#F#-###	#	5	5	####

RACK	1/2					
SLOT	A	B	C	D	E	
		X	X	X	X	
MODEL I#F#-###	#	5	5	5	5	####

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
		X	X	X	X	X	X	X	X	X	X	
MODEL I#F#-###	#	5	5	5	5	5	5	5	5	5	5	####

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TITULO: CONEXIONES EXTERNAS ENTRADAS/SALIDAS DIGITALES
TITLE: EXTERNAL CONNECTIONS DIGITAL INPUT/OUTPUTS

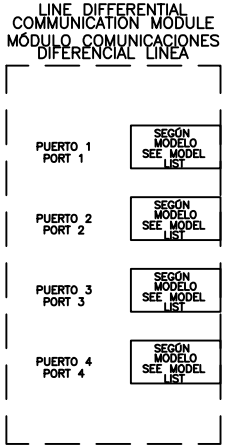
PROYECTO / *PROJECT:* IRF#-####5555555555####

Rev.0

NUM.: 3RX0206/0015

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	06/09/21	J.M.S.
Aprobado / *Approved*	06/09/21	P.A.

Hoja / *Sheet:* 1
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RACK	1/3			
SLOT	A	B	C	
				CPU
MODEL I#F#-###	#	#	#	XYZW

RACK	1/2					
SLOT	A	B	C	D	E	
						CPU
MODEL I#F#-###	#	#	#	#	Z	XYZW

RACK	1											
SLOT	A	B	C	D	E	F	G	H	I	J	K	
												CPU
MODEL I#F#-###	#	#	#	#	#	#	#	#	#	#	Z	XYZW

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TITULO: CONEXIONES EXTERNAS CPU
TITLE: EXTERNAL CONNECTIONS CPU

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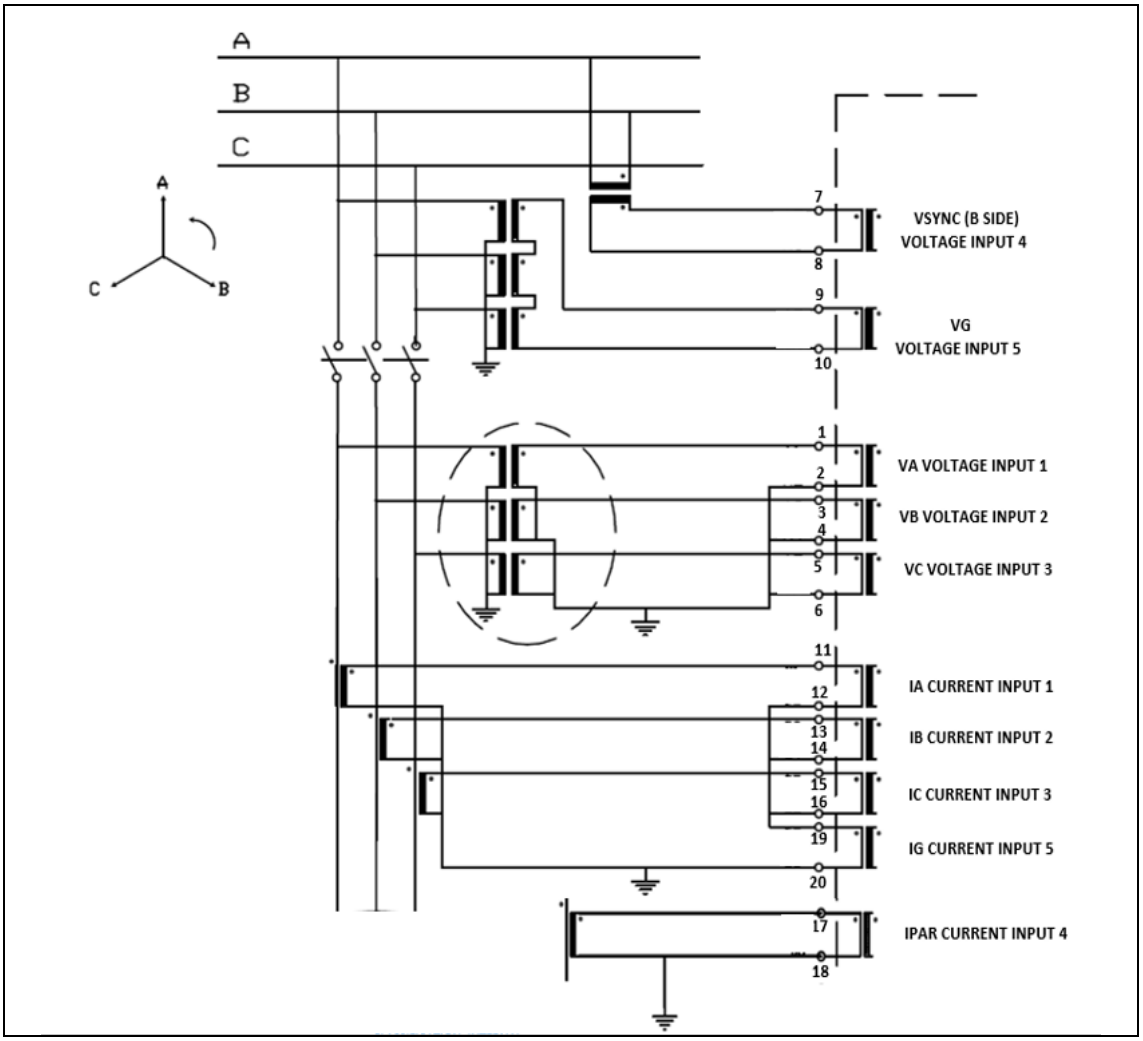
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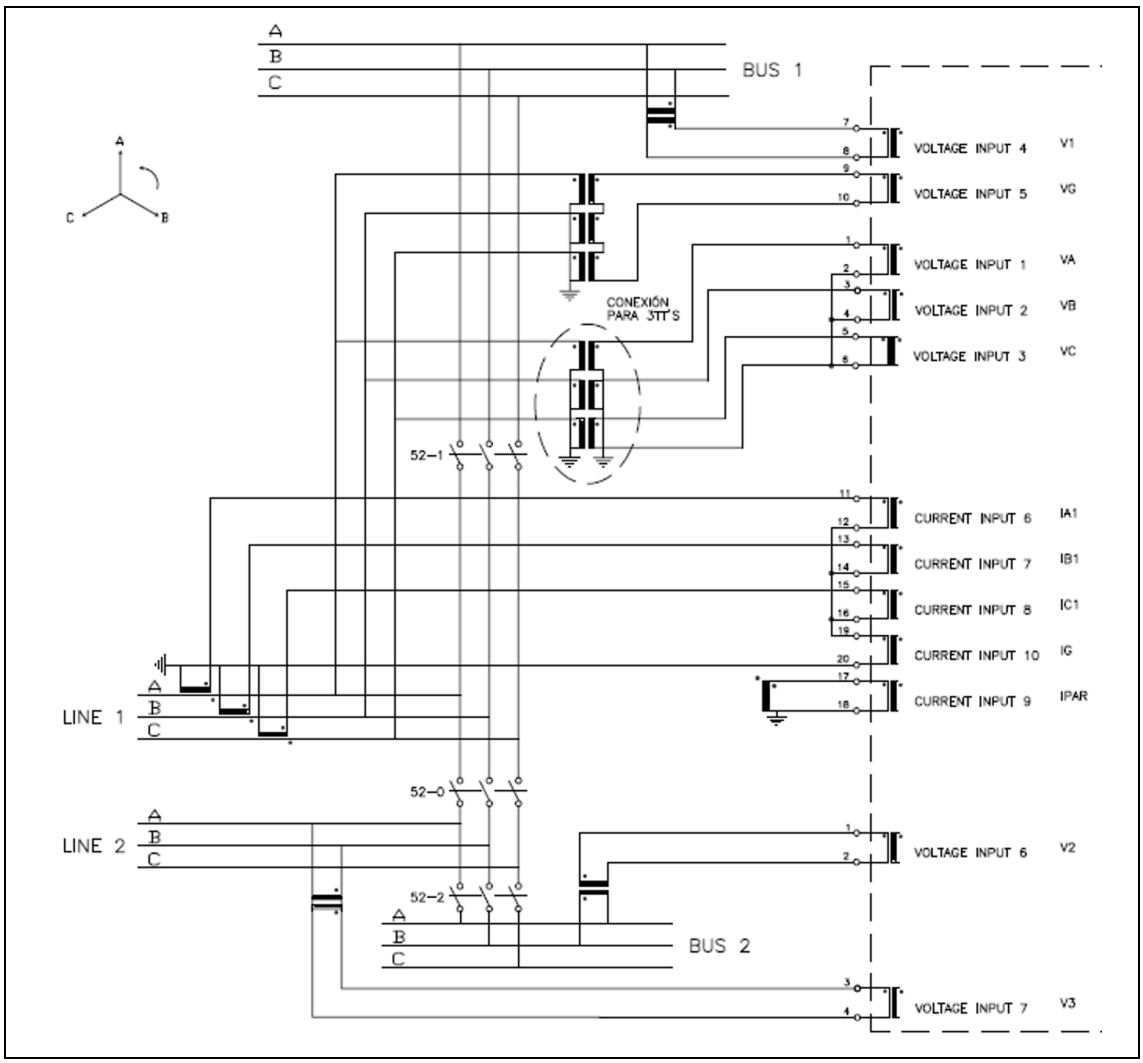
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Example: Analogue Inputs External Connections (DLF-A)



Example: Analogue Inputs External Connections (DLF-B)



1.10 Alarm Codes

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1.10.1 Introduction

The occurrence of alarms is notified by following routes:

- Activation of an Alarm Generation Signal and Event.
- Update of the Alarm Status Magnitude.
- Indication on the HMI Stand-by Screen.

1.10.2 Activation of Signal and Alarm Generation Event

The IED has 2 status contact input signals to indicate critical and non-critical level alarms:

- Non-critical system error: **ERR_NONCRIT**
- Critical system error: **ERR_CRIT**

The activation of any of these signals generates its associated event. These signals can be used as inputs to be processed by the user-developed algorithms. Likewise, these signals can be connected to any of the communications protocols for their remote notification.

1.10.3 Update of the Alarm Status Magnitude

The IED has a magnitude whose value is determined by the combination of active alarms in the IED. This magnitude can be used as input to be processed by the user-developed algorithms. Likewise, a user-developed algorithm can connect this magnitude (or the outcome of the processing of the same by the user logic) to any of the communications protocols for transmission.

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Following table shows the possible causes of alarm coded by alarm magnitude, together with their level of severity.

Table 1.10-1: Alarm Status Magnitude and Severity Level

Alarm	Value	Severity	Meaning
Alarm in Local Port	0x00000002	NON-CRITICAL	Error while operating with the front USB port.
Protection Out-of-Service Alarm	0x00000004	CRITICAL	Protection error. Protection Out-of-Service.
Error in ADC	0x00000008	CRITICAL	Error in the ADC or in the auxiliary microcontroller that receives and controls the samples.
Digital Inputs / Outputs Alarm	0x00000010	CRITICAL	Problems in the I/O Module.
Error in Flash	0x00000020	CRITICAL	Problems in Flash memory.
Error lack of VCC in circuits	0x00000040	CRITICAL	Internal power failure.
Error IEC 61850	0x00000080	NON-CRITICAL	Problem with data files, CID that accompanies the SW, Unknown relay model, inability to choose a data model or parse error on a previously validated CID.
Error in configuration	0x00000100	NON-CRITICAL	The error occurs if the system cannot be configured with the requested configuration.
Program error	0x00000200	CRITICAL	Unexpected SW problems that prevent its operation.
Remote Port 1 Alarm	0x00000400	NON-CRITICAL	Serial remote port HW error.
Hardware error	0x00000800	CRITICAL	Incorrect HW Configuration. The HW detected by the IED does not correspond to the internal models provided by the SW.
UCONTROLER Alarm	0x00001000	CRITICAL	Error in communication with the auxiliary microcontroller that controls the different boards.
RTC Alarm	0x00002000	NON-CRITICAL	Loss of time or due to no detection of the clock.
Alarm in Transducer Input	0x00004000	CRITICAL	Error in communication with the Transducer Input.
Communications card 87L Alarm	0x00004000	NON-CRITICAL	Communication error with the 87L communication card.

In the case of more than one alarm at once, the sum of the codes of these alarms is seen in hexadecimal form.

1.10.4 Indication on the HMI Stand-By Screen

The activation of the **Critical System Error** signal produces the display of the current magnitude of the status of alarms of the IED in hexadecimal format on the stand-by display of the HMI.

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1.10.5 LED Indication and Operating States of the Equipment

The LED on the top of the IED together with the label "READY" is not configurable and shows, depending on the color and the blinking, the different operating states of the equipment.

- **Fixed Green**. Equipment in service and under normal operating conditions. As non-critical alarms do not prevent normal operation of the equipment, the equipment will not change this indication.
- **Fixed Red**. Equipment in critical alarm mode:
  - The control logic is still running.
  - PROCOME Protocol only allows control messages.
  - IEC 61850 disables subscriptions and GOOSE messages.
  - The IED continues its measurement tasks, but stops recording historical data.
  - The protection is not operative.
  - Equipment contact indicating out of service.
- **Blinking Red**. Protection setting Out-of-Service.
  - Protection Out-of-Service.
  - Control logic stops working, while maintaining the values it has at that moment, that is, the logic signals do not return to 0 when it is put out of service, freezing the values until they are recalculated when the equipment is put in service again.
  - Protection continues with measures.
  - The IED keeps communicating, the measurements are updated by communications and only digital signals not related with the logic or with the protection will be updated.
  - Equipment contact indicating out of service.
- **Blinking Green**: equipment *booting up*.
- **Blinking Orange**: equipment recording in flash memory.
- **Fixed Orange**: equipment in Test Mode (future functionality).

1.10.6 General Alarm Counter

The relay is provided with three counters on the HMI to inform on the number of starts, re-starts and Traps:

- **Number of starts** (NARRANQS). Informs on the number of times the relay has been cold restarted (relay power supply failure).
- **Number of restarts** (NREARRAQS). Informs on the number of times the relay has been hot restarted (manually through change in configuration, or change of any nominal setting or relay reset).
- **Number of Traps** (NTRAPS). Number of exceptions produced in the relay followed by a reset.

Warning: contact the manufacturer if the unit displays any of these alarms codes.

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1.11 Troubleshooting

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1.11.1 Introduction

The purpose of this Chapter is to allow identifying error conditions in the device so that the user can carry out the appropriate corrective action in each case.

1.11.2 Software with Self-Checking

The relay performs continuous monitoring and self-checking its hardware and software. If any problem is detected, the device will show an alarm message in the HMI as it is explained in the Chapter 1.10.1, Alarm Codes.

The alarms generated by the self-checking module are divided in two levels, critical and non-critical alarms (table located in Chapter 1.10.1, Alarm Codes). When there is a non-critical alarm, the corresponding alarm message is displayed in the HMI and the device keeps on working due to the fact that the error level detected does not prevent the basic protection functionality, while when there is a critical alarm along with the error message in the HMI the alarm or watchdog contact of the relay changes its position because the protection goes out of service.

1.11.3 Power Up

If the relay does not appear to power up, verify the following points in order to determine if the error is located in the external wiring, in the power supply module or in the display.

Table 1.11-1: Power Up

Test	Check	Actions
1	Measure the auxiliary voltage on terminals of the relay, verifying that the voltage level and polarity is the one defined on the front label. Verify the positive and negative terminal in the external connection drawing.	If the auxiliary voltage is correct, proceed to test 2. If the auxiliary voltage is not the expected one, verify the wiring, fuses and/or minicircuit breakers should be checked.
2	Verify the alarm/watchdog contact of the relay. Check terminals in the external connections scheme of the equipment.	In the device is in service status (contact), the “READY” LED on green and the display is backlit but nothing is displayed, contact your supplier and the ZIV Quality Department. If the device is out of service, contact your supplier and the Quality Department of ZIV.

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1.11.4 In Service / Alarm Contact

Table 1.11-2: In Service / Alarm Contact		
Test	**Check**	**Actions**
1	Access through the HMI or with the communication program to the setting called as “Unit In Service” which is inside General. If it is enabled proceed to test 2.	If the setting is disabled, enable it and verify that the alarm/watchdog contact switched from alarm status to in service status. If it does not change, proceed to test 2.
2	Check if there is any alarm message in the HMI and verify if it is a critical alarm taking into account the table located in the Chapter 1.10, Alarm Codes.	Contact your supplier and the Quality Department of ZIV.

1.11.5 Error Messages during Power Up

If the device, once the power up process has finished, is not showing the default screen (model, date and time) verify the following points.

- **IEC61850 Devices**

Table 1.11-3: Error Messages during Power Up - IEC61850 Devices		
Test	Check	Actions
1	IEC61850 power up stops showing the following message: ----------.CID	Protection is operating but communications cannot run because the device has no CID file. Load a correct CID file to the relay with correct XML format and IP address equal to that of the equipment in question.
2	IEC61850 power up stops showing the 3010 error	Protection is operating but communications cannot run because there is a problem while loading the IEC61850 profile. Contact your supplier and the Quality Department of ZIV.
3	IEC61850 power up stops showing the 3011 error	Protection is operating but communications cannot run because there is a problem while loading the CID file. Verify in the logs (web server or FTP) the error reason, modify the CID file and load the corrected file.
4	IEC61850 power up stops showing the 3020 error	Protection is operating but communications cannot run because the FW version of the protection and the IEC61850 FW are not matching. Contact your supplier and the Quality Department of ZIV.
5	IEC61850 power up stops showing the 3030 error	Protection is operating but communications cannot run because there is a mistake in the external control logic configuration of the CID (InRefs, LOGGAPC). Verify in the logs (web server or FTP) the error reason, modify the CID file and load the corrected file.

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Table 1.11-3: Error Messages during Power Up - IEC61850 Devices		
Test	**Check**	**Actions**
6	IEC61850 power up stops showing the 3060 error	Protection is operating but communications cannot run because there is a mistake in the GOOSE subscription configuration. Verify in the logs (web server or FTP) the error reason, modify the CID file and load the corrected file.
7	IEC61850 power up stops showing the 3070 error	Protection is operating but communications cannot run because there is an error in the internal file that manages the Ethernet connection. Contact your supplier and the Quality Department of ZIV.
8	IEC61850 power up stops showing the 3080 error	Protection is operating but communications cannot run because there is a problem in the interfaces. Contact your supplier and the Quality Department of ZIV.
9	IEC61850 power up stops showing the 3200 error	Protection is operating but communications cannot run because there is a problem with the interruptions of the DPRAM. Contact your supplier and the Quality Department of ZIV.
10	If there is a generic non IEC61850 error message in the HMI, check which kind of error it is according to the table that appears in Chapter 1.10, Alarm Codes.	Contact your supplier and the Quality Department of ZIV.

- **Non IEC61850 Devices**

Table 1.11-4: Error Messages during Power Up - IEC61850 Devices		
Test	**Check**	**Actions**
1	If there is an error message in the HMI, check which kind of error it is according to the table that appears in Chapter 1.10, Alarm Codes.	Contact your supplier and the Quality Department of ZIV.

1.11.6 Error Messages when the Relay is in Normal Operation

Table 1.11-5:Error Messages when the Relay is in Normal Operation		
Test	**Check**	**Actions**
1	If there is an error message in the HMI, check which kind of error it is according to the table that appears in Chapter 1.10, Alarm Codes.	Contact your supplier and the Quality Department of ZIV. Take into account that, with non-critical errors, control and protection are still operational.
2	If there is a 40000 error message on the HMI.	Contact your supplier and the Quality Department of ZIV. The differential protection functions have stopped working due to an error on the 87L communication card. Protection functions using only local measurements (distance, overcurrent, etc.) will continue operating normally.

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1.11.7 Errors while Communicating

Table 1.11-6: Errors while Communicating

Test	Check	Actions
1	If a communication error takes place when trying to communicate with *ZIV e-NET tool*® program through the frontal port with the following message: Doesn't communicate. Cannot get identifier.	Verify: - That you are using a crossed cable (5-5, 2-3). - That you are using a suitable USB cable and you have all the drivers installed. - That the communication parameters of the device and the ones set in the communications program fit. Click two times in the screen of *ZIV e-NET tool*® and scan the PC port used for the connection with the relay to obtain automatically the suitable parameters. To verify the COM port associated with the USB port and to use it as a parameter for the communication, move the mouse on *Help / About ...* with the Shift + Ctrl + Alt keys pressed and the corresponding port appears in the upper right corner. If even with those parameters the message is still appearing, contact your supplier and the Quality Department of ZIV.
2	If a communication error takes place when trying to communicate with *ZIV e-NET tool*® program through the frontal port with the following message: *Cannot locate the identifier corresponding profile: XXXX*.	Close *ZIV e-NET tool*® program, update the database and run again *ZIV e-NET tool*® in order to communicate with the relay.
3	If a communication error takes place when trying to communicate with *ZIV e-NET tool*® program through the serial rear port of the relay.	Verify: - That you are using a crossed cable. - That the communication parameters of the device and the ones set in the communications program fit. - That the protocol of the rear port has been set to PROCOME. Click two times in the screen of *ZIV e-NET tool*® and scan the PC port used for the connection with the relay to obtain automatically the suitable parameters. If even with those parameters the message is still appearing, contact your supplier and the Quality Department of ZIV.
4	If a communication error takes place when trying to communicate with *ZIV e-NET tool*® program through the LAN port of the relay.	Verify: - The IP address of the relay is the same one set in *ZIV e-NET tool*®. - That the TCP port set in *ZIV e-NET tool*® is 32001. - That the network parameter selected is the transparent. - That the IP address of the PC belongs to the same family address of the one set in the relay and the network masks are correct. If the error is still appearing, contact your supplier and the Quality Department of ZIV.

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Table 1.11-4: Errors while Communicating		
Test	**Check**	**Actions**
5	Errors when communicating in Modbus and DNP3 through the serial remote port.	Verify: - That you are using a crossed cable. - That the communication parameters of the device and the ones set in the communications program fit. - That the rear port in the relay has been set with the appropriate protocol (DNP3). - That the control configuration of the relay has the addresses requested by the master. If you cannot communicate, verify the correct behavior of the port trying to communicate in PROCOME with *ZIV e-NET tool*®. If it works, check again the initial points. If it does not work, contact your supplier and the Quality Department of ZIV.
6	Errors when communicating in Modbus RTU and DNP3 through the LAN port.	Verify: - The IP address of the relay is the same one set in the master. - That the TCP/IP port fits. - That the instance is adjusted with the appropriate protocol. - That the control configuration of the relay has the addresses requested by the master. - That the IP address of the PC/master belongs to the same IP family address of the one set in the relay and the network masks are correct. If you cannot communicate, verify the correct behavior of the port trying to communicate in PROCOME with *ZIV e-NET tool*®. If it works, check again the initial points. If it does not work, contact your supplier and the Quality Department of ZIV.

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1.11.8 Communications Error 87L

Table 1.11-7: Communications Error 87L		
Test	**Check**	**Actions**
1	If a communication error 87L occurs and the differential units remain blocked by communications.	Check on the back of the equipment the status of the leds corresponding to the differential card (Slot E in ½ rack equipment): - If the LED is off, check that the SFP module (if used) is correctly inserted, that it is the homologated SFP and that the communication channel corresponding to that port is enabled in the settings (see chapter 1.5). - If the LED is red, check that the fiber is correctly connected to the SFP module (the LC connector must be fully inserted in the SFP module and cannot be removed without pressing the security tab) or to the ST connector. Check that the RX and TX correspondence is correct and that the fiber is not split at any point. If not, the link may be broken somewhere in the network. You can use the loop mode to rule out problems in the equipment itself regarding the communications network. Another possibility is that the remote equipment to which the equipment with problems is connected is not communicating for some reason (port not configured in some enabled communications channel, remote equipment without power, etc.). - If the LED is permanently yellow, there may be a problem in the configured address settings. - If the LED is flashing green, it indicates that the link is active on that port. Check all other ports that communicate with other DLF equipment. In configurations with redundancy, if the LED on a port is not flashing green, there is no reason to block the differential units for communications. If you do not want to disassemble the equipment, you can check the communication status through the HMI or through ZIVercomPlus. To know the meaning of each signal, see Chapter 1.5. If it does not work, contact your supplier and the Quality Department of ZIV.

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1.11.9 Error in Digital Inputs

Table 1.11-8:Error in Digital Inputs		
Test	**Check**	**Actions**
1	Verify that the DI is energized (positive and negative as external connection wiring diagram) checking the voltage level and polarity taking into account the indications of the front label (Name Plate) of the relay.	If the voltage supply of the DI is correct (positive and negative) skip to step 2. If the auxiliary voltage is not the expected one, check the external wiring, fuses and/or mini circuit breakers of the circuit.
2	If you are using a DI that can be configured for coil supervision, check that the corresponding setting has been set to NO.	Access through HMI or *ZIV e-NET tool*® to the coil supervision settings and disable them. If they were enabled go to step 3.
3	Check the activation/deactivation voltage levels as the table that appears in Digital Inputs inside Chapter 1.3, Technical Data.	If the voltage is located inside the activation margin and the DI is not activating, verify that the FW of the relay matches with the model of the front label (Name Plate) of the relay. In any case contact your supplier and the Quality Department of ZIV. If the FW does not match, contact your supplier and the ZIV Quality Department.

1.11.10 Error in Digital Outputs

Table 1.11-9:Error in Digital Outputs		
Test	**Check**	**Actions**
1	If the auxiliary contacts are not operating.	Verify the signals that activate the outputs and used in the protection settings for this purpose. If they are correct, make the necessary actions in order to execute the protection or the control logic and give the closing command. Verify if the output is changing the status in the HMI and in the events of the relay. If any of the outputs are not operating contact your supplier or the Quality Department of ZIV. If you are seeing the DO changing in the HMI, verify the activation of the output contact a multimeter, taking into account the external connection wiring diagram. If the physical output is not activating, contact your supplier and the Quality Department of ZIV.

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1.11.11 Error in Transducer Inputs

Table 1.11-10: Error in Transducer Inputs		
Test	**Check**	**Actions**
1	Verify that the input transducer has a suitable input signal taking into account the type of input transducer of the relay (see Model Selection table).	If the input signal is not the expected one, check the external wiring, intermediate devices, etc. If the input signal is the correct one, contact your supplier and the Quality Department of ZIV.

1.11.12 Error in Measurements

- Compare the measurements shown in the HMI of the relay with the magnitudes metered with a multimeter in the terminals of the relay.
- Check that the transformation ratios of the CTs and VTs are the correct ones.
- Check that the terminals wired in the relay are the correct ones.
- Check the angle shift in order to confirm that the inputs are correctly wired.

If all the verifications are correct (external wiring, polarity and measurements in terminals of the relay), contact your supplier and the Quality Department of ZIV because it could be a problem of the equipment HW.

1.11.13 Fatal Errors

The device can reset itself in order to escape from transient anomalies, whose cause could be internal or external to the relay and which do not imply a damage of the relay itself. When there is an evidence of a malfunctionality of the device and/or a spontaneous reset, access through the HMI to the FW information screen (ENT / Information / Relay Information / Software/) and check if it is appearing a Trap indication with the date on which the fault occurred. If so, collect the available information of the relay (events, logs, fault reports, disturbance recorder files, etc.), connect by FTP to the computer with user *coredump* and password *coredump*, download all the information present in the accessed folder and contact your supplier and the Quality Department of ZIV.

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Chapter 2.

Differential Protection Units

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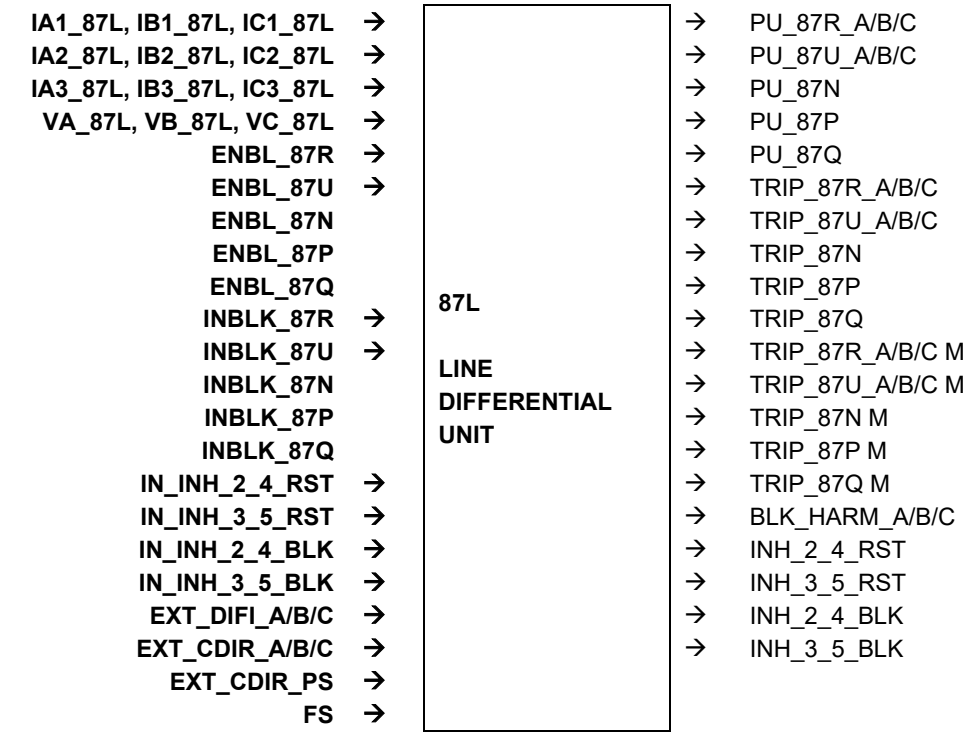
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2.1.1 Identification

The Line Differential unit integrates the functions of phase, neutral, positive and negative sequence differential protection.

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Phase Differential Unit with Restraint	PDIF		**87R**
Phase Differential Unit without Restraint	NRPDIF		**87U**
Neutral Differential Unit with Restraint	GNDPDIF		**87N**
Positive Sequence Differential Unit with Restraint	PSPDIF		**87P**
Negative Sequence Differential Unit with Restraint	NSPDIF		**87Q**

2.1.2 General Block



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2.1.3 Communications for the Line Differential Function

The line differential relay has a communications card with up to 4 ports that allow it to communicate with the remote equipment located at the ends of the line and carry out the line differential function.

For each remote computer, you can configure the use of one port or two (with redundancy). In case one of the communication links fails and there is no redundancy, the equipment that stops receiving information will block the line differential units. In case of redundancy, the equipment will automatically switch to the redundant port and will continue to operate the enabled line differential units, as long as the redundant link is active and without error.

2.1.3.a Communications Configuration

Each **DLF** unit must be configured with an absolute and unique local address (from 0 to 255) by setting ***Local E1 Address*** and with the addresses of the remote units: ***Remote E2 Address*** and ***Remote E3 Address*** according to the number of **DLF** units connected to each other and which will integrate the line protection.

DLF units send Direct Transfer Trip (DTT) signals to all connected remote units when one of the differential units trips and the ***Allow Send DTT*** setting is activated.

Trips by Differential Line Units and Direct Transfer Trips (DTT) will be supervised by activation of the fault detector emitting them in the event that the ***Fault Det Supervision*** setting, in the trip logic, is active. In weak infeed conditions, undervoltage units will be used to supervise the trip (the trip will be supervised by an OR of the fault detector and undervoltage units). The undervoltage units will be blocked if a fuse failure is detected or the pole of the corresponding phase is open.

In order to provide greater security, the Direct Transfer Trip (DTT) will follow an M/N window scheme where M frames must be received with DTT flag activated over total N frames, by default configured as 1/1. To do this, the desired filter must be selected using the ***DTT Filter*** setting. The filters can be configured in the Virtual Digital Inputs section, within the group of Inputs, Outputs and LEDs.

In the configuration of the communications scheme, two concepts must be distinguished: channels and ports. On the one hand, the channels are used to define with which equipment the local equipment is going to communicate, through which port or ports and the information about currents to send and receive. It will be possible to communicate with as many remote equipment as the number of channels the equipment has (depending on the model). On the other hand, the ports establish the type of communication and the technical particularities of each port.

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2.1.3.b Channels Configuration

Once the channel has been enabled using the ***Enable*** setting, the configured ports remain active for communication. The ***Remote Extreme*** setting indicates with which remote unit the communication is to be established. The ***Main Port*** and ***Redundancy Port*** settings are used to establish which physical ports will be used in the channel. By default, there will always be at least one port set as the main port. If there is a redundant port, the communication will be established by default in the main port and will only be switched to the redundant port in case there is an error in the communication of the main port.

Note: Under no circumstances may the same port be used on different channels.

The channel configuration will allow you to select whether the local equipment will communicate with 1 or 2 remote ends. If Channel 1 is enabled, and it is configured to communicate with Remote End E2 and receive current I2, it will be understood that there will only be two **DLF** equipment protecting a two-end line. If two channels are enabled, configured as Channel 1 with Remote Terminal E2 and Channel 2 with Remote Terminal E3 and the reception of I2 and I3, respectively, it will be understood that there will be three **DLF** equipment protecting a three-ended line. In this last situation, disabling Channel 2 will return to the situation where two **DLF** equipments protect a two-ended line.

- **Transmission Current Groups**

There will be only one group of local currents (referred to as I1). The currents sent will be the currents measured locally by the analog board (IA, IB and IC). By default, it is set to I1. These currents used in the line differential units will be represented at phase level in ***ZivercomPlus***® as IA1_87L, IB1_87L and IC1_87L and in abbreviated form in the HMI and in the Oscillography as IA1_L, IB1_L and IC1_L.

Both the transformation ratios of the local CTs and the remote equipment will be adjusted in each relay that will integrate the line differential protection. These settings can be found in General Settings (***Phase 1 CT Ratio***, ***Phase 2 CT Ratio*** and ***Phase 3 CT Ratio***).

The compensations are made with respect to local current I1. The CT ratio of the remote ends configured in the local relay must be the same as the one configured as ***Phase 1 CT Ratio*** in this remote relay.

- **Receiving Current Groups**

There will be two remote current groups to be configured (denominated as I2 and I3) that can be configured as ***Current A*** or ***Current B***. The latter will only be used in cases where two currents can be sent through the same channel (depending on the model). These currents I2 and I3 that are used in the line differential units will be represented at phase level in ***ZivercomPlus***® as IA2_87L, IB2_87L, IC2_87L, IA3_87L, IB3_87L and IC3_87L and in abbreviated form both in the HMI and in the Oscillography as IA2_L, IB2_L, IC2_L, IA3_L, IB3_L and IC3_L.

Note: if only one group of current is received, it must be configured as "Current A". A current to be received must always be set as " Current A ".

Note: when a current group is configured in one channel, it can no longer be used in another channel.

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2.1.3.c Port Configuration

The equipment can have 2 or 4 ports (depending on the model) dedicated to communication for the realization of the differential function. There are three types of communications that can be selected using the ***Connection Type*** setting:

- C37.94 Multiplexor. Intended to communicate with SDH multiplexers using protocol C37.94. Speed adjustable from 1x64 kbits to 12x64 kbits.
- 2 Mbits/s Multiplexor. Intended to communicate with SDH multiplexers via G.703 (E1). **External optical-electric compatible converter** required. A fixed transmission speed of 2 Mbits is used.
- Point to Point. For direct fiber optic connections between equipments. A fixed transmission speed of 2 Mbits is used.

If the setting ***Connection Type*** is configured as ***C37.94 Multiplexor***, then the data transmission speed can be set using ***C37.94 Speed*** setting.

The ***Data Transmission Clock Type*** setting must be set to the ***Recovered Clock*** mode on all line protection equipment if the equipment is connected to an SDH multiplexer or to an external optical-electric converter. On the other hand, if point-to-point connections are used, this setting must be configured alternately. That is to say, the port of the local equipment must be configured as ***Clock Generated*** while the port of the remote equipment to which it is connected must be configured as ***Clock Recovered*** or vice versa. Connecting ports from two different devices in point-to-point configurations such as ***Generated Clock-Generated Clock*** or ***Retrieved Clock-Retrieved Clock*** may cause occasional or permanent communications problems.

The ***Loop Mode*** setting allows the user to check the operation of the equipment without the need to connect it to another equipment. While this mode is activated, the address field of the configured remote equipment will be the same as that of the local equipment without the need to change address settings. The message that the port is in loop mode will appear in the standby screen. There is no necessity to use an external fiber but, in case of use SFP, the SFPs must be inserted.

Additionally, externally manual loops are also possible (TX to RX of the same port) but, the ***Loop Mode*** setting must be disabled and the address of local and remote IEDs must be the same. In this case, no message will be shown in the standby screen.

Care should be taken not to externally loop a single-mode SFP that has a long reach, as this could overload the reception of the SFP itself leading to reading incorrect values and, in more serious cases, the failure of the SFP itself. If such SFPs are to be looped anyway, attenuators with appropriate values must be used. An attenuation of 10dB will be enough to avoid saturation of the receiver.

If necessary, the samples can be reversed so that the measured differential current is zero if set to ***With Inverted Samples***.

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In models where SFP-LC modules are used, it is possible to monitor the status of the SFP using the Digital Diagnostic Monitoring (DDM) standard. To do this, the SFP module used must be compatible with this standard. The DDM standard allows to know internally measured SFP values of temperature, voltage, current, emitted optical power and received optical power. In this way, the user will be able to know the status of the SFP in the event of possible incidents and determine the origin of these. A practical application is to know the optical power in the reception to determine if the line attenuation level is too high for the correct reception of the communication. Activating the ***SFP Monitoring via DDM*** setting allows both the display of these parameters and the sending of alarms, generated internally in the SFP, to the system. These alarms will have no effect on the execution of the line differential function.

2.1.3.d Sampling for Differential Function

Samples sent to the remote end shall be obtained from native samples at 4800 Hz (previously synchronized with the PPS and calibrated angularly). For a transmission rate of 2 Mb/s, the native samples of the equipment shall be used directly, that is to say, at a sampling frequency of 4800 Hz. For speeds between 384 kbit/s and 768 kbit/s a decimation at 1600 Hz shall be carried out. For speeds below 384 kbit/s, decimation shall be carried out at 800 Hz. Before the decimation an anti-aliasing filter is applied to avoid the appearance of the aliasing effect. In the receiver the inverse process is carried out to obtain the samples at 4800 Hz and thus be able to carry out the line differential function.

2.1.3.e Communications Protocol

Communication between **DLF** equipment is based on the HDLC communications protocol. If a communication is chosen using the C37.94 standard, then the HDLC frame is encapsulated in the C37.94 frame.

Communication via HDLC protocol is protected by the following error detection mechanisms:

- Frame length check.
- Checking the direction field of the frame with respect to the local direction of the relay.
- 16-bit CRC.
- Redundant sequences with known value and distributed in specific points of the frame to detect unwanted variations of the frame content.

The structure of the frame will vary according to the transmission speed selected by the user. The following table shows the main characteristics of the frame according to transmission speed.

Table 2.1-1: Characteristics of Different Transmission Speeds

Transmission Speed (kbits)	64	128 to 384	448 to 768	2.048
Sampling frequency in sending (Hz)	800	800	1600	4800
Positive Sequence Voltage	NO	YES	NO	NO
Phase Voltages	NO	NO	YES	YES
Direct Transfer Trip by Phase	YES	YES	YES	YES
Saturation Detector by Phase	YES	YES	YES	YES
Number of configurable digital signals	16	16	16	16

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2.1.3.f Synchronization of the Measurement between Equipments

The time lag between the sampling clock of the local equipment and the sampling clock of the remote equipment, known as ΔT or clock phase, can be obtained using two methods: synchronization using the ping-pong method or synchronization using communications and synchronization using an external clock. To activate the latter, it is necessary to activate it using the ***External Synchronization*** setting. This synchronization will only work if the local equipment and the corresponding remote units are properly synchronized by IRIG-B or PTP. Regardless of whether the external synchronization is activated, the equipment will continue to use the synchronization by means of communications as a backup in case of eventual loss of the external clock.

- **Communications Synchronization**

Synchronization through communications or the ping-pong method is based on an exchange of time tags that allow the deduction of both the phase between the equipment clocks and the round-trip channel time (*tchannel_rt*). The round-trip channel time (or *2*tchannel* when there is symmetry) will be used as a reference in the settings. Synchronization will be performed once every 50 ms, regardless of the set transmission rate.

With the information obtained during this process, the local equipment proceeds to the calculation of ΔT and the round-trip channel time with equations (1) and (2), and assuming that the outgoing channel time (*tchannel1*) is equal to the return channel time (*tchannel2*), i.e. there is symmetry in the link:

$$tchannel1 = tchannel2 = tchannel$$
$$2 * tchannel = tchannel_rt$$

$$\begin{aligned} tl1 + tchannel &= \Delta T + tr1 \\ tl2 &= \Delta T + tr2 + tchannel \end{aligned} \quad (1)$$

With the above equations:

$$tchannel_rt = (tl2 - tl1) - (tr2 - tr1)$$
$$\Delta T = \frac{tl1 + tl2}{2} - \frac{tr1 + tr2}{2} \quad (2)$$

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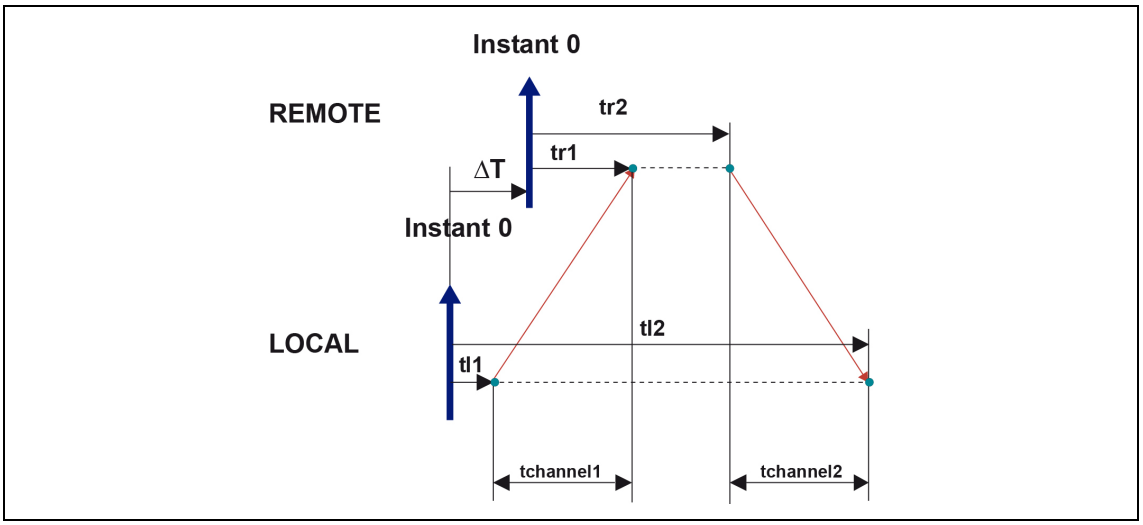


Figure 2.1.1 Ping-Pong Method Synchronization.

- **External Clock Synchronization**

If the ***External Synchronization*** setting is activated, the phase between the sampling clocks of the differential units will be calculated with respect to the time marked by the external clock, provided it is available on both devices Therefore, a local equipment will know the phase of the sampling clock of the remote equipment with respect to the external clock and its own with respect to the external clock. During external synchronization, the asymmetry of the communications channel (*tchannel1* and *tchannel2*) will be calculated and must be available for consultation.

Previously, the external synchronization source must be configured in the necessary DLF equipments through the **Synchronization** section (see 1.5.8). It will be possible to synchronize the line differential units when a precise source of synchronization is used, specifically, IRIG-B or PTP.

If the external synchronization signal is lost (both locally and remotely), the value ΔT calculated from the synchronization by communications will be automatically applied. If the external synchronization signal does not return within 3 seconds, an **External Synchronization Loss in Port N Alarm** signal will be activated if the ***External Synchronization*** setting is activated.

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2.1.3.g Sample Synchronization Process

After communications have been established between the equipments and before aligning and generating samples for the execution of the line differential function, a sample synchronization process will be initiated. This process includes a series of channel time calculations, using the method described above, to determine if the round-trip channel time is constant on all configured ports. During this process, the **Line Differential Unit in Synchronization Process** signal will be active. In order for the channel time to be considered constant on a given port, the following conditions must be met:

1. All calculated channel time values during the setting ***Timing for Constant Channel T.*** (setting in Communications configuration) are lower than the ***Max. Channel Time*** setting (setting in Ports configuration). The channel time considered in the setting is round trip.
   If the maximum channel time is greater than the set time, then the **Excessive Channel Time in Port N** signal will be activated.
2. All calculated channel time values during the ***Timing for Constant Channel T.*** setting have a difference from the average channel times (calculated from the channel times accumulated during the ***Timing for Constant Channel T.***) lower than the ***Max. Channel Switch Time*** setting. The last setting will be set taking into account the maximum jitter that may exist in the link.

If both operations are satisfactory, the signal ***Constant Channel Time in Port N*** will be activated, being N = {1,2,3 and 4} the port, and the *signal* ***Constant Channel Time in Channel M***, being M = {1 and 2} the channel in which this port is configured. At that moment, values ΔT are accumulated until reaching the value set in ***Values for Channel T. Calc.***, as long as the signal ***Constant Channel Time in Port N*** is maintained. Once the amount of values ΔT has been accumulated, the regression line that will characterize ΔT and the variation of ΔT (slope) is calculated. This regression line will be updated each time a new calculation of ΔT is made. The corresponding ΔT of each sample will be used to align the remote samples with the local samples. Finally, the ***Line Differential Protection Synchronized*** signal will be activated. In configurations with port redundancy, the regression line will be calculated simultaneously on both ports.

When the ***Constant Channel Time in Port N*** signal is deactivated on a given port (meaning that the channel time no longer meets either of the above conditions and there is no communication channel failure), the corresponding regression line (and subsequent ones) will not be calculated until the corresponding ***Constant Channel Time in Port N*** signal is reactivated. This is due to the fact that the variation of the channel time is indicative of a path change, which will generate transitory asymmetries that will temporarily invalidate the calculation of new regression lines. At that moment, the last valid regression line memorized will be used. The maximum time in which this stored regression line will be used is defined by the sum of the value of the setting ***Max. Channel Switch Time*** (setting in Communications configuration) and the setting ***Values for Channel T. Calc.*** multiplied by 50 ms. Once this time has elapsed and if the channel time is not constant, the **Line Differential Protection Synchronized** signal will be deactivated (if there is no port redundancy) and the differential functions will be blocked. When the channel time becomes constant again, then the calculation of a new regression line will start and once the calculation is finished, the differential units will be unblocked **and Line Differential Protection Synchronized** signal will be activated.

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As long as a channel does not have the **Constant Channel Time in Channel M** signal activated and there is no communications error on that port, the **Line Differential Protection in Synchronization Process** signal will be active, and the **Line Differential Protection Synchronized** signal will be deactivated. Both signals will be deactivated when the **Differential Units Blocked by Communications** signal is active.

It should be noted that the stored regression line is only used when the channel time has remained constant for more than 10 s. Otherwise, when the **Constant Channel Time in Channel M** signal is deactivated, the **Line Differential Protection Synchronized** signal will also be deactivated.

If, after the ***Max. Channel Switch Time*** has elapsed, the **Constant Channel Time in Port N** signal is active, the values ΔT will be accumulated again until the value set in ***Values for Channel T. Calc.*** is reached and the recently calculated regression line will be used again. At this point, the previous regression line will be discarded, and a time delay of 10 s will be activated during which the channel time must be constant in order to use the current regression line again due to changes in the channel time.

2.1.3.h Operation with Asymmetries in the Channel

The equipment includes two methods to be able to operate with communications networks with permanent asymmetries.

The first method consists of making a manual correction through the setting called ***Channel Asymmetry Correction***, within the port configuration, which allows compensating the difference between the round-trip channel times when there is no symmetry in the channel. This difference could be measured during commissioning and can be used if there is no variation in it during the operation of the communications network. The value of ΔT will be corrected according to the following formula (3):

$$\Delta T = \frac{tl1 + tl2}{2} - \frac{tr1 + tr2}{2} + \frac{tchannel1 - tchannel2}{2} \qquad (3)$$

This manual correction only takes effect when operating line differential relays using the communications synchronization explained in the previous section. That is, the ***External Synchronization*** setting must be disabled.

The second method is to perform an automatic correction of the asymmetry by using the external clock synchronization, i.e. when the ***External Synchronization*** setting is activated. In addition, externally synchronized equipment must receive a correct clock signal for this compensation method to work properly. Using the external synchronization, the **DLF** equipment is able to calculate the value of Tchannel 1 and Tchannel 2 and, therefore, the channel asymmetry to be corrected according to the formula (3).

If the external synchronization signal is lost (or local or remote) a transition period will be entered. During the first 0.5 seconds, the value ΔT calculated from the external synchronization is frozen. In turn, the asymmetry value calculated before the loss of the external synchronization is frozen.

If the external synchronization signal does not return within 0.5 seconds, the value ΔT calculated from the communications synchronization will be automatically applied, as long as there is a valid regression line, compensated with the frozen asymmetry measurement.

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If there is no valid regression line, then the **Differential Units Communication Blocking** signal will be activated. The alignment of samples can be done by communications synchronization when there is a valid regression line.

If the external synchronization signal does not return within a period of 3 seconds, an **External Synchronization Loss Alarm on Port N** signal will be activated.

If a channel time change is detected (at any time since the external synchronization was lost) due to a path switching, the **Differential Units Communication Blocking** signal will be activated and will remain active until one of the following events occurs:

- The **External Sync.** signal is recovered, both local and remote, and a value of ΔT and the asymmetry can be recalculated. The **External Synchronization Loss Alarm on Port N** signal (where N is 1, ...,4) will be reset and the frozen asymmetry will no longer be applied.

- The external synchronization is disabled and there is a valid regression line to apply. The **External Synchronization Loss on Port N Alarm** signal will be reset, and the frozen asymmetry will no longer be applied, and the one defined by the ***Port N Asymmetry Correction*** setting will be applied.

In the blocking status, samples will continue to be aligned by applying the ΔT by communications and the last reliable asymmetry, i.e., the frozen one.

The reason for blocking a differential unit is to avoid compensating asymmetries that may have changed due to a reconfiguration of the communications network.

2.1.3.i Errors, Measures and Communication Quality Rates

The **DLF** equipment constantly monitors the status and quality of the communication in each communication port related to the operation of the line differential.

- **Errors in Communication**

The following signals can be distinguished (being N the port number):

Loss of Signal in Port N General (LOS). Also known as Loss of Signal, it is activated when a general signal loss is detected. This happens when any of the following signals are activated.

- **Loss of Signal in Port N Interface**. It is physically generated by the receiver when the received signal is below the minimum detectable threshold.
- **Loss of Signal in Port N PLL**. It is generated when the SW communications controller does not detect signal variations in the port.
- **Loss of Signal in Port N C37.94**. It is generated according to standard C37.94.

Alarm Indication Signal in Port N (AIS). It is generated when an AIS or all 1's condition is detected according to standard C37.94. Indicates that a higher SDH link has been dropped.

Yellow Bit in Port N. It is generated when a yellow bit indication is received from the SDH multiplexer or from the converter to which the equipment is connected.

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- **Quality Measurements**

Bit Error Ratio (BER) is the percentage of erroneous bits detected between the number of bits analyzed during a certain adjustable time period. The BER measurement is representative as long as the communication has been stable for a significant period of time. The BER measurement can be reset by activating the signal **Reset Stats Value in Port N**.

Error Free Seconds (EFS) indicates that in the last second of the communication there was no erroneous bit. This measurement will be made on those bits of the frame that have been received and that have a known or expected value (the identification of the link and the redundant sequence) and the CRC check.

Errored Seconds (ES) indicates that in the last second of the communication there has been at least one erroneous bit, either a loss of input signal (LOS) has been detected, or an AIS (Alarm Indication Signal) is received or the CRC is incorrect.

Severely Errored Seconds (SES) indicates that in the last second the BER is equal to or worse than 1E-3, either an input signal loss is detected, or an AIS or all 1's indication is received.

- **Quality Rates**

The team calculates a series of rates to monitor the quality of long-term communication, as long as there is no LOS or AIS condition. The period of registration and calculation of rates can be set using the setting ***Record Time***. The calculated rates are as follows:

Erroneous Seconds Rate (ESR). It is the percentage of ES with respect to the total number of seconds that the communication has lasted, as long as this duration does not exceed the time established in the ***Record Time***. This measurement is only performed when a link is available. It is assumed that at the beginning the measurement will oscillate and that as time passes the measurement will converge towards a stable value. If a certain threshold is exceeded, defined by the setting ***ESR Threshold***, the signal **ESR Threshold Exceeded in Port N** will be activated. By default, this threshold will be 4%. The ESR rate can be reset by activating the **Reset Stats Value in Port N** signal. This alarm will be merely informative and has no effect on the functionality of the protection.

Severely Erroneous Seconds Rate (SESR). It is the percentage of SES with respect to the total number of seconds that the communication has lasted, as long as this duration does not exceed the time established in the ***Record Time***. This measure is only carried out when a link is available. It is assumed that at the beginning the measurement will oscillate and that as time passes the measurement will converge towards a stable value. If a certain threshold is exceeded, the signal **SESR Threshold Exceeded in Port N** will be activated. By default, this threshold will be 0.2%. The SESR rate can be restarted by activating the **Reset Stats Value in Port N** signal. This alarm will be merely informative and has no effect on the functionality of the protection.

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Availability Rate (ATR). It is the percentage of time that the link is available with respect to the total number of seconds that the communication has lasted, as long as this duration does not exceed the time established in the ***Record Time***. It is assumed that at the beginning the measurement will oscillate and that as time passes the measurement will converge towards a stable value. If the available time falls below a certain threshold, the signal **ATR Threshold Exceeded in Port N** will be delivered. By default, this threshold will be 99.9%. The ATR rate can be reset by activating the **Reset Stats Value in Port N** signal. This alarm will be merely informative and has no effect on the functionality of the protection.

2.1.3.j Communications Alarms

The team has several mechanisms to detect configuration problems, link quality problems and link losses. The occurrence of any of these alarms blocks the line differential units.

- **Wrong Address Alarm**

This alarm is generated each time a received frame is detected whose address field does not match the expected value. In this case, the signal **Alarm Wrong Address in Port N** will be activated. This alarm will be reset when several frames are received, defined by the setting ***Reset Wrong Address Alarm***, with the correct value.

- **Excessive Samples Loss Alarm**

The alarm **Excessive Sample Lost in Port N** is activated when the loss of several samples above a threshold is detected. This threshold depends on the sampling frequency used to send samples. Thus, the loss of 4 samples at sampling frequencies of 800 and 1600 Hz and of 8 samples at sampling frequency of 4800Hz is supported. If the number of samples lost during half a cycle (10ms) also exceeds the previous value (even if they are not consecutive samples), the **Excessive Sample Lost in Port N** alarm will also be activated. In case the sample loss does not exceed the threshold, the loss samples are interpolated.

This alarm is only activated when a time jump is detected in the received samples. In case of serious communication interruptions (detected by other mechanisms) this alarm is not activated as it requires the reception of samples to check that there has been a time jump.

- **Communications Loss Alarm**

This alarm is indicated by the **Alarm Communications Lost in Port N** signal. If an N port within an M-channel declares this situation and there is no redundant port or if both ports declare such a situation, then the **Alarm Communications Lost in Channel M** signal is activated. It is activated when the alarm occurs excessive erroneous frames or declares an unavailability of the link which are described below:

Excessive Erroneous Frames Alarm. The equipment has one counter per port for received erroneous frames. This counter increases each time an erroneous frame is received and decreases when a correct frame is received. It is considered an erroneous frame when it is detected:

- Wrong address.
- Wrong frame length.
- Erroneous CRC.
- Any wrong redundant sequence.
- The non-receipt of frames for a time longer than the ***Max. Channel Time*** setting divided by two.

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The ***Excessive Erroneous Frame Counter Alarm*** signal is activated when it equals or exceeds a configurable threshold through the ***Errored Frames Cnt. Threshold*** setting and is deactivated when the value equals or is lower than the ***Reset of Errored Frames Cnt*** setting.

Note: A wrong direction alarm will result in an alarm of excessive wrong frames.

Link Unavailability Alarm. It is defined as a period of unavailability that begins when a number is detected, determined by the setting ***SES Threshold to Link Unavbl*** of consecutive seconds classified as SES, and ends when a number is detected, determined by the setting **No *SES Threshold to Link Avbl***, of consecutive seconds that are not SES. When a link unavailability is declared by activating the ***Alarm Link Unavailability in Port N*** signal, the line differential units will be blocked except if there is port redundancy and the redundant port is not affected. This alarm is especially indicated for situations where communication is noisy and therefore unreliable.

Note: the value of the loss of communications alarm is updated with a period shorter than the excessive erroneous frames alarm and unavailability of link alarm at the time of displaying them in the oscillography.

- **Remote Port Synchronization Watchdog**

This signal is activated when there is no response, due to a unidirectional communication problem, to synchronization request sent by the local IED to the remote one during more than 400 ms. This prevents that a unidirectional communication problem produces an accumulated error on ΔT and, therefore, a local and remote current shift due to lack of syncing processes.

2.1.3.k Port Status

The port status indicates whether you are communicating and receiving samples and signals properly. When the ***Port N Active*** signal is activated, the port is receiving samples and communicating correctly. If this signal is deactivated, it indicates that there is a communication problem that may be caused by the above alarms. When the port is not active, and in the absence of a valid redundant port, the line differential units are blocked.

2.1.3.l Blocking of Differential Units by Communications

Line Differential Units are blocked when one of the following cases occurs:

- When no channel is enabled.
- When an alarm due to excessive loss frames, excessive erroneous frames or link unavailability has been detected.
- When any channel is enabled and both the main port and the redundant port (if configured) are not active for any reason (communication errors, HW errors, etc.).

In any of these situations, the signal **Differential Units Blocked by Communications** and the signal **Prefault Based Units Blocked by Communications** are activated and will only be reset when the conditions listed above disappear. The effect and reset of each signal is different as described below:

Differential Units Blocked by Communications. While this alarm is active, all differential units will be blocked. This blocking signal is reset when the previously mentioned conditions disappear for at least 1 cycle (20ms).

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Prefault Based Units Blocked by Communications. While this alarm is active, all units based on current variation or pre-fault current will be disabled: fault detector based on differential and restraint currents (the fault initiation will be defined, in that case, by the fault detector based on sequence currents, which uses only local samples) and the direct sequence comparison unit (logic "2 of 3" will become logic "1 of 2" and logic "3 of 3" will become logic "2 of 2"). This blocking signal is reset when the above conditions disappear for at least 3 cycles.

2.1.3.m SFP Interface Statistics and Alarms

The **DLF** equipment can obtain statistical data from the SFPs, connected to the differential communications board, if they use the DDM (SFF-8472 Digital Diagnostic Monitoring Interface) standard. This information facilitates the start-up of the equipment, maintenance and detection of communication problems. The available data are as follows:

- Temperature (ºC).
- Applied voltage (V).
- Circulating current (mA).
- Emitted power (dBm).
- Received power (dBm).

To monitor these values, the setting ***SFP Monitoring via DDM*** must be activated for the port to which the SFP is connected. The range and accuracy of measurements will depend on the SFP used and can be obtained from the data sheet of the corresponding model.

In addition, SFP modules complying with the DDM standard provide a series of alarms related to the measures mentioned above. Thus, two levels of alarms are considered: warning level and alarm level. These levels for each of the measurements are established and recorded internally in the SFP. The monitoring of these alarms does not occur when the setting ***SFP DDM Monitoring*** is not enabled. Regardless of the set value, these alarms have no effect on the line differential units and are merely informative.

2.1.3.n Loop Mode

The loop mode setting allows the user to test the communication of the equipment on himself by making a loop on the same port and without the need to change the equipment addresses. To do this, it is necessary to connect the TX with the RX of the same port. This loop mode can be activated per port using the ***Loop Mode*** setting in the port configuration. If loop mode is activated on any of the ports, then the **Port N in Loop Mode** signal is activated.

If it is set to **YES**, the samples sent are those received, so that the measured differential current is twice the injected current. If, on the other hand, it is set to ***With Inverted Samples***, then the measured differential current will be zero.

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2.1.3.o Default Screen

The equipment default screen shows the status of the available ports (depending on the model). The states will be shown according to the following display priority, i.e. only the state with the highest active priority will be shown, even if there are several active states.

1.LOS.
2.AIS.
3.Wrong Add.
4.Link Lost
5.Yell Bit.
6.Sync Wdg.
7.Exc. ChT.
8.Loop Mode.
9.Active.
10.Standby.
11.Disabled.

2.1.3.p Examples of Communications Configuration

The following are some examples of communication configurations.

- **Point-to-Point with two Ends and No Redundancy**

In a point-to-point scheme, the ports to communicate with each other must always be configured in one unit as a generated clock and in the other as a recovered clock.

Equipment 1:

Communications		
Local E1 Address		105
Remote E2 Address		11
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Generated Clock

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Equipment 2:

Communications		
Local E1 Address		11
Remote E2 Address		105
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Recovered Clock

- **Point-to-Point with Two Ends and with Redundancy**

Equipment 1:

Communications		
Local E1 Address		27
Remote E2 Address		32
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		Port 2
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Generated Clock
Port 2		
Connection Type		Point-to-Point
Relay Type		Generated Clock

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Equipment 2:

Communications		
Local E1 Address		32
Remote E2 Address		27
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		Port 2
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Recovered Clock
Port 2		
Connection Type		Point-to-Point
Relay Type		Recovered Clock

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- **Point-to-Point with Three Ends and No Redundancy**

Equipment 1:

Communications		
Local E1 Address		13
Remote E2 Address		14
Remote E3 Address		15
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Channel 2		
Enable		YES
Remote End		Remote End E3
Main Port		Port 2
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I3
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Generated Clock
Port 2		
Connection Type		Point-to-Point
Relay Type		Generated Clock

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Equipment 2:

Communications		
Local E1 Address		14
Remote E2 Address		13
Remote E3 Address		15
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		No
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Channel 2		
Enable		YES
Remote End		Remote End E3
Main Port		Port 2
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I3
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Recovered Clock
Port 2		
Connection Type		Point-to-Point
Relay Type		Generated Clock

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Equipment 3:

Communications		
Local E1 Address		15
Remote E2 Address		13
Remote E3 Address		14
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Channel 2		
Enable		YES
Remote End		Remote End E3
Main Port		Port 2
Redundancy Port		NO
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I3
	Current B	None
Port 1		
Connection Type		Point-to-Point
Relay Type		Recovered Clock
Port 2		
Connection Type		Point-to-Point
Relay Type		Recovered Clock

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- **Connection to Multiplexer with C37.94 with Two Ends and with Redundancy**

When connected by multiplexers or optical-electric converters, the ***Relay Type*** setting must be set as a Recovered Clock on all ports.

Equipment 1:

Communications		
Local E1 Address		44
Remote E2 Address		46
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		Port 2
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		C37.94 Multiplexor
Relay Type		Recovered Clock
Port 2		
Connection Type		C37.94 Multiplexor
Relay Type		Recovered Clock

Equipment 2:

Communications		
Local E1 Address		44
Remote E2 Address		46
Remote E3 Address		0
Channel 1		
Enable		YES
Remote End		Remote End E2
Main Port		Port 1
Redundancy Port		Port 2
Transmission Current Groups		
Transmission	Current A	I1
Receiving Current Groups		
Reception	Current A	I2
	Current B	None
Port 1		
Connection Type		C37.94 Multiplexor
Relay Type		Recovered Clock
Port 2		
Connection Type		C37.94 Multiplexor
Relay Type		Recovered Clock

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2.1.3.q Communications Settings

87L Communications General Settings					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Local Address E1	Local E1 Add.	DIFPDCF.AddNod1	0 - 255	1	0
Remote E2 Address	Remote E2 Add.	DIFPDCF.AddNod2	0 - 255	1	0
Remote E3 Address	Remote E3 Add.	DIFPDCF.AddNod3	0 - 255	1	0
External Synchronization	Ext. Sinchr.	DIFPDCF.SynEx	YES / NO		NO
Timing for Constant Channel T.	Tmg. Const. Ch. T.	DIFPDCF.ChEvTmms	0.1 - 1s	0.05s	0.2s
Values for Channel T. Calc.	deltaT Calc Values	DIFPDCF.NumSmp	10-20 values	1	10
Max. Channel Switch Time	Max. Ch. Switch T.	DIFPDCF.MaxSwTmms	0.02 - 2	0.02	1 s
Reset Wrong Address Alarm	Rst. Wrong Add. Al	DIFPDCF.RsAlmErr	0 - 255	1	10
Errored Frames Cnt. Threshold	Err. Frames Thold.	DIFPDCF.FerLim	0 - 255	1	50
Reset of Errored Frames Cnt.	Err. Frames Rst.	DIFPDCF.FerRs	0 - 255	1	40
SES Threshold to Link Unavbl	SES Link Unvbl	DIFPDCF.SESLnkUnav	1 - 10	1	2
No SES Threshold to Link Avbl	No SES Link Avbl	DIFPDCF.NoSESLnkAv	0 - 10	1	2
ESR Threshold	ESR Thold.	DIFPDCF.ErrSLim	0 - 100%	0.1%	4%
SESR Threshold	SESR Thold.	DIFPDCF.SevErrSLim	0 - 100%	0.01%	0.2%
Availability Rate Threshold	Availability Thold	DIFPDCF.AvLim	0 - 100%	0.01%	99.9%
Record Time	Record Time	DIFPDCF.QRegTmh	12-720 hours	1	12 h
Allow Send DTT	Allow Send DTT	DIFPDCF.AllDTT	YES / NO		YES
DTT Filter	DTT filter	DIFPDCF.DTTTrgFil	None Filter Filter 1 Filter 2 Filter 3 Filter 4		None Filter

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Communications Channel M (M=1,2)					
Setting	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Enable	CHDIFPDCF.ChEna	YES / NO		NO
Remote End	Remote End	CHDIFPDCF.NodAdd	Remote End E2 Remote End E3		Remote End E2
Main Port	Main Port	CHDIFPDCF.Port	Port 1 Port 2 Port 3 Port 4		Port 1
Redundancy Port	Redundancy Port	CHDIFPDCF.RedPort	NO Port 1 Port 2 Port 3 Port 4		NO
Transmission Current Groups	TX Current Groups				
Current A	Current A	CHDIFPDCF.AGrTx	None / I1		I1
Receiving Current Groups	RX Current Groups				
Current A	Current A	CHDIFPDCF.AddNod3	None / I2 / I3		None
Current B	Current B	CHDIFPDCF.AddNod4	None / I2 / I3		None

Serial Port N (N=1,2,3,4)					
Setting	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Connection Type	Conection Type	PTDIFPDCFx.ConnTyp	C37.94 Multiplexor 2 Mbit/s Multiplexor Point-to-Point		Point-to-Point
C37.94 Speed	C37.94 Speed	PTDIFPDCFx.Spd	64 Kbaud 128 Kbaud 192 Kbaud 256 Kbaud 320 Kbaud 384 Kbaud 448 Kbaud 512 Kbaud 576 Kbaud 640 Kbaud 704 Kbaud 768 Kbaud		768 Kbaud
Clock Data Transmission Type	Clk. Data Tx. Type	PTDIFPDCFx.ClkTrTyp	Recovered Clock Generated Clock		Recov. Clock
Max. Channel Time	Max. Ch. Time	PTDIFPDCFx.ChMaxTmms	0 - 50 ms	0.1 ms	20 ms
Max. Deviation Channel T.	Max. Dev. Ch. Time	PTDIFPDCFx.ChStabTmms	0.1 - 8 ms	0.05 ms	1 ms
Channel Asymmetry Correction	Ch. Asymmetry	PTDIFPDCFx.ChAsymTmms	-20 - 20 ms	0.1 ms	0 ms
Loop Mode	Loop Mode	PTDIFPDCFx.LoopMod	NO YES With Inverted Samples		NO
SFP DDM Monitoring	SFP DDM	PTDIFPDCFx.SFPDDMSup	YES / NO		NO

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2.1.3.r Digital Inputs

Table 2.1-2: Digital Inputs and Events of the Communications System					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_CHDIF 1_RST_TRM_ERR	Reposition commands	PTDIFPDCF1.StatRst	Reset Stats Value in Port 1		Resets the port statistics.
IN_CHDIF 2_RST_TRM_ERR		PTDIFPDCF2.StatRst	Reset Stats Value in Port 2		
IN_CHDIF 3_RST_TRM_ERR		PTDIFPDCF3.StatRst	Reset Stats Value in Port 3		
IN_CHDIF 4_RST_TRM_ERR		PTDIFPDCF4.StatRst	Reset Stats Value in Port 4		

2.1.3.s Digital Outputs and Events

Table 2.1-3: Digital Outputs and Events - Communications - Port N					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
LDC_PORT_N_ENBLD	Others	PTDIFPDCFx.PortEna	Port N Enabled Line Differential Protection	I	Indicates that port N is enabled.
LDC_PORT_N_LOOPMODE			Port N in Loop Mode	I	Indicates that port N is in Loop mode.
LDC_PORT_N_TCHANNEL_EXCESS		PTDIFPDCFx.ExcChTm	Excessive Channel Time Port N	I	The channel time measured at the N port exceeds the "Maximum channel time" setting.
LDC_PORT_N_CONST_TIME		PTDIFPDCFx.ConsChTm	Constant Channel Time Port N	I	The channel time has been constant during constant channel timing.
LDC_ALRM_PORT_N_SYNC_LOST			External Synchronization Loss Port N Alarm	I	Indicates that there has been loss of external synchronization on port N.
LDC_PORT_1_87L_ACT		PTDIFPDCFx.PorAct	Port N Active Line Differential Protection	I	Indicates that the N port is supplying samples to the differential units.
LDC_PORT_N_LOS		PTDIFPDCFx.SigLos	Signal Loss in Port N Line Differential Protection	I	Indicates that on port N there is loss of signals
LDC_PORT_N_LOS_SFP_ST			Interface Signal Loss in Port N Line Differential Protection	I	Indicates loss of signals by interface
LDC_PORT_N_LOS_PLL			PLL Signal Loss in Port N Line Differential Protection	I	Indicates that there has been a loss of signals by PLL

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Table 2.1-3: Digital Outputs and Events - Communications - Port N					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
LDC_PORT_N_LOS_C3794			C37.94 Signal Loss in Port N Line Differential Protection	I	Indicates that there has been a loss of signals by C37.94 protocol
LDC_PORT_N_AIS		PTDIFPDCFx.Alm	Alarm Indication Signal in Port N Line Differential Protection	I	Indicates that an AIS has occurred
LDC_PORT_N_YELLOW		PTDIFPDCFx.YellowBit	Yellow Bit in Port N Line Differential Protection	I	Indicates that Yellow Bit has been detected
LDC_PORT_N_WATCHDOG_SYNCR			Remote Port Synchronization Watchdog	I	Indicates that the synchronization with the remote port has been lost.
LDC_ALRM_PORT_N_SMPS_LOST			Communication Lost in Port N Line Differential Protection Alarm	I	Alarm due to loss of communications.
LDC_ALRM_PORT_N_ADDR_ERR		PTDIFPDCFx.IncAddAlm	Incorrect Address Port N Alarm	I	Indicates incorrect address.
LDC_ALRM_PORT_N_BAD_FRAMES			Alarm Counter Excessive Erroneous Frames Port N	I	Indicates that there have been excessive erroneous frames
LDC_ALRM_PORT_N_LINK_LOST		PTDIFPDCFx.LnkLosAlm	Alarm Link Unavailability in Port N Line Differential Protection	I	Indicates that unavailability has been detected due to excessive SES
LDC_ALRM_PORT_N_COMMS_LOST		PTDIFPDCFx.CommLosAlm	Alarm Communication Lost in Port N Line Differential Protection	I	Indicates that there has been a loss of communications in the port N.
LDC_ALRM_PORT_N_ESR			ESR Threshold Exceeded in Port N Line Differential Protection	I	Indicates that the N port has exceeded the adjusted ESR (erroneous seconds rate).
LDC_ALRM_PORT_N_SESR			SESR Threshold Exceeded in Port N Line Differential Protection	I	Indicates that port N has exceeded the adjusted SESR (severely erroneous seconds rate) adjusted.
LDC_ALRM_PORT_N_ATR			ATR Threshold Exceeded in Port N Line Differential Protection	I	Indicates that the N port has exceeded the adjusted ATR rate.

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Table 2.1-3: Digital Outputs and Events - Communications - Port N					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
LDC_ALRM_SFP_N_LTEMP			Low Temperature in SFP Port N Line Differential Protection	I	Indicates SFP low temperature alert level.
LDC_ALRM_SFP_N_HTEMP			High Temperature in SFP Port N Line Differential Protection	I	Indicates SFP high temperature alert level.
LDC_ALRM_SFP_N_LVOLT			Low Voltage in SFP Port N Line Differential Protection	I	Indicates SFP excessively low voltage alert level.
LDC_ALRM_SFP_N_HVOLT			High Voltage in SFP Port N Line Differential Protection	I	Indicates SFP excessively high voltage alert level.
LDC_ALRM_SFP_N_LBIASCUR			Low Bias Current in SFP Port N Line Differential Protection	I	Indicates SFP insufficient current flow alert level.
LDC_ALRM_SFP_N_HBIASCUR			High Bias Current in SFP Port N Line Differential Protection	I	Indicates SFP excessive current flow alert level.
LDC_ALRM_SFP_N_LTXPOWER			Low TX Power in SFP Port N Line Differential Protection	I	Indicates SFP insufficient TX power alert level.
LDC_ALRM_SFP_N_HTXPOWER			High TX Power in SFP Port N Line Differential Protection	I	Indicates SFP excessive TX power alert level.
LDC_ALRM_SFP_N_LRXPOWER			Low RX Power in SFP Port N Line Differential Protection	I	Indicates SFP insufficient RX power alert level.
LDC_ALRM_SFP_N_HRXPOWER			High RX Power in SFP Port N Line Differential Protection	I	Indicates SFP excessive RX power alert level.
LDC_ALRM_WARNING_SFP_N			Level Alarm exceeded on SFP port N	I	Indicates that the alarm level has been exceeded in one of the SFP parameters.

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Table 2.1-4: Digital Outputs and Events - Communications - Channel M					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
LDC_CH_M_ENBLD	Others	CHDIFPDCFx.ChEna	Channel M Enabled Line Differential Protection	I	The differential unit is synchronized and operative.
LDC_CH_M_CONST_TIME		CHDIFPDCFx.ConsTm	Constant Channel Time in Channel M Line Differential Protection	I	The channel time has been constant during the constant channel timing on any of the ports configured in the channel.
LDC_ALRM_CH_1_COMMS_LOST		CHDIFPDCFx.CommLosAlm	Alarm Communication Lost in Channel M Line Differential Protection	I	It indicates that there has been loss of communications in the ports of the channel.

Table 2.1-5: Digital Outputs and Events - Communications - Equipments - General					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
DTT_A_Act	Trip Protection Outputs	DIFPDCF1.DTTRx	DTT from any remote far end Phase A		DTT received from any remote far end phase A.
DTT_B_Act		DIFPDCF1.DTTRx	DTT from any remote far end Phase B		DTT received from any remote far end phase B.
DTT_C_Act		DIFPDCF1.DTTRx	DTT from any remote far end Phase C		DTT received from any remote far end phase C.
M_DTT_A_Act	Masked Trips		Masked DTT from any remote far end Phase A		DTT received masked phase A.
M_DTT_B_Act			Masked DTT from any remote far end Phase B		DTT received masked phase B.
M_DTT_C_Act			Masked DTT from any remote far end Phase C		DTT received masked phase C.

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Table 2.1-6: Digital Outputs and Events - Communications - Equipments - Local E1					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
SEND_DTT_A	Virtual Digital Outputs	DIFPDCF1.DTTTx	DTT to Remote Far Ends Phase A		DTT sent phase A.
SEND_DTT_B		DIFPDCF1.DTTTx	DTT to Remote Far Ends Phase B		DTT sent phase B.
SEND_DTT_C		DIFPDCF1.DTTTx	DTT to Remote Far Ends Phase C		DTT sent phase C.
SEND_DTT_A_M			DTT masked to Remote Far Ends Phase A		DTT sent masked phase A.
SEND_DTT_B_M			DTT masked to Remote Far Ends Phase B		DTT sent masked phase B.
SEND_DTT_C_M			DTT masked to Remote Far Ends Phase C		DTT sent masked phase C.

Table 2.1-7: Digital Outputs and Events - Communications - Equipments - Local E2					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
E2_DTT_A_Act	Trip Protection Outputs	DIFPDCF1.DTTE2Rx	DTT from Remote Equipment E2 Phase A		DTT received from remote far end E2 phase A.
E2_DTT_B_Act		DIFPDCF1.DTTE2Rx	DTT rom Remote Equipment E2 Phase B		DTT received from remote far end E2 phase B.
E2_DTT_C_Act		DIFPDCF1.DTTE2Rx	DTT rom Remote Equipment E2 Phase C		DTT received from remote far end E2 phase C.

Table 2.1-8: Digital Outputs and Events - Communications - Equipments - Local E3					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
E3_DTT_A_Act	Trip Protection Outputs	DIFPDCF1.DTTE3Rx	DTT from Remote Equipment E3 Phase A		DTT received from remote far end E3 phase A.
E3_DTT_B_Act		DIFPDCF1.DTTE3Rx	DTT rom Remote Equipment E3 Phase B		DTT received from remote far end E3 phase B.
E3_DTT_C_Act		DIFPDCF1.DTTE3Rx	DTT rom Remote Equipment E3 Phase C		DTT received from remote far end E3 phase C.

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Table 2.1-9: Digital Outputs and Events - General Communications					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
LDC_BLK_COMMS_UNID_DIF	Others	DIFPDCF1.PDIFBlk	Differential Units blocked by communications		Differential units blocked by some communications error.
LDC_BLK_COMMS_UNID_PREF		DIFPDCF1.PreFltBlk	Pre-fault Differential Units Blocked by Communications		Differential units with pre-fault blocked by some communications error.
LDC_87L_SYNCING_PROCESS			Line Differential Protection in Syncing Process		The differential unit is in synchronization process.
LDC_87L_SYNCED		DIFPDCF1.SynOn	Line Differential Protection Synced		The differential unit is synchronized and operative.
LDC_I2_GRUPO_PRESENCE			Presence of Current Group I2		The line differential unit receives the current group I2.
LDC_I3_GRUPO_PRESENCE			Presence of Current Group I3		The line differential unit receives the current group I3.
LDC_CCC_ALLOWED		DIFPDCF1.CapCompOn	Capacitive Current Compensation Enable		There are conditions for applying capacitive compensation.
LDC_CAP_COMP_I1		DIFPDCF1.CapComCh1	Capacitive Current Compensation of Differential Channel 1		Compensation of active capacitive current in I1.
LDC_CAP_COMP_I2		DIFPDCF1.CapComCh2	Capacitive Current Compensation of Differential Channel 2		Compensation of active capacitive current in I2.
LDC_CAP_COMP_I3		DIFPDCF1.CapComCh3	Capacitive Current Compensation of Differential Channel 3		Compensation of active capacitive current in I3.
LDC_LOOPMODE_ENBLD		DIFPDCF1.LoopModOn	Loop Mode Unit Differential		Some port with a loop activated.

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2.1.4 Operating Principle of a Generic Differential Unit

Figure 2.1.2 represents a two-terminal device.

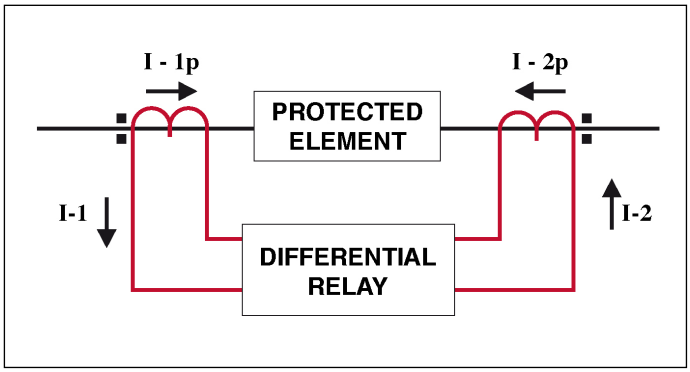


Figure 2.1.2 Transformer Configurations that can be Protected by ZIV Model DLF.

The differential unit calculates the differential current as the sum of the currents fluxing through the protected element: IDIF = I-1 + I-2. Current passing through the protected area, whether from external faults or load, creates very small differential current due to the CT polarity. On the other hand, internal faults generate high differential current. The differential unit operates when the differential current is above the pickup value.

Errors and tolerances in the CTs, the relay, and other sources, increase the differential current during external faults. The larger the current circulating on the CTs, the larger the increase in differential current. To compensate for this effect, the differential unit uses a percentage restraint characteristic, so that the differential current needed to operate will be increased by the restraint current, which represents the current fluxing through of the CTs that define the protection zone. There are different formulas for calculating the restraint current. The **DLF** uses the following:

$$I_{RES1} = \frac{|I-1| + |I-2| - |I_{DIF}|}{2}$$

$$I_{RES2} = \frac{|I-1| + |I-2|}{2}$$

Figure 2.1.3 shows the percentage restraint characteristic.

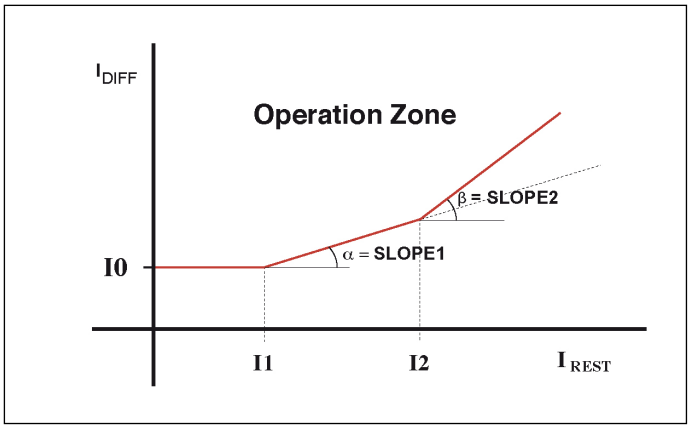


Figure 2.1.3 Percentage Restraint Characteristic.

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2.1.5 Line Differential Unit Common Settings

The **DLF** equipment incorporates four differential units, which will be used according to the requirements of the system to be protected, the differential units being the following:

- Phase Differential Unit.
- Neutral Differential Unit.
- Positive Sequence Differential Unit.
- Negative Sequence Differential Unit.

2.1.5.a Setting Ranges

General					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Wndg 1 Connection	Wndg 1 connection	YPTR1.WdgTyp1	WYE DELTA ZIGZAG		WYE
ZS Filter Wndg 1	ZS Filter wndg 1	YPTR1.ZerAExc1	YES / NO		YES
Wndg 2 Connection	Wndg 2 connection	YPTR1.WdgTyp2	WYE DELTA ZIGZAG		WYE
Wndg 2 Phase Ang	Wndg 2 phase ang	YPTR1.ConC1	0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11		0
ZS Filter Wndg 2	ZS Filter wndg 2	YPTR1.ZerAExc2	YES / NO		YES
Wndg 3 Connection	Wndg 3 connection	YPTR1.WdgTyp3	WYE DELTA ZIGZAG		WYE
Wndg 3 Phase Ang	Wndg 3 phase ang	YPTR1.ConC2	0 / 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 / 11		0
ZS Filter Wndg 3	ZS Filter wndg 3	YPTR1.ZerAExc3	YES / NO		YES
Reference Current	Reference current	YPTR1.RefWdg	1-3	1	1
Type of Tap	Tap Type	YPTR1.TapTyp	Automatic Manual		Automatic
Power	Power	YPTR1.PwrRtg	0.2-10000 MVA	0.1 MVA	100 MVA
Voltage 1	Voltage 1	YPTR1.WdgVol1	0.4-1200 kV	0.1 kV	400 kV
Voltage 2	Voltage 2	YPTR1.WdgVol2	0.4-1200 kV	0.1 kV	400 kV
Voltage 3	Voltage 3	YPTR1.WdgVol3	0.4-1200 kV	0.1 kV	400 kV
Tap 1	Tap 1	YPTR1.Tap1	(0.02 - 30) In		1 * In
Tap 2	Tap 2	YPTR1.Tap2	(0.02 - 30) In		1 * In
Tap 3	Tap 3	YPTR1.Tap3	(0.02 - 30) In		1 * In
Restraint Type	Restraint Type	PDIF1.RstTyp	(I1+I2-Id)/2 (I1+I2)/2		(I1+I2-Id)/2
Transformer in Protection Zone	Trafo in zone		YES / NO		NO
Capacitive Curr. Compensation	Capac. Curr. Comp.		YES / NO		NO
Diff Curr Measure	Diff curr measure	YPTR1.DifAInd (ENG)	Times Tap x Ref Tap		Times Tap

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2.1.6 Compensations for Differential Units

It is necessary to carry out a series of compensations so that the differential units can compare the currents coming from the different equipments.

2.1.6.a Capacitive Current Compensation

Capacitive current compensation will only be performed on the differential unit if the ***Capacitive Curr Compensation*** setting is set to "Local". If this setting is set to "Local", the capacitive current will be compensated using the following equations, the N value being equal to 1.

To make this compensation, it is necessary to measure the phase voltages and positive sequence (C1) and zero sequence (C0) line capacities must be known. The instantaneous capacitive current is calculated as follows:

$$iphcap = \frac{C1}{N} \cdot \left(\frac{dvph}{dt} - \frac{dv0}{dt} \right) + \frac{C0}{N} \cdot \frac{dv0}{dt}$$

Where:

- C1 represents the total positive sequence capacity of the line (when the capacity of the different segments of the line is entered, facing the locator, all the capacities will be added together to obtain the total capacity).
- C0 represents the total zero sequence capacity of the line (when the capacity of the different segments of the line is entered, facing the locator, all the capacities will be added together to obtain the total capacity).
- N represents the number of line ends that perform capacitive current compensation.
- Vph represents the phase voltage.
- V0 represents the zero sequence voltage calculated as the instantaneous sum of the samples of the three phases divided by three:

$$V0_i = \left(Va_i + Vb_i + Vc_i \right) / 3$$

In a discrete system, the expression of the capacitive phase current will be:

$$iphcap_t = \frac{C1}{N} \cdot \left(\frac{vph_t - vph_{t-1}}{t_{samples}} - \frac{v0_i - v0_{t-1}}{t_{samples}} \right) + \frac{C0}{N} \cdot \left(\frac{v0_t - v0_{t-1}}{t_{samples}} \right)$$

Where t and t-1 represent consecutive sampling instants and *tsamples* represent the time between samples (0.0002083333 s). This compensation is done prior to dowsampling and/or after upsampling.

The instantaneous phase current that is sent to the remote end is calculated as:

$$iph_comp = iph - iphcap$$

Where:

- *iph_comp* is the compensated current.
- *iph* is the measured phase current.

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Capacitive current compensation on the local device will be disabled under the following conditions:

- The ***Capacitive Curr. Compensation*** enable setting is set to NO.
- The capacitive current compensation enable input is set to NO.
- Some pole of the breaker of the local equipment that performs the compensation is open (in breaker and a half positions the signal of any open pole must be activated in the two breakers associated with the position).
- The fuse failure blocking signal associated with the voltage used for compensation has been activated.

2.1.6.b Transformer Compensation in the Protection Zone

If there is a transformer in the protection zone, the setting ***Transformer in Protection Zone*** (General Settings of the Differential Unit) must be in YES. In that case each of the 3 inputs to the differential unit will be considered a "winding" of the transformer. The following compensations will be included:

- Tap Compensation.
- Connection Group Compensation.
- Zero Sequence Current Compensation (zero sequence filter).

- **Tap Compensation**

All **DLF** equipment must have the same tap compensation information but referring to its primary.

If only two windings are connected (winding 1 and winding 2, winding 1 and winding 3, or winding 2 and winding 3), the secondary values of the rated current of each winding can be different. The CTs transformation ratios may not compensate exactly the power transformer ratio. This difference will result in a differential current. To eliminate such difference, the differential unit adds the "per unit" currents, dividing each current by the corresponding base current or tap. The tap corresponding to the current input n (n = 1 ... 3) will be calculated as follows:

$$tn = \frac{S}{\sqrt{3} \cdot Vn \cdot r_{CTn}} \quad (1)$$

Where **S** is the power of the transformer, **Vn** the voltage associated to the current input n and **RCTn** the current input's transformation ratio.

The following settings will be considered in the tap calculation:

- ***Maximum Power of the Transformer***.
- ***Phase-Phase Voltage of Current Input n***, n = 1 ... 3.
- ***Transformation Ratio of Current Input n*** (n = 1 ... 3). This setting will be entered in the analog inputs and units configuration module.

The ***Tap Values*** setting includes **the Auto / Manual** options. The **Automatic** value calculates the tap with the formula (1). The **Manual** value requires that the tap value is entered manually in the ***Tap n*** setting (n = 1 ... 3)

Note: in formula (1) the same power value must be used to calculate the tap of all windings. This power value will always be the maximum power of the transformer.

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- **Connection Group Compensation**

The connection group of the machine to be protected introduces a set of changes (angular phase shifts and amplitude multipliers) that prevent a direct comparison of the phase to phase currents, associated with the different windings. The simple sum of these currents generates a high differential current without internal faults. For this reason, it is necessary to include a compensation element in the device, whose transfer function is adjusted according to the connection group and which compensates for the deviations introduced. All **DLF** equipment must have the same connection group compensation information but referring to the local primary.

This element makes eliminates the need to use intermediate transformers to perform the compensation.

Figure 2.1.4 shows the winding currents of a Yd11 transformer. The line currents of the second winding, on the delta side, are delayed by 30 ° with respect to the line currents of the first winding. If both currents are added, once the polarity reversal is applied to the second winding currents generated by the CTs, the differential current would not be zero.

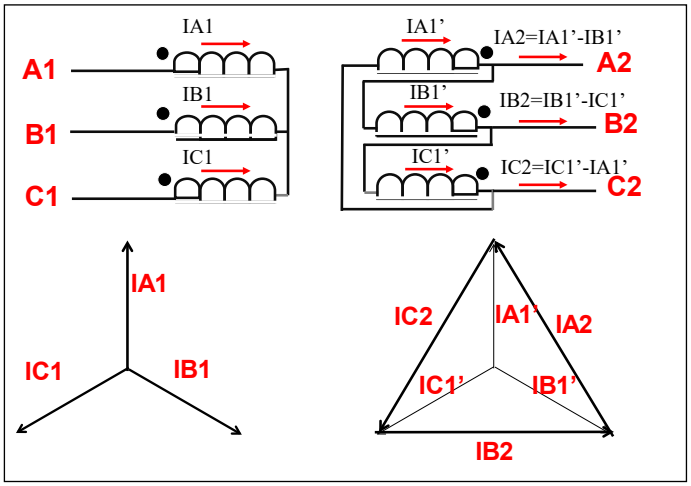


Figure 2.1.4 Yd11 Transformation.

To correct the phase currents of the second winding, it is necessary to multiply them by a transformation matrix.

Since the magnetomotive forces in each phase are equal, it is possible to infer the following relation between the currents of the second and the first winding:

$$IA2 = (IA1 - IB1) \cdot \frac{N1}{N2}$$

$$IB2 = (IB1 - IC1) \cdot \frac{N1}{N2}$$

$$IC2 = (IC1 - IA1) \cdot \frac{N1}{N2}$$

Where N1 and N2 are the number of primary and secondary turns, respectively.

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Expressed in matrix form:

$$\begin{pmatrix} IA2 \\ IB2 \\ IC2 \end{pmatrix} = \begin{pmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} IA1 \\ IB1 \\ IC1 \end{pmatrix} \cdot \frac{1}{\sqrt{3}} \cdot RT$$

Where:

$$RT = \frac{V1_{PH-PH}}{V2_{PH-PH}} = \frac{\sqrt{3} \cdot N1}{N2}$$

The following equation can be obtained from the previous expression:

$$\begin{pmatrix} IA1 \\ IB1 \\ IC1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix} \cdot \begin{pmatrix} IA2 \\ IB2 \\ IC2 \end{pmatrix} \cdot \frac{1}{\sqrt{3}} \cdot \frac{1}{RT}$$

To correct the currents of the second winding it is necessary to multiply $\begin{pmatrix} IA2 \\ IB2 \\ IC2 \end{pmatrix}$ by the matrix

$$M21 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix}$$

Each connection group has an associated inverse transformation matrix. The **DLF** memory stores the inverse transformation matrices for all possible connection groups that may exist between two windings of a machine.

When compensating the effect of the connection group in the **DLF**, the current input 1, I1, is considered the reference current, so that no correction is made on such current. The rest of current inputs, I2 and I3, are multiplied by a matrix that reverses the existing transformation between the reference current (I1) and the corresponding current.

All current inputs have a of ***Connection Type*** setting (Connection Type 1, Connection Type 2 and Connection Type 3). Likewise, currents 2 and 3 include a clock-hour setting with respect to current 1 (clock-hour setting 2 and clock-hour setting 3). By means of these settings, the device determines the inverse transformation matrices M21 and M31 to be applied to the currents I2 and I3, respectively.

- **Zero Sequence Filter**

The positive and negative sequence currents are transformed correctly from one winding to another, regardless of the connection group that exists between them. The transformation of the zero sequence currents, however, does depend on the phase displacement. Some connections allow the flux of zero sequence current in one of the windings, and other connections do not. Such connections are wye-delta, wye-zig-zag, or delta-zig-zag.

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The difference on zero sequence current flux between windings generates zero sequence differential current that will translate in a phase differential current. To eliminate this differential current, it is necessary to eliminate the zero-sequence current of the winding / s in which the circulation is allowed.

Figure 2.1.5 shows a ground fault on the wye side of a Dyn transformer. The zero-sequence current will flux in the line CTs of the wye-connected winding but will not flux in the line CTs of the delta-connected winding. The current at the output of a delta winding, equal to the subtraction of two of the internal phase currents, will be zero if said internal currents are equal (zero sequence currents). Therefore, in the delta winding there will be zero sequence current within it (which will maintain the balance of m.m.f) but not outside it. To avoid the generation of differential current it is necessary to eliminate the zero-sequence current of the wye winding.

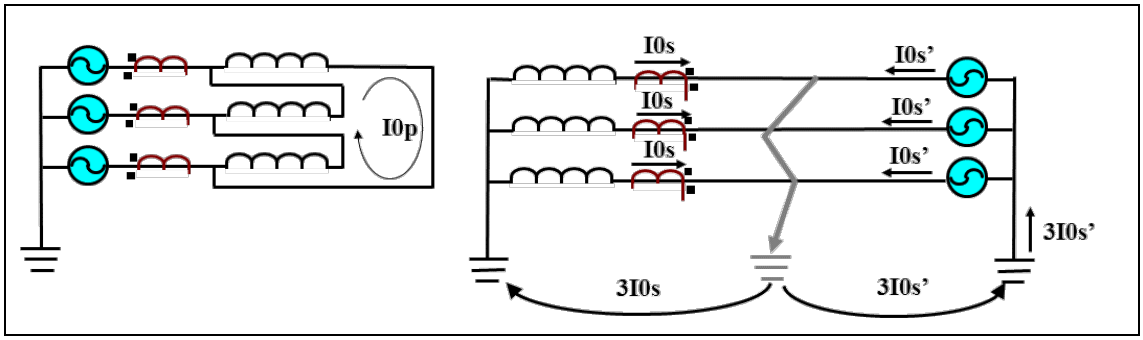


Figure 2.1.5 Dyn Transformer with Ground Fault on the Wye Winding.

The **DLF** includes a setting called ***Zero Sequence Filter*** for each of the current inputs (or windings) to the differential function. If this setting is set to YES, the phase current of the corresponding winding will be subtracted from the zero-sequence current fluxing through it.

Note: for exclusive line protection, the activation of the zero sequence filter is not recommended as it prevents the correct execution of the neutral differential. If a zero sequence filter is enabled, then the neutral differential unit will be blocked.

Figure 2.1.6 shows a Dyn transformer that includes a zig-zag earthing transformer on the delta side, within the protection zone bounded by the line CTs. If a ground fault occurs on the delta side, because of the grounding transformer, zero sequence current will flux through the line CTs. However, zero sequence current will not circulate in the CTs of the wye winding. Therefore, it is necessary to apply the zero-sequence filter to the wye winding (since ground faults in said winding will generate zero-sequence current without zero sequence current in the line CTs of the delta winding), and it is also necessary to apply the zero-sequence filter in the delta winding.

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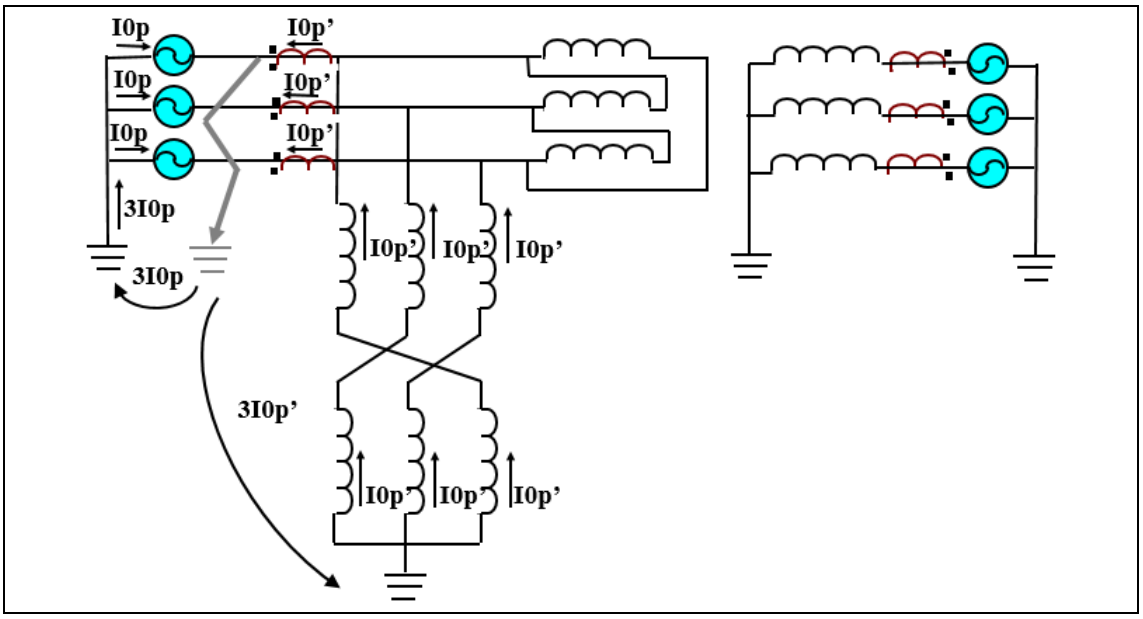


Figure 2.1.6 Dyn Transformer with Earthing Transformer and Fault on the Delta Winding.

When the connection group is wye-zig-zag or delta-zig-zag it is necessary to enable the zero-sequence filter on the side of the zig-zag, since both the side of the wye and the side of the delta cannot circulate the zero-sequence current. Figure 2.1.7 shows a Yz11 transformer.

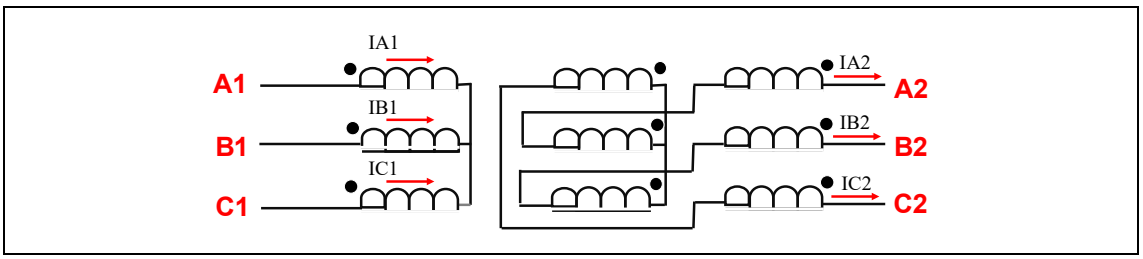


Figure 2.1.7 Yz11 Transformer.

Considering the equality of magnetomotive forces, each phase will display the following:

$$N1 \cdot IA1 = \frac{N2}{2} \cdot IA2 - \frac{N2}{2} \cdot IC2$$

$$N1 \cdot IB1 = \frac{N2}{2} \cdot IB2 - \frac{N2}{2} \cdot IA2$$

$$N1 \cdot IC1 = \frac{N2}{2} \cdot IC2 - \frac{N2}{2} \cdot IB2$$

$$RT = \frac{V1_{PH-PH}}{V2_{PH-PH}} = \frac{2}{\sqrt{3}} \cdot \frac{N1}{N2}$$

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In matrix form the following equation will be fulfilled:

$$\begin{pmatrix} IA1 \\ IB1 \\ IC1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & -1 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix} \cdot \begin{pmatrix} IA2 \\ IB2 \\ IC2 \end{pmatrix} \cdot \frac{1}{\sqrt{3}} \cdot \frac{1}{RT}$$

As can be seen, the transformation matrix from the zig-zag winding to the wye winding (M21) is like that between a wye winding and a delta winding. It can be deduced that no zero-sequence current can circulate in the wye winding, hence it's necessary the application of the zero-sequence filter in said winding.

Figure 2.1.8 shows a transformer with connection group Dz0.

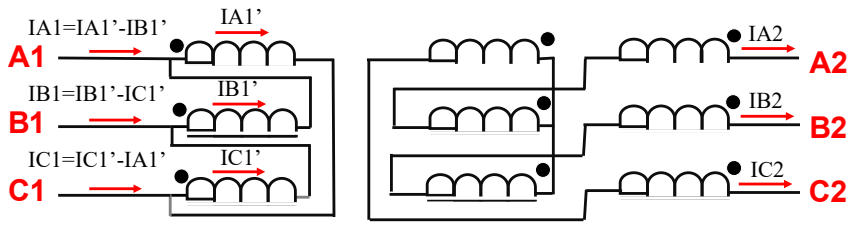


Figure 2.1.8 Dz0 Transformer.

Applying the equality of magnetomotive forces, each phase will display the following:

$$N1 \cdot IA1 = N2 \cdot IA2 - \frac{N2}{2} \cdot IB2 - \frac{N2}{2} \cdot IC2$$

$$N1 \cdot IB1 = -\frac{N2}{2} \cdot IA2 + N2 \cdot IB2 - \frac{N2}{2} \cdot IC2$$

$$N1 \cdot IC1 = -\frac{N2}{2} \cdot IA2 - \frac{N2}{2} \cdot IB2 + N2 \cdot IC2$$

The relationship between the windings 1 and 2 currents in matrix form will be:

$$\begin{pmatrix} IA1 \\ IB1 \\ IC1 \end{pmatrix} = \begin{pmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{pmatrix} \cdot \begin{pmatrix} IA2 \\ IB2 \\ IC2 \end{pmatrix} \cdot \frac{1}{3} \cdot \frac{1}{RT},$$

where

$$RT = \frac{V1_{PH-PH}}{V2_{PH-PH}} = \frac{2}{3} \cdot \frac{N1}{N2}$$

As can be seen, no zero-sequence current can flux in the line CTs of the delta winding, given that IA1 + IB1 + IC1 = 0. For this reason, it is necessary to apply the zero-sequence filter in the zig-zag winding.

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In a three-leg YY transformer, when an external ground fault occurs, a zero-sequence flux will be generated without a low-reluctance return path, as in the case of 4/5 leg transformers, armored transformers or transformers with single-phase banks. In that case the flux must return through the air, the transformer tank or other elements of high reluctance, which generates a relatively small zero sequence magnetization reactance. Said reactance, which is in derivation in the equivalent circuit of zero sequence of the transformer, will give rise to a differential current of zero sequence that could trip the differential unit. To eliminate this differential current, it is necessary to enable the zero-sequence filter in the two wye windings.

It should be noted that when the winding on which it is necessary to apply the zero-sequence filter is not the winding 1, the correction matrix of the connection group itself is already a zero-sequence filter. For example, in a Dy11 transformer, the transformation matrix that is applied over the currents of the wye winding is a wye-delta transformation matrix that already eliminates the zero-sequence current. In that case it would not be necessary to enable the zero-sequence filter in the wye winding. In any case, enabling the filter does not have any negative consequences. All transformation matrices yd, zy, zd act as a zero-sequence filter.

If the zero-sequence filter must be applied on the winding 1 (for example if the transformer has a connection group Yd11), since the currents of said winding are not corrected with any transformation matrix, it is necessary to enable the filter in that winding. In the case of YY transformers with three legs, it is necessary, as mentioned before, to enable the zero-sequence filter in both windings.

The zero sequence current is calculated from the phase currents measured in the applicable winding. This option implies a reduction of the differential current on internal ground faults. In order to reduce the loss of sensitivity that this reduction of the differential current implies, **DLF** relays also subtract the zero sequence current in the restraint current. The application of the zero sequence filter from phase currents can cause, on the other hand, the operation of the differential current elements associated to the healthy phases on single phase faults. In order to correctly ascertain the type of fault, **DLF** relays include a Phase Selector separate from the Phase Differential elements. When the zero sequence filter is applied from phase currents, the phase directional comparison element can use a type **2 of 3** cross-blocking logic, which implies increased safety on external faults with severe saturation of a CT.

It is worth mentioning that in an autotransformer the ground current contains the ground current of both primary and secondary windings. Taking into account that the zero sequence current to be subtracted from each winding must be divided by its tapping (secondary rated current of that winding) the exact fraction of the ground current corresponding to each winding must be known. Since this current distribution is not known, the zero sequence filter cannot be applied with the ground current of an autotransformer.

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2.1.6.c Compensated Currents

The differential units calculate the compensated currents by applying the zero sequence filter, the correction of the connection group and/or the tap compensation according to whether there is a transformer in the protection zone or not. These calculations are carried out for each of the phase currents from sample to sample.

2.1.6.d Without Transformer in the Protection Zone

When there is no transformer in the protection zone, the differential unit will continue to operate with currents in per unit, dividing each current by its tap. In this case, the adjusted power will be the nominal power of the line and the phase-phase voltages associated to each current input to the differential unit will all be adjusted with the same value. The tap will be calculated automatically or manually, depending on the ***Type of Tap*** setting.

Phase Differential

$$Ia1_{COMP} = \frac{ia1_87L}{t1} \qquad Ia2_{COMP} = \frac{ia2_87L}{t1} \qquad Ia3_{COMP} = \frac{ia3_87L}{t3}$$

$$Ib1_{COMP} = \frac{ib1_87L}{t1} \qquad Ib2_{COMP} = \frac{ib2_87L}{t1} \qquad Ib3_{COMP} = \frac{ib3_87L}{t3}$$

$$Ic1_{COMP} = \frac{ic1_87L}{t1} \qquad Ic2_{COMP} = \frac{ic2_87L}{t1} \qquad Ic3_{COMP} = \frac{ic3_87L}{t3}$$

Neutral Differential

$$In1_{COMP} = Ia1_{COMP} + Ib1_{COMP} + Ic1_{COMP}$$
$$In2_{COMP} = Ia2_{COMP} + Ib2_{COMP} + Ic2_{COMP}$$
$$In3_{COMP} = Ia3_{COMP} + Ib3_{COMP} + Ic3_{COMP}$$

Positive Sequence Differential

$$Ips1_{COMP} = \frac{Ia1_{COMP} + Ib1_{COMP} \cdot a + Ic1_{COMP} \cdot a^2}{3}$$

$$Ips2_{COMP} = \frac{Ia2_{COMP} + Ib2_{COMP} \cdot a + Ic2_{COMP} \cdot a^2}{3}$$

$$Ips3_{COMP} = \frac{Ia3_{COMP} + Ib3_{COMP} \cdot a + Ic3_{COMP} \cdot a^2}{3}$$

Negative Sequence Differential

$$Ins1_{COMP} = \frac{Ia1_{COMP} + Ib1_{COMP} \cdot a^2 + Ic1_{COMP} \cdot a}{3}$$

$$Ins2_{COMP} = \frac{Ia2_{COMP} + Ib2_{COMP} \cdot a^2 + Ic2_{COMP} \cdot a}{3}$$

$$Ins3_{COMP} = \frac{Ia3_{COMP} + Ib3_{COMP} \cdot a^2 + Ic3_{COMP} \cdot a}{3}$$

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2.1.6.e With Transformer in the Protection Zone

The application of the zero-sequence filter (except for the neutral differential unit), the correction of the connection group and the compensation of the tap are carried out vectorially for each of the phase, neutral, positive sequence and negative sequence currents, sample to sample:

Zero Sequence Filter

$$i01 = \frac{Ia1_87L + Ib1_87L + Ic1_87L}{3}$$
$$i02 = \frac{Ia2_87L + Ib2_87L + Ic2_87L}{3}$$
$$i03 = \frac{Ia3_87L + Ib3_87L + Ic3_87L}{3}$$

Phase Differential

$$Ia1_{COMP} = \frac{(ia1_87L - i01)}{t1}$$
$$Ib1_{COMP} = \frac{(ib1_87L - i01)}{t1}$$
$$Ic1_{COMP} = \frac{(ic1_87L - i01)}{t1}$$

$$Ia2_{COMP} = \frac{(ia2_87L - i02)*M21_{11} + (ib2_87L - i02)*M21_{12} + (ic2_87L - i02)*M21_{13}}{t2}$$
$$Ib2_{COMP} = \frac{(ia2_87L - i02)*M21_{21} + (ib2_87L - i02)*M21_{22} + (ic2_87L - i02)*M21_{23}}{t2}$$
$$Ic2_{COMP} = \frac{(ia2_87L - i02)*M21_{31} + (ib2_87L - i02)*M21_{32} + (ic2_87L - i02)*M21_{33}}{t2}$$

$$Ia3_{COMP} = \frac{(ia3_87L - i03)*M31_{11} + (ib3_87L - i03)*M31_{12} + (ic3_87L - i03)*M31_{13}}{t3}$$
$$Ib3_{COMP} = \frac{(ia3_87L - i03)*M31_{21} + (ib3_87L - i03)*M31_{22} + (ic3_87L - i03)*M31_{23}}{t3}$$
$$Ic3_{COMP} = \frac{(ia3_87L - i03)*M31_{31} + (ib3_87L - i03)*M31_{32} + (ic3_87L - i03)*M31_{33}}{t3}$$

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Neutral Differential

$$In1_{COMP} = Ia1_{COMP} + Ib1_{COMP} + Ic1_{COMP}$$
$$In2_{COMP} = Ia2_{COMP} + Ib2_{COMP} + Ic2_{COMP}$$
$$In3_{COMP} = Ia3_{COMP} + Ib3_{COMP} + Ic3_{COMP}$$

The compensated phase currents, used in the calculation of the neutral compensated current, must not be influenced by the zero sequence filter. This filter must always be disabled in order to be able to use the neutral differential unit, since applying this compensation would generate a false neutral differential.

Positive Sequence Differential

$$Ips1_{COMP} = \frac{Ia1_{COMP} + Ib1_{COMP} \cdot a + Ic1_{COMP} \cdot a^2}{3}$$
$$Ips2_{COMP} = \frac{Ia2_{COMP} + Ib2_{COMP} \cdot a + Ic2_{COMP} \cdot a^2}{3}$$
$$Ips3_{COMP} = \frac{Ia3_{COMP} + Ib3_{COMP} \cdot a + Ic3_{COMP} \cdot a^2}{3}$$

Negative Sequence Differential

$$Ins1_{COMP} = \frac{Ia1_{COMP} + Ib1_{COMP} \cdot a^2 + Ic1_{COMP} \cdot a}{3}$$
$$Ins2_{COMP} = \frac{Ia2_{COMP} + Ib2_{COMP} \cdot a^2 + Ic2_{COMP} \cdot a}{3}$$
$$Ins3_{COMP} = \frac{Ia3_{COMP} + Ib3_{COMP} \cdot a^2 + Ic3_{COMP} \cdot a}{3}$$

Where:

MX1nm (X = 1, 2, ..., 3, n = 1, ..., 3, m = 1, ..., 3) represents the element of row n and column m of the transformation matrix of winding X to winding 1

i0X (X = 1, 2, ..., 3) represents the zero-sequence current associated with winding X.

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2.1.7 Phase Differential Units

DLF units incorporate two phase differential units, one with percentage restraint characteristic and with restraint and/or harmonic blocking, and another without any type of restraint / blocking. Both differential units have up to three three-phase input currents, allowing lines of up to three ends.

2.1.7.a Differential Current

The differential current is calculated as the algebraic sum of the instantaneous values of all the compensated currents of the same phase:

$$iadif = ia1_{COMP} + ia2_{COMP} + ia3_{COMP}$$

$$ibdif = ib1_{COMP} + ib2_{COMP} + ib3_{COMP}$$

$$icdif = ic1_{COMP} + ic2_{COMP} + ic3_{COMP}$$

Once the differential current waveforms are obtained, its fundamental component is calculated, obtaining IADIF, IBDIF, ICDIF. Likewise, the 2nd, 3rd, 4th and 5th harmonic components are calculated to be used by the harmonic restraint / blocking units.

2.1.7.b Restraint Current

The restraint current represents the total current that fluxes through all the CTs that delimit the protection zone. The percentage restraint characteristic increases the differential current necessary to operate when the restraint current increases. In this way, the percentage errors produced by the CTs, the relay itself, the tap changer, and other sources are compensated.

To obtain the restraint current, the DLF previously calculates the "true RMS" current of all compensated currents, obtaining IA1COMP_RMS, IB1COMP_RMS, IC1COMP_RMS, ..., IA3COMP_RMS, IB3COMP_RMS, IC3COMP_RMS.

The ***Restraint Type*** setting allows the user to select the formula used to calculate the restraint current:

- **Restraint Current = (I1+I2-Id)/2**

$$IAREST = \frac{IA1COMP_RMS + IA2COMP_RMS + IA3COMP_RMS - IADIF}{2}$$

$$IBREST = \frac{IB1COMP_RMS + IB2COMP_RMS + IB3COMP_RMS - IBDIF}{2}$$

$$ICREST = \frac{IC1COMP_RMS + IC2COMP_RMS + IC3COMP_RMS - ICDIF}{2}$$

- **Restraint Current = (I1+I2)/2**

$$IAREST = \frac{IA1COMP_RMS + IA2COMP_RMS + IA3COMP_RMS}{2}$$

$$IBREST = \frac{IB1COMP_RMS + IB2COMP_RMS + IB3COMP_RMS}{2}$$

$$ICREST = \frac{IC1COMP_RMS + IC2COMP_RMS + IC3COMP_RMS}{2}$$

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The first restraint current formula offers greater obedience, given that the value of restraint current is lower during internal faults with a high differential current. On the other hand, it presents lower security during external faults with CT saturation, since the differential current generated by this condition reduces the restraint current. In any case, to ensure security during external faults with CT saturation, the External Fault Detector is used, so the use of the first restraint current formula is recommended.

2.1.7.c Display of Currents Calculated by the Differential Unit

Within the ***General*** settings menu, the **DLF** includes a setting called ***Differential Current Measurement*** that has two values:

- **Times tap**: in this case both the differential and restraint currents are displayed in "per unit".
- **Reference tap**: in this case the calculated value of the differential and restraint currents in per unit is multiplied by the reference winding tap. In that case both currents are represented in Amperes.

It should be noted that the differential unit is always set and operates with per unit values. The ***Differential Current Measurement*** setting only affects the display of the differential and restraint currents.

2.1.7.d Reference Current

The **DLF** has a setting, called ***Reference Current*** (within the group of the differential unit protection settings), which allows displaying the differential and restraint currents on the HMI display, in the status screen of ***ZIV eNET tool***®, and collecting them by communications, multiplied by the selected tap setting (if the ***Differential Current Measurement*** setting is set as **Reference Tap**, within the ***General*** settings group).

This setting effects only the display and in no case does it affect internal calculations of the Differential unit.

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2.1.7.e Percentage Restraint Characteristic

The differential unit includes a percentage restraint characteristic as shown in Figure 2.1.9. The x-axis is the restraint, passing or restricting current (Irest) and the y-axis is the differential current (Idiff). The feature includes two restraint slopes.

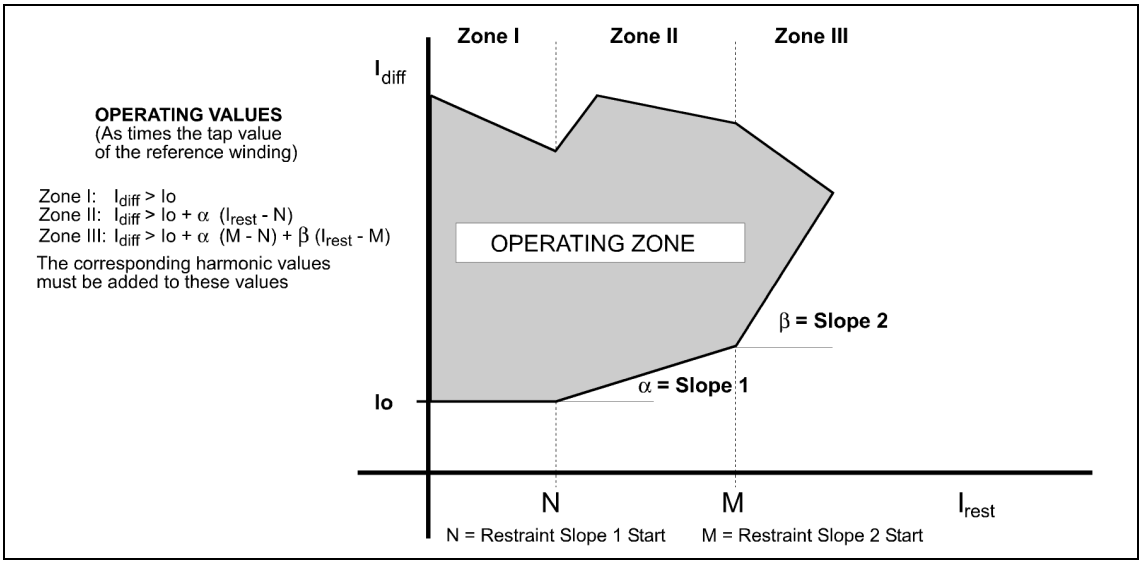


Figure 2.1.9 Operating Characteristic of the Percentage Restraint Differential Unit.

For higher restraint currents the imbalances are larger, and a greater amount of differential current is needed to operate the unit. Slope 1 is usually used to compensate for the following errors:

- Measurement errors of the current transformers in the linear zone of their magnetization characteristic (without reaching the saturation elbow).
- Errors due to the variation of the output voltage of a winding because of the operation of the tap changer. Point 2.1.5.a shows that the calculation of the taps for each winding depends on the corresponding winding voltage. If this voltage varies, the tap setting will not correspond to the actual tap existing at that moment, which will cause a differential current. The voltage that is used for the calculation of a winding tap usually corresponds to the voltage value at the center tap.
- Measurement errors of the relay itself.

Slope 2 provides security against current transformer saturation due to severe external faults.

The multiplication coefficients α and β, defined between the pass-through current values **N** and **M** and from **M** onwards, are adjustable and are called ***Percentage Restraint Coefficients*** (**Slope 1** and **Slope 2**).

The parameter **Io** is the **Differential Sensitivity** of the unit. Io defines the minimum differential current value necessary to operate the unit. It is set to compensate for absolute errors of differential current, such as the magnetization current of the transformer under normal conditions.

Sensitivity values and start values of first and second slope are always set in per unit (or times the reference tap).

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2.1.7.f Energization and Over-Excitation of a Transformer

The energization and overexcitation of a power transformer produce a saturation in the transformer that results in very high magnetization currents. Figure 2.1.10 shows the equivalent circuit of a power transformer. Xp 'and Rp' represent the reactance and resistance of the primary winding referred both to the secondary winding; Xs and Rs represent the reactance and resistance of the secondary winding; Xm represents the magnetization reactance. As it is shown, the magnetization current (im) is pure differential current.

To avoid the operation of the differential unit during both events, the harmonic restraint and blocking units described below are used.

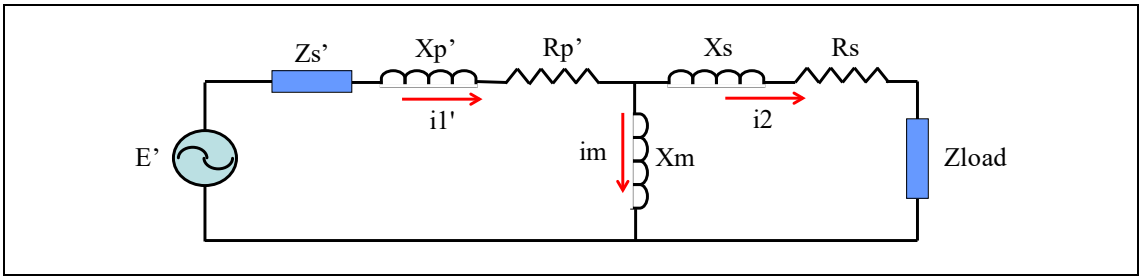


Figure 2.1.10 Equivalent Circuit of a Power Transformer.

- **Energizing Current**

A transformer saturates during energizing by the DC transient components originating in the flux, which can cause the increase of the total fluxes. These components are produced to compensate for abrupt variations of the core flux, because of variations in the supply voltage to the machine. The presence of residual fluxes can aggravate the saturation level of the transformer, by increasing the difference between the initial flux and the core flux. Energizing currents can occur under the following conditions:

- **Energizing of the transformer**: when a transformer is de-energized it has a residual flux. On the moment when voltage is applied, a core flux will occur which does not have to coincide with the residual flux. The difference between the two fluxes generates a DC flux that can saturate the transformer. The DC flux is damped because of the voltage drop generated by the energizing current in the source resistance of the system. The saturation of the power transformer usually lasts several cycles.
- **Clearance of an external fault**: the change of voltage in the clearance of an external fault gives rise to a phenomenon like that of the energizing of the transformer.
- **Energization of a parallel transformer**: when energizing a transformer connected in parallel to an already energized transformer, an energizing current is produced in the first transformer. The voltage drop generated by this current in the system resistance (source resistance plus transformer resistance) not only dampens the DC component of the transformer flux that is energized but also introduces a DC component into the flux of the already energized transformer, reaching saturation. This phenomenon gives rise to magnetization currents with very high damping constants.

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Figure 2.1.11 shows an example of the energizing current:

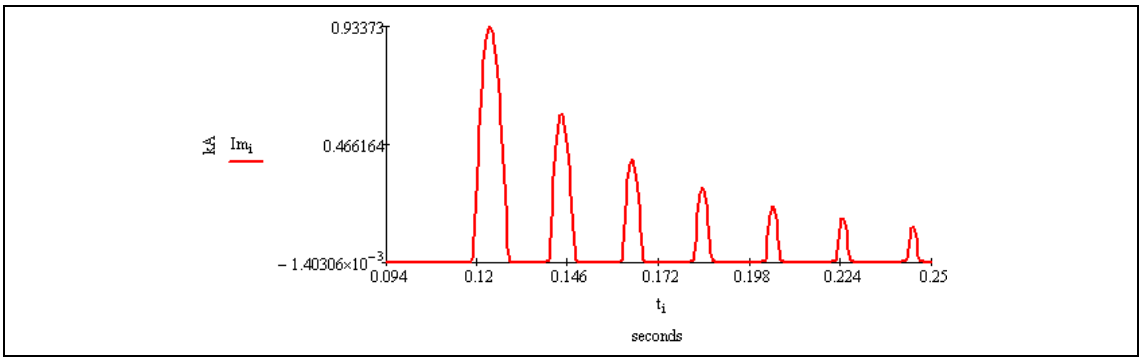


Figure 2.1.11 Example of the energizing current.

The energizing currents present a high content in even harmonics, mainly second and fourth.

- **Overexcitation Current**

Overexcitation of a transformer occurs when the Voltage / Frequency ratio is high, in conditions of overvoltage and / or underfrequency. In such conditions, a saturation of the power transformer occurs due to the existence of a symmetrical core flux.

Figure 2.1.12 shows an example of the overexcitation Currents:

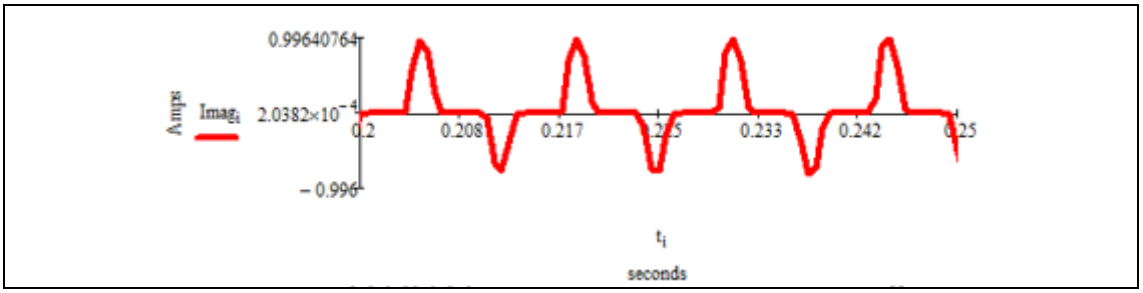


Figure 2.1.12 Example of Overexcitation Currents.

Overexcitation currents have a high content of odd harmonics, mainly third and fifth.

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2.1.7.g Harmonic Restraint

To avoid differential unit trips during energizing and overexcitation events, harmonic restraint desensitizes the differential unit under large differential current harmonic content. The characteristic shown in Figure 2.1.13 is used for this purpose.

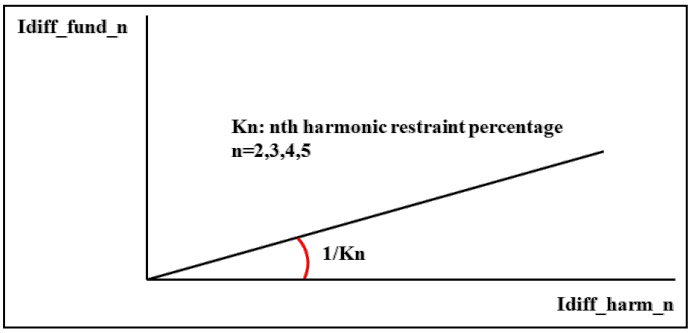


Figure 2.1.13 Harmonic Restraint Characteristic.

There is a characteristic for each harmonic component of the differential current: 2nd, 3rd, 4th and 5th. Each value of the harmonic component (*Idiff_harm_n*; n = 2..5 – x-axis), with the corresponding slope setting (***Percentage of Harmonic Restraint n***: αn = 1 / Kn, n = 2 ... 5), has a fundamental differential current value (*Idiff_fund_n*; n = 2 ... 5 – y-axis) that will be added to the differential current value obtained from the percentage restraint characteristic. The effect produced by the harmonic restraint is a rise in the differential characteristic.

It should be noted that the slope of the harmonic restraint characteristic is the inverse of the setting: αn = 1 / Kn. In this way, if the percentage of harmonic restraint selected is 20%, the slope of the characteristic will be 500%. The smaller the percentage of harmonic restraint, the greater the restraint slope. This implementation allows to relate the percentage of restraint with the harmonic content of the differential current waveform.

The four calculated fundamental currents (*Idiff_harm_n*, n = 2, ..., 5) are added to obtain a total fundamental differential current (*Idiff_fund_total*). This last current is being the one that will be added to the differential current obtained from the percentage restraint characteristic (see Figure 2.1.14).

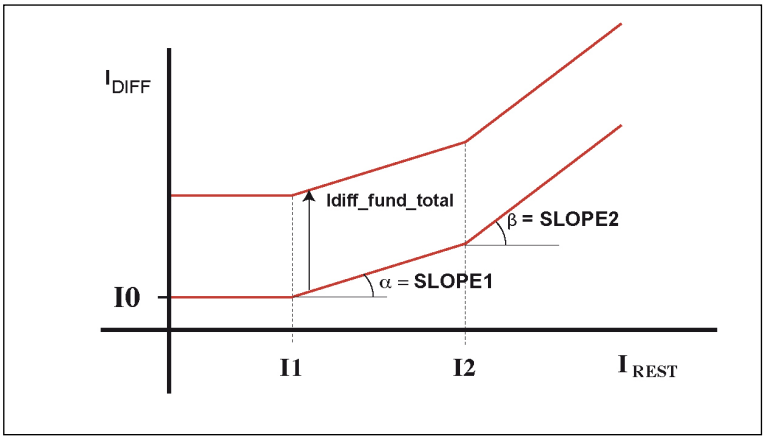


Figure 2.1.14 Rise of the Differential Percentage Restraint Characteristic because of Harmonic Restraint.

$$I_{diff_fund} > \underset{\substack{diff\\through\\current\\restraint}}{I_{diff}} + \underset{\substack{diff\\harmonic\\restraint}}{I_{diff}} = I_{rest} \cdot f(\alpha,\beta) + \sum_{n=2}^{5} \frac{I_{diff_harm_n}}{Kn} \qquad (2)$$

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In order to increase the safety offered by harmonic restraint in cases of energization where some of the phases do not reach a sufficient level of harmonic percentage to prevent tripping of the differential unit, the device has an **Extended Harmonic Restraint** algorithm that applies a safety coefficient on the phases that do not reach the harmonic level to restrain tripping. This algorithm is only applied if the harmonic percentage of any of the phases restrains the trip.

The **Extended Harmonic Restraint** algorithm, in detail, operates as follows:

(2.1) First, it evaluates the harmonic content in each phase and checks whether the differential current exceeds the sensitivity:

- If [IdifA_harm_2 + IdifA_harm_3 + IdifA_harm_4 + IdifA_harm_5] / Min (K2, K3, K4, K5) > IdifA_fund and, at the same time, IdifA_fund > Differential ***Sensitivity*** setting.
- If [IdifB_harm_2 + IdifB_harm_3 + IdifB_harm_4 + IdifB_harm_5] / Min (K2, K3, K4, K5) > IdifB_fund and, at the same time, IdifB_fund > Differential ***Sensitivity*** setting.
- If [IdifC_harm_2 + IdifC_harm_3 + IdifC_harm_4 + IdifC_harm_5] / Min (K2, K3, K4, K5) > IdifC_fund and, at the same time, IdifC_fund > Differential ***Sensitivity*** setting.

If the conditions (2.1) are fulfilled in all 3 phases, the **Harmonic Restraint** operates in all 3 phases, i.e., for tripping to occur in one phase, equation (2) must be fulfilled:

$$I_{diff_fund} > \underset{\substack{through\\ current\\ restraint}}{I_{diff}} + \underset{\substack{harmonic\\ restraint}}{I_{diff}} = I_{rest} \cdot f(\alpha,\beta) + \sum_{n=2}^{5} \frac{I_{diff_harm_n}}{Kn}$$

The same would apply for the rest of the phases.

If the conditions (2.1) are not fulfilled in any of the phases, the **Harmonic Restraint** operates in all 3 phases. Same as the previous point.

But if the conditions (2.1) are met in any of the phases, those phases will operate with the **Harmonic Restraint** (according to equation 2), but the rest of the phases will operate with the **Extended Harmonic Restraint** according to the following equation:

Differential trip on Phase X will occur:

- If IdifX_fund > Irest * f(α, β) + 3 * [IdifX_harm_2 + IdifX_harm_3 + IdifX_harm_4 + IdifX_harm_5] / Max (K2, K3, K4, K5).

While this algorithm increases safety during transformer energization, it should be noted that, in lockout situation on internal fault with saturation, the harmonic percentage of the faulted phase must not exceed the adjusted harmonic percentage divided by the safety coefficient applied by the **Extended Harmonic Restraint**. If it is exceeded, the trip will be blocked, so the user should enable the **Cross Harmonic Blocking** logic instead of **Harmonic Restraint**).

There are four settings that activate or deactivate the restraint by 2nd, 3rd, 4th and 5th harmonic. Obviously, the algorithms only work with the harmonics that are enabled.

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2.1.7.h Harmonic Blocking

The harmonic blocking unit calculates the relationship between the harmonic differential current n (n = 2 and 5) and the fundamental differential current. When this ratio is above the set value, the harmonic blocking n is activated.

$$\frac{I_{diff_harm_n}}{I_{diff_fund}} > Kn \text{ (n=2 and 5)}$$

The operating condition of the differential unit with harmonic blocking will be:

$$\left(I_{diff_fund} > I_{\substack{diff \\ through \\ current \\ restraint}} = I_{rest} \cdot f(\alpha, \beta) \right) \otimes \left(\frac{I_{diff_harm_n}}{I_{diff_fund}} < Kn \right) \quad (3)$$

There are two independent settings that enable or disable blocking by 2nd and 5th harmonics, as well as two other percentage adjustments of 2nd and 5th harmonics that must be exceeded to activate the blocking.

Blocking activation occurs at 1 time setting and reset at 0.95 times the setting.

2.1.7.i Comparison between Harmonic Restraint and Harmonic Blocking

Equation (3) can be expressed as:

$$\left(I_{diff_fund} > I_{rest} \cdot f(\alpha, \beta) \right) \otimes \left(I_{diff_fund} > \frac{I_{diff_harm_n}}{Kn} \right) \quad (4)$$

Comparing equation (4) with equation (2), the latter corresponding to harmonic restraint, we can conclude that harmonic restraint is more restrictive. However, harmonic restraint does not allow to apply cross-blocking logic as shown in the next point. These logics are only associated with the harmonic blocking.

2.1.7.j Cross Blocking

The energization of relatively new power transformers can produce, in some of the three phases, magnetization currents with a low second harmonic component, less than 10%. The percentage restraint and harmonic blocking settings normally used are around 20%. Reducing these settings to values below 10% could compromise the obedience of the differential unit since any small distortion of the differential current in the event of an internal fault could activate the harmonic restraint / blocking. To maintain security, the percentage of restraint / blocking in normal values, of the order of 20%, is maintained and the cross-blocking logic is used. These logics desensitize the differential unit of the phase with low second harmonic component when the other phases show a high harmonic component. Under normal circumstances during energizing there is usually only one phase with a low second harmonic component.

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The **DLF** includes a setting called ***Cross-Blocking Type*** that selects the cross-blocking logic to apply. There are several options:

- **1 of 3**: If the differential current of any phase has harmonic content above the set percentage, the harmonic blocking is activated in the other two phases, independently of the harmonic content of the differential current in those phases. This logic is very secure but could block the operation of the differential unit with internal faults that occur during the energization of the transformer (close onto fault), since the healthy phases can present a high content of second harmonic.
- **2 of 3**: if the differential current of two phases has harmonic content above the set percentage, the harmonic blocking is activated in the other phase, regardless of the harmonic content of its differential current. This logic provides a better balance between security and obedience with respect to the logic "**1 of 3**", since it will never operate during two-phase faults that occur at the time of transformer energization. On the other hand, if the transformer is a wye-delta and is energized by wye side, in a single-phase ground fault that occurs during energization, the fault current will flow through the healthy phases due to the existing delta winding coupling. The same will happen in three-leg wye-wye transformers because of the "phantom tertiary" effect. In that case, there will be a significant increase in the fundamental differential current in the healthy phases, which will prevent compliance with the logic "2 of 3", allowing the differential unit trip.
- **Three-phase sum**: this logic calculates a three-phase differential ratio of the second harmonic with the following formula:

$$3phase_harm_ratio = \left(\frac{I_{diff_harm_A} + I_{diff_harm_B} + I_{diff_harm_C}}{I_{diff_fund_A} + I_{diff_fund_B} + I_{diff_fund_C}} \right)$$

  This last logic provides good security during energizing because the phase / s with high second harmonic content in the differential current increases the value of the three-phase ratio. On the other hand, the logic also provides a good obedience, since during internal faults the fundamental differential current of the missing phase / s will be high, which will reduce the value of the three-phase relationship.

The **DLF** includes a setting called ***Cross-Blocking Time*** that limits the time that the cross-blocking logic is applied. Since the low second harmonic content in the differential current only occurs during the first 4 or 5 cycles after energizing, the duration of the cross-blocking logic can be limited to that time. The time will start counting after the conditions to activate the logic are met.

It should be noted that harmonic blocking prevents the pickup of the restraint differential unit but does not resets the unit after the pickup.

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2.1.7.k Harmonic Restraint and Blocking Inhibit

The harmonic restraint or blocking can delay the tripping of the differential unit in the event of internal faults with saturation in any CT, given the harmonic content that the differential current waveform presents in that case. To avoid unnecessary delays, there is the possibility of applying the restraint or blocking intermittently. For this, it is necessary to set the ***Harmonic Restraint*** and ***Blocking*** settings in **Dynamic** mode.

- **Restraint Blocking by 2nd / 4th Harmonic**

Restraint or blocking by even harmonics will be used under the following conditions:

- The transformer of the protection zone is **de-energized**; this situation is detected when there is no current flowing through any of the ends (the current in all the channels would be below the ***Open Pole Current*** setting corresponding to the channel in question). After detection of the energizing of the transformer (current in some end above the threshold), the ***Inhibit Time by Harmonics*** will initiate to disable the restraint / blocking by 2nd and 4th harmonics. This setting must be greater than the maximum energizing time of the transformer.
- Once the transformer is **energized**, an external fault condition is detected, either by the differential unit with instantaneous values or by the phase or positive sequence directional comparison units. From the deactivation of the external fault condition, harmonic restraint / blocking will remain enabled during the ***Harmonic Inhibit Time***.
- 2.5 cycles after the activation of the fault start during the ***Harmonic Inhibit Time***.

- **Restraint / Blocking by 5th Harmonic**

Restraint / blocking by fifth harmonic will be disabled when three units of sub excitation are active, that is when the voltage / frequency ratio of the phase voltages associated to the differential unit (refer to the section on configuration of analog inputs and units) are below 1.05 times the nominal ratio (Vnominal / Fnominal). If no voltage is configured, then restraint / blocking by 5th harmonic will always be enabled.

If the ***Harmonic Restraint*** and ***Blocking*** is set to **Continuous** mode, the 5th harmonic restraint and blocking will always be enabled.

The input **Change to continuous Restraint and Blocking** activates continuous harmonic restraint and blocking, independently of the setting values.

The 2nd harmonic restraint and blocking inhibit method based on currents does not allow to distinguish energizing when closing onto faults. During the energization of the transformer the harmonic restraint and blocking will always be active.

Since the harmonic restraint and blocking inhibit that uses currents is based on the activation of the external fault detector, when this is disabled the harmonic restraint and blocking will be applied continuously.

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- **Parallel Transformer**

The **DLF** has a ***Parallel Transformer*** setting (within the Restraint Differential unit settings group), which increases the security of the dynamic harmonic restraint and blocking (refer to point 2.1.8.g) against a possible energization of a transformer connected in parallel (*sympathetic inrush*).

Setting to **YES**, the ***Parallel Transformer*** setting will prevent the 2nd and 4th harmonic restraint and blocking inhibit when any of the following conditions are met:

- AND of the external fault by differential unit with instantaneous values of the three phases, during 8 ms, if the zero-sequence filter is enabled. If the zero-sequence filter is disabled, an OR for the external fault would be used by the differential unit with instantaneous values of the three phases.
- AND of the external fault by directional comparison of phases for 1.5 cycles if the zero-sequence filter is enabled. If the zero-sequence filter is disabled, an OR of the external fault would be used by directional comparison of the three phases.
- External fault by positive sequence directional comparison for 1.5 cycles.

Also, the 2nd and 4th harmonic restraint / blocking will remain enabled, if during 2.5 cycles after the activation of the fault start (**FS**) the condition of harmonic restraint / blocking inhibit during the time set as ***Harmonic Inhibit Time*** is not validated. In any case, once this time window has ended (2.5 cycles since the fault start), the inhibit will be deactivated (the corresponding blocking will be activated) and until the ***Harmonic Inhibit Time*** ends, the inhibit cannot be activated even with a new fault start.

2.1.7.l Restraint Differential Unit Output

The restraint differential unit picks up at 100% and resets at 0.8I0 if there is no harmonic restraint. With harmonic restraint, the reset occurs at the higher of the following two values:

- 0.8 * Io
- 0.5 * Iharmonic / Kharmonic

  where this last ratio can be I2nd harmonic / k2, I3rd harmonic / k3, I4th harmonic / k4 or I5th harmonic / k5, where k is the harmonic restraint slope setting.

A time setting is available for time delayed trips if required. The output activation requires the pickup to remain active for the complete length of the timer. Any reset brings the logic to its initial conditions, so that a new activation initiates the timer from zero.

A **Trip Blocking** input is available, preventing the unit from tripping if the input is active before the trip command is generated. If the blocking is activated after the trip, it resets the trip. To use this blocking logic, the input **Restraint Differential Unit Trip Blocking** must be programmed.

The activation of the external fault detector can block the unit if the setting ***External Fault Detector Block Enable*** is set to **YES**.

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2.1.7.m Close-Onto-Fault Sensitivity

When a fault close-onto-fault occurs and it is not configured or there is no possibility to perform capacitive current compensation, it is possible that the calculated differential current is significant due to the exponential character of the capacitive current. To prevent the unit from operating improperly, in addition to the differential ***Sensitivity*** setting, an additional sensitivity called ***Sensitivity COF*** can be adjusted. This sensitivity value will only be applied when the corresponding unit detects a breaker closing (based on the open pole detector, the dead line detector and the manual closing and reclosing inputs) during the time defined in ***COF Time*** setting. After this time has elapsed, the reference sensitivity for the phase differential unit will return to that defined by the Differential ***Sensitivity*** setting.

2.1.7.n Unrestrained Differential Unit

The unrestrained differential unit is used to clear severe internal faults that saturate the CTs. Due to the harmonic content present in the differential current during this type of faults, the harmonic restraint and blocking could operate, delaying or even blocking the trip. The unrestrained differential unit is not affected by the harmonic blocking or restraint. It also does not include any restraint for pass through current. It simply consists of a comparator of the differential current with a setting.

The pickup of the unrestrained differential unit must be set above the maximum inrush current.

The unit picks up at 100% and resets at 95% of the calculated pickup value.

A time setting is available for time delayed trips if required. The output activation requires the pickup to remain active for the complete length of the timer. Any reset brings the logic to its initial conditions, so that a new activation initiates the timer from zero.

A **Trip Blocking** input is available, preventing the unit from tripping if the input is active before the trip command is generated. If the blocking is activated after the trip, it resets the trip. To use this blocking logic, the input **Unrestrained Differential Unit Trip Blocking** must be programmed. The activation of the External Fault Detector can block the unit if the setting ***External Fault Detector Block Enable*** is set to **YES**.

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2.1.7.o Setting Ranges

Differential Unit with Restraint					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Diff Enable	Diff Enable	PDIF1.Mod	YES / NO		NO
Sensitivity	Sensitivity	PDIF1.LoSet	(0.05-4) xtap (pu)	0.01	0.3
Sensitivity CSF	Sensitivity COF	PDIF1.COFLoSet	(0.1-4) xtap (pu)	0.01	0.5
Restraint Slope 1	Restraint slope 1	PDIF1.RstPct1	5 - 100%	0.01%	25%
R Slope 1 Start	R Slope 1 Start	PDIF1.StrRst1	0 - 2 pu	0.01	1
Restraint Slope 2	Restraint slope 2	PDIF1.RstPct2	5 - 200%	0.01%	75%
R Slope 2 Start	R Slope 2 Start	PDIF1.StrRst2	2 - 20 pu	0.01	5
Ext Fault Block Enable	Ext Fault Block	PDIF1.ExtFltEna	YES / NO		YES
2nd Restr. Enab.	2nd Restr. Enab.	DIFPHAR1.Rst2Ena	YES / NO		NO
2nd Restraint PU	2nd Restraint PU	DIFPHAR1.Str2Rst	5 - 100%	1%	20%
3rd Restr. Enab.	3rd Restr. Enab.	DIFPHAR1.Rst3Ena	YES / NO		NO
3rd Restraint PU	3rd Restraint PU	DIFPHAR1.Str3Rst	5 - 80%	1%	35%
4th Restr. Enab.	4th Restr. Enab.	DIFPHAR1.Rst4Ena	YES / NO		NO
4th Restraint PU	4th Restraint PU	DIFPHAR1.Str4Rst	5 - 80%	1%	20%
5th Restr. Enab.	5th Restr. Enab.	DIFPHAR1.Rst5Ena	YES / NO		NO
5th Restraint PU	5th Restraint PU	DIFPHAR1.Str5Rst	5 - 80%		35%
Harmonic Restrain Mode	Harmonic restrain	DIFPHAR1.RstTyp	Continous Dynamic		Continous
Diff Time Delay	Diff Time Delay	PDIF1.OpDlTmms	0 - 300 s	0.01 s	0
H Blocking Logic	H Blocking Logic	DIFPHAR1.HBlkTyp	1 OUT OF 3 NONE 2 OUT OF 3 3PH SUM		2 OUT OF 3
Cross Blocking Time	Cross Bloq Time	DIFPHAR1.BlkOrTmms	0.05 - 300 s	0.01 s	0.1s
2nd Block. Enab.	2nd Block. Enab.	DIFPHAR1.BlkEna1	YES / NO		YES
2nd Blocking PU	2nd Blocking PU	DIFPHAR1.BlkValPct1	5 - 100%	1%	20%
5th Block. Enab.	5th Block. Enab.	DIFPHAR1.BlkEna2	YES / NO		YES
5th Blocking PU	5th Blocking PU	DIFPHAR1.BlkValPct2	5 - 100%	1%	35%
Harmonic Blocking Type	Harmonic blocking	DIFPHAR1.BlkTyp	Continous Dynamic		Continous
Inhibition Time for Harmonics	Inhibition Time	DIFPHAR1.InhTmms	5 - 300 s 1 - 300s	0.01 s	80 s
Parallel Transformer	Parallel transfor.	PDIF1.ParTrf	YES / NO		NO

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Differential Unit without Restraint					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Inst Diff Enable	Inst Diff Enable	NRPDIF1.Mod	YES / NO		NO
Inst Diff Pickup	Inst Diff Pickup	NRPDIF1.StrVal	1 - 20 pu	0.01	8
Inst Diff Delay	Inst Diff Delay	NRPDIF1.OpDlTmms	0 - 300 s	0.01 s	0s
Ext Fault Block Enable	Ext Fault Block	NRPDIF1.ExtFltEna	YES / NO		YES

2.1.7.p Digital Inputs

Table 2.1-10:Digital Inputs to the Differential Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_87R	Enabling Commands	PDIF1.Mod	Enable Differential Unit		Activation of this input puts the Differential Units into service. It can be assigned to digital inputs by level or to a commands from the communications protocol or from the HMI. The default value of this logic input signals is a "1."
ENBL_87U		NRPDIF1.Mod	Enable Instantaneous Differential Unit		
INBLK_87R	Logic Inputs to Protection	PDIF1.Mod	Block Differential Unit		Activation of the input before the trip is generated prevents the unit from operating. If activated after the trip, it resets.
INBLK_87U		NRPDIF1.Mod	Block Instantaneous Differential Unit		
IN_HAR_CON		DIFPHAR1.ConsMod	Continuos Harmonic Restraint / Blocking Mode Input		Activation of this input enables continuous mode of harmonics restraint and blocking, independently from the mode selected by setting.
IN_INH_2_4_RST		DIFPHAR1.Rst24InhIn	2nd and 4th Harmonic Restraint Inhibit Input		Activation of this input inhibits the restraint by 2nd and 4th harmonics.
IN_INH_3_5_RST		DIFPHAR1.Rst35InhIn	3rd and 5th Harmonic Restraint Inhibit Input		Activation of this input inhibits the restraint by 3rd and 5th harmonics.
IN_INH_2_4_BLK		DIFPHAR1.Blk24InhIn	2nd and 4th Harmonic Blocking Inhibit Input		Activation of this input inhibits the blocking by 2nd and 4th harmonics.
IN_INH_3_5_BLK		DIFPHAR1.Blk35InhIn	3rd and 5th Harmonic Blocking Inhibit Input		Activation of this input inhibits the blocking by 3rd and 5th harmonics.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.7.q Auxiliary Outputs and Events of the Differential Modules

Table 2.1-11: Auxiliary Outputs and Events of the Differential Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_87R_A	Pick-up Protection Output	PDIF1.Str	Phase A Differential Unit Pick-up		Pick-up of differential units.
PU_87R_B		PDIF1.Str	Phase B Differential Unit Pick-up		
PU_87R_C		PDIF1.Str	Phase C Differential Unit Pick-up		
PU_87U_A		NRPDIF1.Str	Phase A Instantaneous Differential Unit Pick-up		
PU_87U_B		NRPDIF1.Str	Phase B Instantaneous Differential Unit Pick-up		
PU_87U_C		NRPDIF1.Str	Phase C Instantaneous Differential Unit Pick-up		
OUT_87R_A	Trip Protection Outputs	PDIF1.Op	Phase A Differential Unit Trip		Trip of differential units.
OUT_87R_B		PDIF1.Op	Phase B Differential Unit Trip		
OUT_87R_C		PDIF1.Op	Phase C Differential Unit Trip		
OUT_87U_A		NRPDIF1.Op	Phase A Instantaneous Differential Unit Trip		
OUT_87U_B		NRPDIF1.Op	Phase B Instantaneous Differential Unit Trip		
OUT_87U_C		NRPDIF1.Op	Phase C Instantaneous Differential Unit Trip		
OUT_87R_AM	Masked Trips		Phase A Differential Unit Masked Trip		Trip of the differential units affected by the trip mask.
OUT_87R_BM			Phase B Differential Unit Masked Trip		
OUT_87R_CM			Phase C Differential Unit Masked Trip		
OUT_87U_AM			Phase A Instantaneous Differential Unit Masked Trip		
OUT_87U_BM			Phase B Instantaneous Differential Unit Masked Trip		
OUT_87U_CM			Phase C Instantaneous Differential Unit Masked Trip		
INH_2_4_RST	Generic Protection Outputs	DIFPHAR1.Rst24Inhln	2nd and 4th Harmonic Restraint Inhibited		Inhibition of the corresponding harmonic restraint / blocking.
INH_3_5_RST		DIFPHAR1.Rst35Inhln	3rd and 5th Harmonic Restraint Inhibited		
INH_2_4_BLK		DIFPHAR1.Blk24Inhln	2nd and 4th Harmonic Blocking Inhibited		
INH_3_5_BLK		DIFPHAR1.Blk35Inhln	3rd and 5th Harmonic Blocking Inhibited		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 2.1-7: Auxiliary Outputs and Events of the Differential Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
BLK_HARM_A	Harmonic Block and Saturation Detector	DIFPHAR1.Str	Phase A differential unit harmonic block	I	It activates when the harmonic content if the differential current is above the threshold.
BLK_HARM_B		DIFPHAR1.Str	Phase B differential unit harmonic block	I	
BLK_HARM_C		DIFPHAR1.Str	Phase C differential unit harmonic block	I	
87R_ENBLD	Enabled Units Protection Outputs	PDIF.Mod	Differential unit enabled		Enabling indication of the unit.
87U_ENBLD		NRPDIF.Mod	Instantaneous Differential unit enabled		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.8 Neutral Differential Unit

The **DLF** equipment incorporates a Neutral Differential unit, with percentage restraint characteristic and harmonic blocking. This differential unit uses up to three three-phase currents (to calculate the corresponding neutral currents), which allows to protect two and three windings transformers.

The neutral differential unit is not influenced by the load flow, since this generates an increase in the restraint current without modifying the differential current (the differential current under load conditions is practically null), shifting the point (IDIFF, IREST) to the right, as shown in Figure 2.1.15. This effect may cause a lack of obedience of the phase differential unit to faults with weak infeed (very resistive faults, faults with very weak source, etc.) and with high load flow.

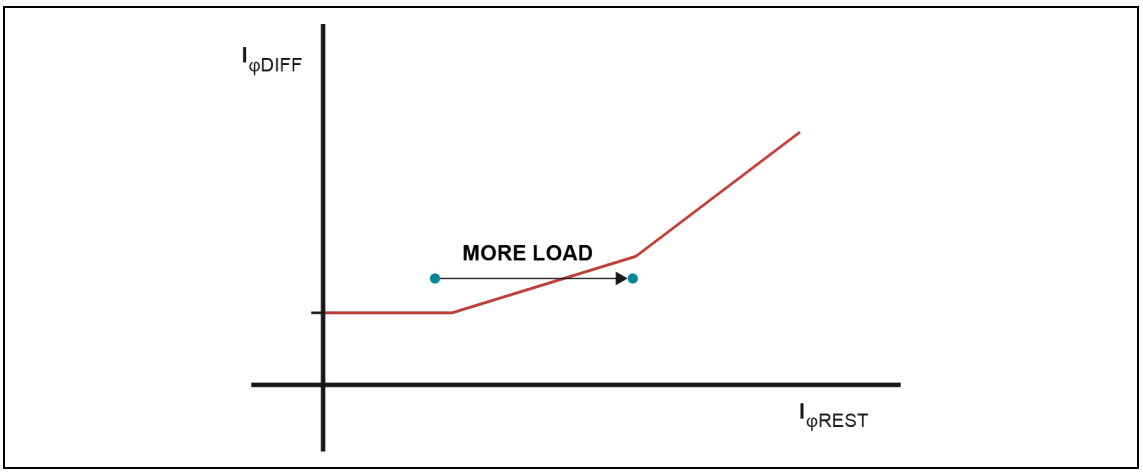


Figure 2.1.15 Effect of the Load on Phase Differential Element.

As stated above, the Ground Differential element is not affected by the load, as the ground current is practically zero under load conditions. As the restraint current is based on ground current, the load flux does not increase. This allows increasing the sensitivity in the presence of the mentioned faults.

2.1.8.a Neutral Differential Current

The Differential Current is calculated as the algebraic sum of the instantaneous values of all compensated neutral currents:

$$InDIFF = In1_{COMP} + In2_{COMP} + In3_{COMP}$$

Once the differential current waves are obtained, their fundamental component is calculated, obtaining INDIFF. Likewise, the 2nd and 5th harmonic components which will be used by the blocking unit for harmonics will be calculated.

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2.1.8.b Restraint Current

The restraint current represents the total current that fluxes through all the CTs that delimit the protection zone. The percentage restraint characteristic increases the differential current necessary to operate when the restraint current increases. In this way, the percentage errors produced by the CTs, the relay itself, the tap changer (if there is a transformer in the protection zone) and other sources are compensated.

To obtain the restraint current, the **DLF** previously calculates the RMS current of all compensated currents (magnitude of the fundamental component of the DFT), obtaining In1COMP_MOD, In2COMP_MOD and In3COMP_MOD.

The ***Restraint Type*** setting allows the user to select the formula used to calculate the restraint current:

- **Restraint Current = (I1+I2-Id)/2**

$$InREST = \frac{In1_{COMP_MOD} + In2_{COMP_MOD} + In3_{COMP_MOD} - InDIFF_{_MOD}}{2}$$

- **Restraint Current = (I1+I2)/2**

$$InREST = \frac{In1_{COMP_MOD} + In2_{COMP_MOD} + In3_{COMP_MOD}}{2}$$

The first restraint current formula offers greater obedience, given that the value of restraint current is lower during internal faults with a high differential current. On the other hand, it presents lower security during external faults with CT saturation, since the differential current generated by this condition reduces the restraint current. In any case, to ensure security during external faults with CT saturation, the External Fault Detector is used, so the use of the first restraint current formula is recommended.

2.1.8.c Display of Currents Calculated by the Differential Unit

Within the ***General*** settings menu, the **DLF** includes a setting called ***Diff Curr Measure*** that has two values:

- **Times tap**: in this case both the differential and restraint currents are displayed in "per unit".
- **Reference tap**: in this case the calculated value of the differential and restraint currents in per unit is multiplied by the reference winding tap. In that case both currents are represented in Amperes.

It should be noted that the differential unit is always set and operates with per unit values. The ***Diff Curr Measure*** setting only affects the display of the differential and restraint currents.

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2.1.8.d Reference Current

The **DLF** has a setting, called ***Reference Current*** (within the group of the differential unit protection settings), which allows selecting a winding of the machine and displaying the differential and restraint currents, on the HMI display, in the status screen of ***ZIV e-NET TOOL***®, and when collecting them by communications, multiplied by the tap setting for such winding, if the ***Diff Curr Measure*** setting is set as **Reference Tap**, within the ***General*** settings group.

This setting effects only the display and in no case does it affect internal calculations of the Differential Unit.

2.1.8.e Characteristic of the Neutral Differential Unit with Percentage Restraint

The Differential Unit includes a percentage restraint characteristic as shown in Figure 2.1.16. The x-axis is the restraint, passing or restricting current (INrest) and the y-axis is the differential current (INdiff). The feature includes one restraint slope.

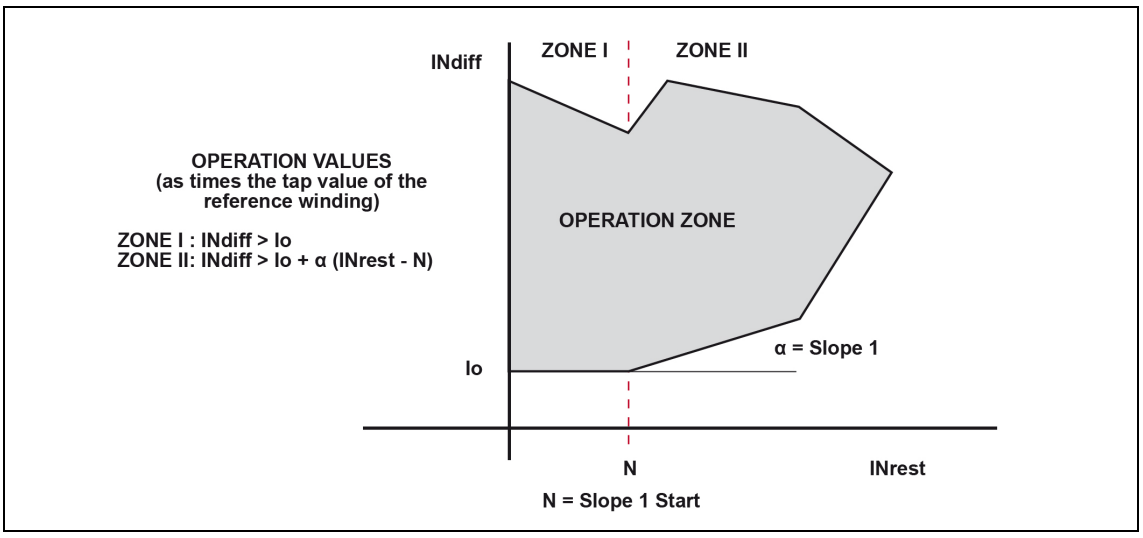


Figure 2.1.16 Operating Characteristic of the Neutral Differential Unit with Percentage Restraint.

The neutral differential unit will operate only when the Phase Selector indicates earth fault and, in addition, it must be taken into account that the neutral differential unit will not be able to operate properly if any zero sequence filter is active since in this case a false neutral differential will be generated. Therefore, the neutral differential unit can only be enabled when:

- The ***Transformer in Protection Zone*** setting is set to NO.
- The ***Transformer in Protection Zone*** setting is set to YES and all zero sequence filter settings are set to NO (see note).

Once the unit is tripped, it will not reset until the differential current is less than 0.8*I0.

Note: It must be taken into account that, when there is a transformer in the protection zone, the zero-sequence filter that will be applied in most cases (even in YY configurations, given the possibility that the transformer core includes three columns), will prevent the use of the neutral differential unit..

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For higher restraint currents the imbalances are larger, and a greater amount of differential current is needed to operate the unit. Slope 1 is usually used to compensate for the following errors:

- Measurement errors of the current transformers in the linear zone of their magnetization characteristic (without reaching the saturation elbow).
- Errors due to the variation of the output voltage of a winding because of the operation of the tap changer. Point 2.1.6.c shows that the calculation of the taps for each winding depends on the corresponding winding voltage. If this voltage varies, the tap setting will not correspond to the actual tap existing at that moment, which will cause a differential current. The voltage that is used for the calculation of a winding tap usually corresponds to the voltage value at the center tap.
- Measurement errors of the relay itself.

The multiplication coefficient α, defined between the values of **N** and above of the pass-through current, is adjustable and is called ***Percentage Restraint Coefficients*** (***Slope 1***).

The parameter **Io** is the **Differential Sensitivity** of the unit. Io defines the minimum differential current value necessary to operate the unit. It is set to compensate for absolute errors of differential current, such as the magnetization current of the transformer under normal conditions.

Sensitivity values and start values of first slope are always set in per unit (or times the reference tap).

2.1.8.f Harmonic Blocking

The harmonic blocking unit calculates the relationship between the harmonic differential current n (n = 2 and 5) and the fundamental neutral differential current the corresponding DFT. When this ratio is above the set value, the harmonic blocking n is activated.

$$\frac{InDIFF_HARM_n_{_MOD}}{InDIFF_{MOD}} > Kn \text{ (n=2 and 5)}$$

The operating condition of the differential unit with harmonic blocking will be:

$$\left(IN_{diff_fund} > I_{\substack{diff \\ through \\ current \\ restraint}} = IN_{rest} \cdot f(\alpha) \right) \otimes \left(\frac{IN_{diff_harm_n}}{IN_{diff_fund}} < Kn \right)$$

There are two independent settings that enable or disable blocking by 2nd and 5th harmonics, as well as two other percentage adjustments of 2nd and 5th harmonics that must be exceeded to activate the blocking.

Blocking activation occurs at 1 time setting and reset at 0.95 times the setting.

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2.1.8.g Cross-Blocking and Inhibition of Harmonic Blocking

Cross-blocking obviously does not apply to the neutral differential unit. Neither will the inhibition of the harmonic blocking for the neutral differential unit be implemented since, in case of faults with CT saturation, the actuation of this unit is not required. It should be noted that the purpose of the neutral differential unit is to clear faults with weak infeed (very resistive faults or faults with a weak source) and high load flow, for which no CT saturation will occur.

2.1.8.h Output of the Neutral Differential Unit with Restraint

The Differential Unit with Restraint picks up at 100% and the reset has to occur at 0.8I0.

- 0,8*Io

A time setting is available for time delayed trips if required. The output activation requires the pickup to remain active for the complete length of the timer. Any reset brings the logic to its initial conditions, so that a new activation initiates the timer from zero.

A **Trip Blocking** input is available, preventing the unit from tripping if the input is active before the trip command is generated. If the blocking is activated after the trip, it resets the trip. To use this blocking logic, signal **Neutral Differential Unit Trip Blocking Input** must be programmed.

The activation of the External Fault Detector can block the unit if the setting ***Ext Fault Block Enable*** is set to **YES**.

2.1.8.i Close-Onto-Fault Sensitivity

When a fault close-onto-fault occurs and it is not configured or there is no possibility to perform capacitive current compensation, it is possible that the calculated differential current is significant due to the exponential character of the capacitive current. To prevent the unit from operating improperly, in addition to the differential ***Sensitivity*** setting, an additional sensitivity called ***Sensitivity COF*** can be adjusted. This sensitivity value will only be applied when the corresponding unit detects a close onto fault during the time defined in the ***COF Time*** setting. Once this time has elapsed, the reference sensitivity for the phase differential unit will revert to that defined by the differential ***Sensitivity*** setting.

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2.1.8.j Open Pole Sensitivity

When capacitive current compensation is enabled (see General settings of the Differential Unit), the neutral current will be calculated from the phase currents already compensated, eliminating the capacitive neutral current.

If there is no capacitive current compensation and a pole is opened, the capacitive neutral current will be significantly higher than normal conditions. Therefore, it is possible to configure a sensitivity for open pole situation (***Sensitivity Open Pole***), when the **One Pole Open** signal is activated, which must be greater than the Differential ***Sensitivity*** value.

If ***Capacitive Curr. Compensation*** setting is enabled, the value set in the ***Sensitivity Open Pole*** setting will never be used.

2.1.8.k Operation in Open Pole Fault Conditions

In open pole condition, the neutral current will normally be higher than normal (with the three poles closed). In the event of faults in this situation (with an open pole), the **restraint current** of the neutral differential unit will operate with the **pure fault neutral currents**, i.e. the pure fault neutral restraint current is obtained by subtracting the pre-fault neutral restraint current taken some time before the activation of the fault start.

$$InREST_{PURE_F} = InREST - InREST_{PF}$$

When the open pole condition is eliminated, the differential unit will return to operating with neutral current.

2.1.8.l Setting Ranges

Neutral Differential Unit with Restraint					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Enable	GNDPDIF1.LNInSvc	YES / NO		NO
Sensitivity	Sensitivity	GNDPDIF1.LoSet	(0.2-2) xtap (pu)	0.01	0.1
Sensitivity COF	Sensitivity COF	GNDPDIF1.COFLoSet	(0.1-2) xtap (pu)	0.01	0.5
Sensitivity Open Pole	Sens. Open Pole	GNDPDIF1.OpnLoSet	(0.1-2) xtap (pu)	0.01	0.3
Restraint Slope 1	Slope 1	GNDPDIF1.RstPct1	5 - 100%	0.01%	10%
Slope 1 Start	Slope 1 Start	GNDPDIF1.StrRst1	0 - 5 pu	0.01	1
2nd Block. Enab.	2nd Block. Enab.	GNDDIFPHAR1.BlkEna1	YES / NO		YES
2nd Blocking PU	2nd Blocking PU	GNDDIFPHAR1.BlkValPct1	5 - 100%	1%	20%
5th Block. Enab.	5th Block. Enab.	GNDDIFPHAR1.BlkEna2	YES / NO		YES
5th Blocking PU	5th Blocking PU	GNDDIFPHAR1.BlkValPct2	5 - 100%	1%	35%
Time Delay	Time Delay	GNDPDIF1.OpDlTmms	0 - 300 s	0.01 s	0.01
Ext Fault Block Enable	Ext Fault Block	GNDPDIF1.ExtFltEna	YES / NO		NO

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2.1.8.m Digital Inputs

Table 2.1-12: Digital Inputs to the Differential Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_87N	Enabling Commands	PDIF1.Mod	Neutral Differential Unit Enable Input		Activation of this input puts the Neutral Differential Unit into service. It can be assigned to digital inputs by level or to a commands from the communications protocol or from the HMI. The default value of this logic input signals is a "1."
INBLK_87N	Logic Input to Protection	PDIF1.Mod	Neutral Differential Unit Trip Blocking Input		Activation of the input before the trip is generated prevents the unit from operating. If activated after the trip, it resets.
IN_I_CAP_ENBLD			Capacitive Current Compensation Enable Input		Activating this input activates capacitive current compensation.
IN_INH_2_BLK_N		GNDDIFPHAR1.Blk2InhIn	2nd Harmonic Blocking Inhibit Input		Activation of this input inhibits the restraint by 2nd harmonic.
IN_INH_5_BLK_N		GNDDIFPHAR1.Blk5InhIn	5th Harmonic Blocking Inhibit Input		Activation of this input inhibits the restraint by 5th harmonic.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.8.n Auxiliary Outputs and Events

Table 2.1-13: Auxiliary Outputs and Events of the Differential Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_87N	Pick-up Protection Output	GNDPDIF1.Str	Neutral Differential Unit Pick-up		Pickup of the Differential Unit and start of the time count.
OUT_87N	Trip Protection Outputs	GNDPDIF1.Op	Neutral Differential Unit Trip		Trip of the Differential Unit.
OUT_87N_M	Masked Trips		Neutral Differential Unit Masked Trip		Trip of the Differential Unit affected by the trip mask.
BLK_HARM_87N	Harmonic lock and Saturation Detector	GNDDIFPHAR1.Str	Neutral Differential Unit Harmonic Blocked		It is activated when the Differential Unit with restraint is blocked by excessive harmonics.
87N_ENBLD	Enabled Units Protection Outputs	GNDPDIF1.Mod	Neutral Differential Unit Enabled		Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.9 Positive Sequence Differential Unit

The **DLF** equipment incorporates a Positive Sequence Differential unit, with percentage restraint characteristic and harmonic blocking. This differential unit uses up to three three-phase currents (to calculate the corresponding positive sequence currents), which allows to protect two and three windings transformers.

The positive sequence differential unit uses pure fault currents. This unit allows to increase the sensitivity, even in resistive three-phase faults, and to reduce the trip time in three-phase faults. The positive sequence differential unit will operate only when a fault start is detected.

2.1.9.a Positive Sequence Differential Current

The positive sequence differential current will be calculated as the vector sum of the positive sequence compensated currents:

$$IpsDIFF = Ips1_{COMP} + Ips2_{COMP} + Ips3_{COMP}$$

Once the differential current waves are obtained, their fundamental component is calculated, obtaining IPSDIFF. Likewise, the 2nd and 5th harmonic components which will be used by the blocking unit for harmonics will be calculated.

2.1.9.b Restraint Current

The restraint current represents the total current that fluxes through all the CTs that delimit the protection zone. The percentage restraint characteristic increases the differential current necessary to operate when the restraint current increases. In this way, the percentage errors produced by the CTs, the relay itself, the tap changer (if there is a transformer in the protection zone) and other sources are compensated.

To obtain the restraint current, the **DLF** previously calculates the RMS current of all compensated currents (magnitude of the fundamental component of the DFT), obtaining In1COMP_MOD, In2COMP_MOD and In3COMP_MOD.

The ***Restraint Type*** setting allows the user to select the formula used to calculate the restraint current:

- **Restraint Current = (I1+I2-Id)/2**

$$IpsREST = \frac{Ips1_{COMP_MOD} + Ips2_{COMP_MOD} + Ips3_{COMP_MOD} - InDIFF_{_MOD}}{2}$$

- **Restraint Current = (I1+I2)/2**

$$IpsREST = \frac{Ips1_{COMP_MOD} + Ips2_{COMP_MOD} + Ips3_{COMP_MOD}}{2}$$

The **restraint current** at which the positive sequence differential unit will operate shall be the **pure fault positive sequence currents**, i.e. the pure fault neutral restraint current is obtained by subtracting the pre-fault positive sequence restraint current taken some time before the activation of the fault start.

$$IpsREST_{PURE_F} = IpsREST - IpsREST_{PF}$$

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The first restraint current formula offers greater obedience, given that the value of restraint current is lower during internal faults with a high differential current. On the other hand, it presents lower security during external faults with CT saturation, since the differential current generated by this condition reduces the restraint current. In any case, to ensure security during external faults with CT saturation, the External Fault Detector is used, so the use of the first restraint current formula is recommended.

2.1.9.c Display of Currents Calculated by the Differential Unit

Within the ***General*** settings menu, the **DLF** includes a setting called ***Diff Curr Measure*** that has two values:

- **Times tap**: in this case both the differential and restraint currents are displayed in "per unit".
- **Reference tap**: in this case the calculated value of the differential and restraint currents in per unit is multiplied by the reference winding tap. In that case both currents are represented in Amperes.

It should be noted that the differential unit is always set and operates with per unit values. The ***Diff Curr Measure*** setting only affects the display of the differential and restraint currents.

2.1.9.d Reference Current

The **DLF** has a setting, called ***Reference Current*** (within the group of the differential unit protection settings), which allows selecting a winding of the machine and displaying the differential and restraint currents, on the HMI display, in the status screen of ***ZIV e-NET TOOL***®, and when collecting them by communications, multiplied by the tap setting for such winding, if the ***Diff Curr Measure*** setting is set as **Reference Tap**, within the ***General*** settings group.

This setting effects only the display and in no case does it affect internal calculations of the Differential Unit.

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2.1.9.e Characteristic of the Positive Sequence Differential Unit with Percentage Restraint

The Differential Unit includes a percentage restraint characteristic as shown in Figure 2.1.17. The x-axis is the restraint, passing or restricting current (I1rest) and the y-axis is the differential current (I1diff). The feature includes one restraint slope.

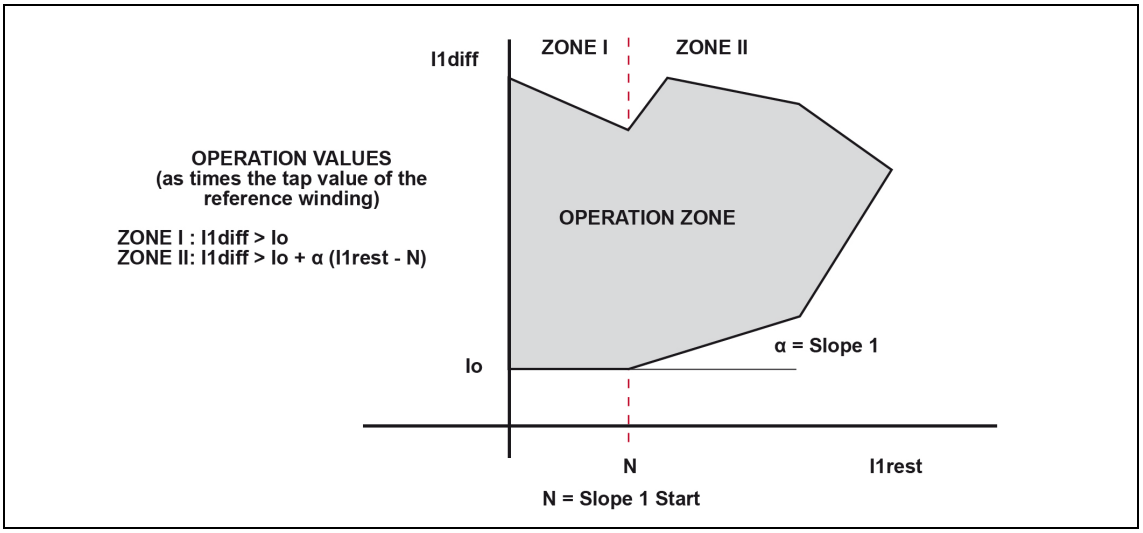


Figure 2.1.17 Operating Characteristic of the Positive Sequence Differential Unit with Percentage Restraint.

The Positive Sequence Differential Unit will operate only when a fault start is detected, otherwise it will not operate. This is because the Positive Sequence Differential Unit will operate with the pure fault positive sequence currents, i.e., once the pre-fault positive sequence current has been subtracted, taken a time before the activation of the fault detector.

Once the unit is tripped, it will not reset until the differential current is less than 0.8*I0.

For higher restraint currents the imbalances are larger, and a greater amount of differential current is needed to operate the unit. Slope 1 is usually used to compensate for the following errors:

- Measurement errors of the current transformers in the linear zone of their magnetization characteristic (without reaching the saturation elbow).
- Errors due to the variation of the output voltage because of the operation of the tap changer, if there is a transformer in the protection zone. In the description of the tap calculation it was seen that it depended on the corresponding voltage. If this voltage varies, the tap setting will not correspond to the actual tap existing at that moment, which will cause a differential current. The voltage that is used for the calculation of a winding tap usually corresponds to the voltage value at the center tap if there are transformers in the protection zone.
- Measurement errors of the relay itself.

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The multiplication coefficient α, defined between the values of **N** and above of the pass-through current, is adjustable and is called ***Percentage Restraint Coefficients*** (***Slope 1***).

The parameter **Io** is the **Differential Sensitivity** of the unit. Io defines the minimum differential current value necessary to operate the unit. It is set to compensate for absolute errors of differential current, such as the magnetization current of the transformer under normal conditions.

Sensitivity values and start values of first slope are always set in per unit (or times the reference tap).

2.1.9.f Harmonic Blocking

To avoid trips of the Positive Sequence Differential Unit under inrush and overexcitation conditions, the outputs of the harmonic blocking unit associated with the Phase Differential Unit shall be used. Blocking will occur if:

- Having set the type of harmonic blocking of the phase differential unit to a value other than "***None***", the harmonic blocking outputs of all three phases are activated. Whenever the Cross-Blocking logic is complied with, the harmonic blocking will be activated in all three phases.
- Having set the harmonic blocking type to "***None***", blocking will occur if the harmonic blocking output of any of the phases is activated.

2.1.9.g Output of the Positive Sequence Differential Unit with Restraint

The Differential Unit with Restraint picks up at 100% and the reset has to occur at $0.8I_0$.

- 0.8*Io

A time setting is available for time delayed trips if required. The output activation requires the pickup to remain active for the complete length of the timer. Any reset brings the logic to its initial conditions, so that a new activation initiates the timer from zero.

A **Trip Blocking** input is available, preventing the unit from tripping if the input is active before the trip command is generated. If the blocking is activated after the trip, it resets the trip. To use this blocking logic, signal **Positive Sequence Differential Unit Trip Blocking Input** must be programmed.

The activation of the External Fault Detector can block the unit if the setting ***Ext Fault Block Enable*** is set to **YES**.

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2.1.9.h Close-Onto-Fault Sensitivity

When a fault close-onto-fault occurs and it is not configured or there is no possibility to perform capacitive current compensation, it is possible that the calculated differential current is significant due to the exponential character of the capacitive current. To prevent the unit from operating improperly, in addition to the differential ***Sensitivity*** setting, an additional sensitivity called ***Sensitivity COF*** can be adjusted. This sensitivity value will only be applied when the corresponding unit detects a close onto fault during the time defined in the ***COF Time*** setting. Once this time has elapsed, the reference sensitivity for the phase differential unit will revert to that defined by the differential ***Sensitivity*** setting.

2.1.9.i Open Pole Sensitivity

When capacitive current compensation is enabled (see General settings of the Differential Unit), the positive sequence current will be calculated from the phase currents already compensated, eliminating the capacitive positive sequence current.

If there is no compensation of the capacitive current and the opening of a pole occurs, the positive sequence capacitive current will be higher or lower depending on the circulating current in the closed phases. To be able to compensate for possible increments of false positive sequence differential current, it is possible to configure a sensitivity for open pole situation (***Sensitivity Open Pole***), when the **One Pole Open** signal is activated, which must be greater than the Differential ***Sensitivity*** value if there is no capacitive current compensation.

If ***Capacitive Curr. Compensation*** setting is enabled, it will be recommended to set the ***Sensitivity Open Pole*** setting to the same value set in the Differential ***Sensitivity*** setting.

2.1.9.j Operation in Open Pole Fault Conditions

In open pole condition, the neutral current will normally be lower than normal (with the three poles closed). In open pole condition, the direct sequence current will be lower than normal (with the three poles closed). When calculating the restraint current, this effect will have no impact as this unit operates with pure fault positive sequence currents.

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2.1.9.k Setting ranges

Positive Sequence Differential Unit with Restraint					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable		PSPDIF1.LNInSvc	YES / NO		NO
Sensitivity		PSPDIF1.LoSet	(0.02-2) xtap (pu)	0.01	0.1
Sensitivity COF		PSPDIF1.COFLoSet	(0.1-2) xtap (pu)	0.01	0.5
Sensitivity Open Pole		PSPDIF1.OpnLoSet	(0.1-2) xtap (pu)	0.01	0.3
Restraint Slope 1		PSPDIF1.RstPct1	5 - 100%	0.01%	10%
Slope 1 Start		PSPDIF1.StrRst1	0 - 5 pu	0.01	1
Time Delay		PSPDIF1.OpDlTmms	0 - 300 s	0.01 s	0.01
Block. Enab.		PSPDIFPHAR1.BlkEna	YES / NO		YES
Ext Fault Block Enable		PSPDIF1.ExtFltEna	YES / NO		YES

2.1.9.l Digital Inputs

Table 2.1-14: Digital Inputs to the Differential Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_87P	Enabling Commands	PSPDIF1.Mod	Positive Sequence Differential Unit Enable Input		Activation of this input puts the Positive Sequence Differential Unit into service. It can be assigned to digital inputs by level or to a commands from the communications protocol or from the HMI. The default value of this logic input signals is a “1.”
INBLK_87P	Logic Input to Protection	PSPDIF1.Mod	Positive Sequence Differential Unit Trip Blocking Input		Activation of the input before the trip is generated prevents the unit from operating. If activated after the trip, it resets.
IN_I_CAP_ENBLD			Capacitive Current Compensation Enable Input		Activating this input activates capacitive current compensation.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.9.m Auxiliary Outputs and Events

Table 2.1-15: Auxiliary Outputs and Events of the Differential Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_87P	Pick-up Protection Outputs	PSPDIF1.Mod	Positive Sequence Differential Unit Pick-up		Pickup of the Differential Unit and start of the time count.
OUT_87P	Trip Protection Outputs	PSPDIF1.Op	Positive Sequence Differential Unit Trip		Trip of the Differential Unit.
OUT_87P_M	Masked Trips		Positive Sequence Differential Masked Trip		Trip of the differential unit affected by the trip mask.
BLK_HARM_87	Harmonic lock and Saturation Detector	PSPDIFPHAR1.Str	Positive Sequence Differential Unit Harmonic Blocked		It is activated when the Differential Unit with restraint is blocked by excessive harmonics.
87P_ENBLD	Enabled Units Protection Outputs	PSPDIF1.Mod	Positive Sequence Differential Unit Enabled		Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.10 Negative Sequence Differential Unit

The **DLF** equipment incorporates a Negative Sequence Differential unit, with percentage restraint characteristic and harmonic blocking. This differential unit uses up to three three-phase currents (to calculate the corresponding negative sequence currents), which allows to protect two and three windings transformers.

The Negative Sequence Differential Unit makes it possible to compensate for the effect of the load on all types of unbalanced faults, even on pure two-phase faults that do not involve ground, against which the Neutral Differential Unit cannot operate. Therefore, the Negative Sequence Differential Unit will operate only when the Phase Selector does not indicate three-phase fault condition.

2.1.10.a Negative Sequence Differential Current

The negative sequence differential current will be calculated as the vector sum of the negative sequence compensated currents:

$$InsDIFF = Ins1_{COMP} + Ins2_{COMP} + Ins3_{COMP}$$

Once the differential current waves are obtained, their fundamental component is calculated, obtaining INSDIFF.

2.1.10.b Restraint Current

The restraint current represents the total current that fluxes through all the CTs that delimit the protection zone. The percentage restraint characteristic increases the differential current necessary to operate when the restraint current increases. In this way, the percentage errors produced by the CTs, the relay itself, the tap changer (if there is a transformer in the protection zone) and other sources are compensated.

To obtain the restraint current, the **DLF** previously calculates the RMS current of all compensated currents (magnitude of the fundamental component of the DFT), obtaining Ins1COMP_MOD, Ins2COMP_MOD and Ins3COMP_MOD.

The ***Restraint Type*** setting allows the user to select the formula used to calculate the restraint current:

- **Restraint Current = (I1+I2-Id)/2**

$$InsREST = \frac{Ins1_{COMP_MOD} + Ins2_{COMP_MOD} + Ins3_{COMP_MOD} - InDIFF_{_MOD}}{2}$$

- **Restraint Current = (I1+I2)/2**

$$InsREST = \frac{Ins1_{COMP_MOD} + Ins2_{COMP_MOD} + Ins3_{COMP_MOD}}{2}$$

The first restraint current formula offers greater obedience, given that the value of restraint current is lower during internal faults with a high differential current. On the other hand, it presents lower security during external faults with CT saturation, since the differential current generated by this condition reduces the restraint current. In any case, to ensure security during external faults with CT saturation, the External Fault Detector is used, so the use of the first restraint current formula is recommended.

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2.1.10.c Display of Currents Calculated by the Differential Unit

Within the ***General*** settings menu, the **DLF** includes a setting called ***Diff Curr Measure*** that has two values:

- **Times tap**: in this case both the differential and restraint currents are displayed in "per unit".
- **Reference tap**: in this case the calculated value of the differential and restraint currents in per unit is multiplied by the reference winding tap. In that case both currents are represented in Amperes.

It should be noted that the differential unit is always set and operates with per unit values. The ***Diff Curr Measure*** setting only affects the display of the differential and restraint currents.

2.1.10.d Reference Current

The **DLF** has a setting, called ***Reference Current*** (within the group of the Differential Unit protection settings), which allows selecting a winding of the machine and displaying the differential and restraint currents, on the HMI display, in the status screen of ***ZIV e-NET TOOL***®, and when collecting them by communications, multiplied by the tap setting for such winding (if the ***Diff Curr Measure*** setting is set as **Reference Tap**, within the ***General*** settings group).

This setting effects only the display and in no case does it affect internal calculations of the Differential Unit.

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2.1.10.e Characteristic of the Negative Sequence Differential Unit with Percentage Restraint

The Differential Unit includes a percentage restraint characteristic as shown in Figure 2.1.18. The x-axis is the restraint, passing or restricting current (I2rest) and the y-axis is the differential current (I2diff). The feature includes one restraint slope.

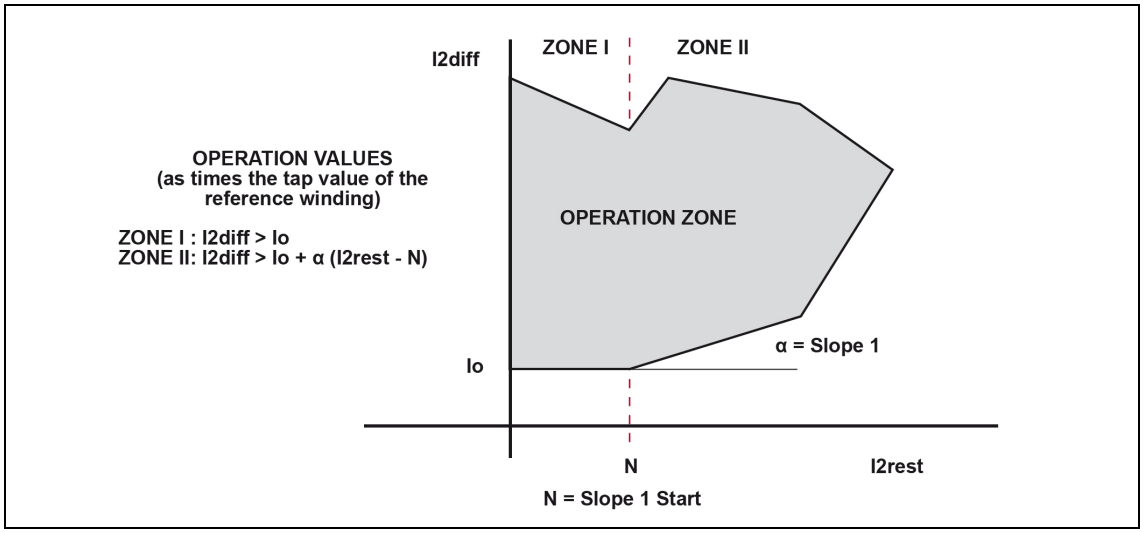


Figure 2.1.18 Operating Characteristic of the Negative Sequence Differential Unit with Percentage Restraint.

The Negative Sequence Differential Unit will operate only when the Phase Selector does not indicate three-phase fault condition. The signal used will be the absence of a "three-phase fault" from the phase selector, but with a reset time of 10 ms. This is due to the fact that this unit allows the load effect to be compensated for all types of unbalanced faults, even in pure two-phase faults that do not involve ground, against which the Neutral Differential Unit cannot operate.

Once the unit is tripped, it will not reset until the differential current is less than 0.8*I0.

For higher restraint currents the imbalances are larger, and a greater amount of differential current is needed to operate the unit. Slope 1 is usually used to compensate for the following errors:

- Measurement errors of the current transformers in the linear zone of their magnetization characteristic (without reaching the saturation elbow).
- Errors due to the variation of the output voltage of a winding because of the operation of the tap changer, if there is a transformer in the protection zone. Point 2.1.6.c shows that the calculation of the taps for each winding depends on the corresponding winding voltage. If this voltage varies, the tap setting will not correspond to the actual tap existing at that moment, which will cause a differential current. The voltage that is used for the calculation of a winding tap usually corresponds to the voltage value at the center tap, if there is a transformer in the protection zone
- Measurement errors of the relay itself.

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The multiplication coefficient α, defined between the values of **N** and above of the pass-through current, is adjustable and is called ***Percentage Restraint Coefficients*** (***Slope 1***).

The parameter **Io** is the **Differential Sensitivity** of the unit. **Io** defines the minimum differential current value necessary to operate the unit. It is set to compensate for absolute errors of differential current, such as the magnetization current of the transformer under normal conditions.

Sensitivity values and start values of first slope are always set in per unit (or times the reference tap).

2.1.10.f Harmonic Blocking

To avoid trips of the Negative Sequence Differential Unit under inrush and overexcitation conditions, the outputs of the harmonic blocking unit associated with the phase differential unit shall be used. Blocking will occur if:

- Having set the type of harmonic blocking of the phase differential unit to a value other than "***None***", the harmonic blocking outputs of all three phases are activated. Whenever the Cross-Blocking logic is complied with, the harmonic blocking will be activated in all three phases.
- Having set the harmonic blocking type to "***None***", blocking will occur if the harmonic blocking output of any of the phases is activated.

2.1.10.g Output of the Negative Sequence Differential Unit with Restraint

The Differential Unit with Restraint picks up at 100% and the reset has to occur at $0.8I_0$.

- 0.8*Io

A time setting is available for time delayed trips if required. The output activation requires the pickup to remain active for the complete length of the timer. Any reset brings the logic to its initial conditions, so that a new activation initiates the timer from zero.

A **Trip Blocking** input is available, preventing the unit from tripping if the input is active before the trip command is generated. If the blocking is activated after the trip, it resets the trip. To use this blocking logic, signal **Negative Sequence Differential Unit Trip Blocking Input** must be programmed.

The activation of the External Fault Detector can block the unit if the setting ***Ext Fault Block Enable*** is set to **YES**.

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2.1.10.h Close-Onto-Fault Sensitivity

When a fault close-onto-fault occurs and it is not configured or there is no possibility to perform capacitive current compensation, it is possible that the calculated differential current is significant due to the exponential character of the capacitive current. To prevent the unit from operating improperly, in addition to the differential ***Sensitivity*** setting, an additional sensitivity called ***Sensitivity COF*** can be adjusted. This sensitivity value will only be applied when the corresponding unit detects a close onto fault during the time defined in the ***COF Time*** setting. Once this time has elapsed, the reference sensitivity for the phase differential unit will revert to that defined by the differential ***Sensitivity*** setting.

2.1.10.i Open Pole Sensitivity

When capacitive current compensation is enabled (see General settings of the Differential Unit), the negative sequence current will be calculated from the phase currents already compensated, eliminating the capacitive negative sequence current.

If there is no capacitive current compensation and a pole is opened, the capacitive negative sequence current will be significantly higher than normal conditions. Therefore, it is possible to configure a sensitivity for open pole situation (***Sensitivity Open Pole***), when the **One Pole Open** signal is activated, which must be greater than the Differential ***Sensitivity*** value.

If ***Capacitive Curr. Compensation*** setting is enabled, the value set in the ***Sensitivity Open Pole*** setting will never be used.

2.1.10.j Operation in Open Pole Fault Conditions

In open pole condition, the neutral current will normally be higher than normal (with the three poles closed). In the event of faults in this situation (with an open pole), the **restraint current** of the Negative Sequence Differential Unit will operate with the **pure fault negative sequence currents**, i.e. the pure fault neutral restraint current is obtained by subtracting the pre-fault negative sequence restraint current taken some time before the activation of the fault start.

$$InsREST_{PURE_F} = InsREST - InsREST_{PF}$$

When the open pole condition is eliminated, the Negative Sequence Differential Unit will operate with the negative sequence fault currents since the pre-fault negative sequence current is practically insignificant.

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2.1.10.k Setting Ranges

Negative Sequence Differential Unit with Restraint					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Enable	NSPDIF1.LNInSvc	YES / NO		NO
Sensitivity	Sensitivity	NSPDIF1.LoSet	(0.2-2) xtap (pu)	0.01	0.1
Sensitivity COF	Sensitivity COF	NSPDIF1.COFLoSet	(0.1-2) xtap (pu)	0.01	0.5
Sensitivity Open Pole	Sens. Open Pole	NSPDIF1.OpnLoSet	(0.1-2) xtap (pu)	0.01	0.3
Restraint Slope 1	Slope 1	NSPDIF1.RstPct1	5 - 100%	0.01%	10%
Slope 1 Start	Slope 1 Start	NSPDIF1.StrRst1	0 - 5 pu	0.01	1
Time Delay	Time Delay	NSPDIF1.OpDITmms	0 - 300 s	0.01 s	0.01 s
Block. Enab.	Ha Block. Enab.	NSPDIFPHAR.BlkEna	YES / NO		NO
Ext Fault Block Enable	Ext Fault Block	NSPDIF1.ExtFltEna	YES / NO		NO

2.1.10.l Digital Inputs

Table 2.1-16: Digital Inputs to the Differential Modules

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_87Q	Enabling Commands	NSPDIF1.Mod	Negative Sequence Differential Unit Enable Input		Activation of this input puts the Negative Sequence Differential Unit into service. It can be assigned to digital inputs by level or to a commands from the communications protocol or from the HMI. The default value of this logic input signals is a "1."
INBLK_87Q	Logic Input to Protection	NSPDIF1.Mod	Negative Sequence Differential Unit Trip Blocking Input		Activation of the input before the trip is generated prevents the unit from operating. If activated after the trip, it resets.
IN_I_CAP_ENBLD			Capacitive Current Compensation Enable Input		Activating this input activates capacitive current compensation.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.10.m Auxiliary Outputs and Events

Table 2.1-17: Auxiliary Outputs and Events of the Differential Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_87Q	Pick-up Protection Outputs	NSPDIF1.Mod	Negative Sequence Differential Unit Pick-up		Pickup of the Differential Unit and start of the time count.
OUT_87Q	Trip Protection Outputs	NSPDIF1.Op	Negative Sequence Differential Unit Trip		Trip of the Differential Unit.
OUT_87Q_M	Masked Trips		Negative Sequence Differential Masked Trip		Trip of the Differential Unit affected by the trip mask.
BLK_HARM_87	Harmonic lock and Saturation Detector	NSPDIFPHAR1.Str	Negative Sequence Differential Unit Harmonic Blocked		It is activated when the Differential Unit with restraint is blocked by excessive harmonics.
87Q_ENBLD	Enabled Units Protection Outputs	NSPDIF1.Mod	Negative Sequence Differential Unit Enabled		Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.1.11 Settings Recommendation

2.1.11.a Capacitive Current Compensation Enable

Capacitive current compensation is normally not required on overhead lines less than 80 kilometers (50 miles) in length and voltage levels less than 115 kV. As the voltage increases, it is recommended to activate the capacitive current compensation. On the other hand, in underground cables, even those that are very short, they can have a very important capacitive current due to the proximity between the potential element (cable) and the ground. Therefore, in underground cables it is recommended to always activate the capacitive current compensation.

It is not recommended to activate the capacitive current compensation when it is not necessary for the application because an incorrect adjustment of the line susceptance values can cause the appearance of a false differential current that produces bad operations of the equipment.

2.1.11.b Restraint Type

The **DLF** incorporates two formulas for the calculation of the restraint current, selectable by setting: **Ifre1** = (I1 + I2-Id) / 2 and **Ifre2** = (I1 + I2) / 2. Since the differential current in a fault external to the transformer is small, the first restraint current will be same as the second. However, in a fault internal to the machine, the first restraint variable will be much lower than the second. If the influence of the load is negligible, since the currents that circulate through all the windings are in phase, the first restraint current would be null. In this way, the compromise between security and obedience that maintains the first restraint formula is better than the second. However, when significant differential currents are generated in external faults as a consequence, for example, of the saturation of some CT, the first restraint current will be lower than the second, which implies a reduction in security. In any case, if the external fault detector is enabled (refer to point 2.2), which provides great stability of the differential unit for external faults with saturation of some CTs, the use of the first restraint current formula is recommended, since this increases obedience during internal faults.

2.1.11.c Phase Differential

- **Sensitivity**

The **Sensitivity** setting defines the minimum differential current required by the Differential Element to operate. Its value depends on the capacitance current, or line to earth leakage current due to line capacitance. As mentioned in section 3.1.8, when the line is energized, a transient capacitive current higher than the steady state current is generated. The same happens when an external fault is cleared as a result of a voltage increase, although in this case the magnitude of the transient capacitive current will be much smaller than during line energization.

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DLF relays include a ***Close-onto-Fault Sensitivity*** setting, as mentioned in section 3.1.8. Said sensitivity will be applied, for a period equal to ***Close-onto-Fault Time*** setting, from the moment the line is energized (breaker closing). This has been designed to prevent tripping under energizing transients. If capacitive current compensation is not enabled, a value 3 times the steady state capacitive current is sufficient. If the latter function is enabled, the close onto fault sensitivity may be reduced to 1.5 times the steady state capacitive current. **Close-onto-Fault Time** must be greater than the transients duration. A value of 300 ms is normally sufficient.

Below is described the calculation procedure for steady state capacitive current.

Normal ***Sensitivity*** must be set so as to prevent tripping under minimum load conditions (minimum restraint current and maximum capacitive current, as voltage equals nominal voltage). If capacitive current compensation is not enabled, a value of 2 times the steady state capacitive current is adequate to prevent incorrect operation on transients resulting from clearance of external faults. If the capacitive current compensation is enabled, the sensitivity may be set to the same value as the steady state capacitive current.

In cases where there is a transformer within the protection zone, the differential current generated by the magnetizing current in normal operation (without inrush or over-excitation) must be taken into account. If the first restraint current formula is selected, when the load current of the transformer is zero and there is only magnetization current, the restraint current will also be zero (since Idiff = I1). If the second restraint current formula is selected, under zero load conditions, the restraint current will be equal to the differential current divided by 2.

In any case, both sensitivities should always be greater than 0.15 per unit. Typical sensitivity values range from 0.2 to 0.3 per unit.

The steady state capacitive current is calculated as:

$$I_C(A) = \frac{V_{nom}(V)}{\sqrt{3}} \cdot y(S/km) \cdot L(km)$$

Where:

Ic	is the capacitive current in amps
Vnom	is the line nominal voltage in volts
y	is the susceptance in Siemens per unit length
L	is the length of the line

Example: let us assume a 110 kV cable with susceptance B=95 uS/Km and a length of 10 km. Capacitive current will be:

$$I_C(A) = \frac{110 \cdot 10^3(V)}{\sqrt{3}} \cdot 95 \cdot 10^{-6}(S/km) \cdot 10(km) = 60{,}33\ A\ primary$$

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- **First Restraint Slope**

The object of the **First Restraint Slope** is to compensate for percentage errors, as a function of the current flow. Said errors are generated by the operation of the tap changer (in case there is a transformer in the protection zone), by CTs (in the unsaturated condition), by communications channel asymmetry (unequal forward and reverse times) and by the relay itself. It is worth mentioning that capacitive current has already been taken into account when setting the sensitivity, for which the maximum steady state capacitive current is calculated. This will occur under minimum load conditions, with nominal voltage. On external faults, as the voltage drops, the capacitive current will be smaller.

When there is a transformer in the protection zone and the first restraint current formula is to be used and the sensitivity has been set to compensate for the magnetizing current of the transformer, the ***First Slope Start*** must be set to 0. If the second restraint formula is used, the start of the second slope must be set to the value of the ***Sensitivity*** divided by 2.

The following describes how to calculate the generated phase difference due to a permanent asymmetry in the communication channel. In degrees this error will be:

$$\phi = (t_{go} - t_{return}) \cdot 180 \cdot f_{nom}$$, where

T_{go} - T_{return} is the difference between forward and reverse times in seconds
f_{nom} is the nominal frequency in Hertz

Said phase difference, φ, generates a differential current: $I_{diff} = 2 \cdot sen\left(\frac{\varphi}{2}\right) \cdot I$ where

I is the current flow at both ends of the line.

Example

Let us assume a communications system with a difference between forward and reverse channel times of 1 ms. Then:

$$\phi = 0.001 \cdot 180 \cdot 50 = 9^{o}$$

Assuming:

$$I_{diff} = 2 \cdot sen\left(\frac{9}{2}\right) \cdot I = 0.16 \cdot I$$

$$I_{rest} = I$$

$$I_{diff} = 0.16 \cdot I_{rest}$$

The error caused by the asymmetry is therefore 16%.

The error introduced by **CTs** depends on their accuracy class. For a TI 5P a maximum error of 5% can be considered. Assuming the errors of the CTs at both ends of the line have opposite signs, a 10% total error will be considered. The error introduced by the **relay** will be less than 5%.

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Allowing a safety margin, in this example the first restraint slope may be set to 35%.

If the sensitivity has been set to compensate only for line capacitive current, the ***First Slope Start*** must be set to the minimum value: 0 A.

- **Second Restraint Slope**

The ***Second Slope Start*** must be calculated taking into account the minimum current, in external fault conditions, which may cause saturation of any of the CTs. The restraint slope will be set to compensate for the differential current generated in this condition. A value of 75% is usually adequate, taking into account that the External Fault Detector provides great security on external faults with saturation of some CTs.

- **Harmonic Restraint or Blocking**

Harmonic Restraint or Blocking is mainly used when there is a transformer in the protection zone. The percentage of the 2nd harmonic restraint and blocking is normally set to 20% for both. The percentage of the 5th harmonic restraint and blocking is recommended to 35% for both. Although harmonic restraint is more restrictive than phase-to-phase harmonic blocking, it does not include cross-blocking logic. Therefore, the use of harmonic blocking versus harmonic restraint is recommended.

With respect to the cross blocking logic, it is recommended to use the **2 of 3** logic if the transformer has some delta winding and the energization of it is done through the wye. Otherwise, the use of the **Three-Phase Sum** logic is recommended.

The restraint by 3rd harmonic is not applicable when the transformer has a delta connection, since this acts as a filter of said harmonic.

- **Pickup Value of the Unrestrained Differential Unit**

Since the unrestrained differential unit aint does not present neither harmonic restraint nor blocking, its pickup value must be greater than the maximum differential current generated under power transformer saturation conditions. The most unfavorable situation is usually the energizing. The maximum magnetization current during saturation will occur at maximum flux. Considering a maximum continuous flux component (2 * Φrated: closing at zero crossing voltage) and a maximum residual flux (0.8 * Φrated), the maximum operating flux can be equal to 2.8 * Φrated. If the magnetization curve of the machine is known, the magnetization current corresponding to said flux value can be obtained. The pickup of the instantaneous differential unit must be greater than this current. A value of 8 pu is usual.

- **Zero Sequence Filter**

The zero-sequence filter must be enabled in case of the existence of a transformer in the protection zone in all grounded wye windings, if there is a delta winding. If there is any artificial earthing within the protection zone on the delta winding side, it is also necessary to enable the zero-sequence filter on the delta side. When the connection group is wye-zig-zag or delta-zig-zag it will be necessary to enable the zero-sequence filter on the zig-zag side.

In general, for wye-to-wye transformers it is not required to enable the zero-sequence filter, except in the case of a three-phase transformer with three legs. In that case, because of the reduced reactance of zero sequence magnetization (due to the high reluctance that the zero-sequence flow presents), a considerable zero sequence differential current can be generated. Therefore, the zero-sequence filter must be enabled in both windings.

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2.1.11.d Ground Differential Element

- **Sensitivity**

It is calculated based on ground capacitive current under minimum load conditions. In this situation a small ground voltage may be generated in untransposed lines. Said capacitive current will be calculated as: $IN_C(A) = 3 \cdot V0(V) \cdot y0(S/km) \cdot L(km)$, where:

INc is the ground capacitive current in amp.
V0 is the zero sequence voltage under minimum load conditions in volt.
y0 is the zero sequence admittance in Siemens per unit length.
L is the length of the line.

The ground capacitive current increases as the ground current increases, as the neutral to ground voltage is proportional to this current. As the error introduced by ground capacitance is proportional to the current flow this will be compensated by means of the first restraint slope (see next section).

During line energization a ground capacitive current will be produced greater than the steady state current. The **Close-onto-Fault Sensitivity** will be set to the same value as the close onto fault sensitivity of the phase differential element.

Normal **Sensitivity** will be set to 2 times the above calculated value or 15% of the nominal current.

- **First restraint slope**

The function of the **First Restraint Slope** is to compensate for percentage errors, as a function of the current flow. Said errors are generated by the capacitive current, by CTs (in the unsaturated condition), by communications channel asymmetry (unequal forward and reverse times) and by the relay itself.

The percentage error introduced by the **capacitive current** is calculated as follows: $IN_C(A) = 3 \cdot V0 \cdot y0 \cdot L$, taking into account that:

- For forward fault: $V0 = -I0 \cdot (Z0SL)$, where Z0SL is the zero sequence impedance of the local source
- For reverse fault: $V0 = I0 \cdot (Z0SR + ZL0)$ where Z0SR is the zero sequence impedance of the remote source and ZL0 is the zero sequence impedance of the line

It can be considered that: $V0 = I0 \cdot K$ where $K = max(Z0SR + ZL0, ZS0)$.

If the following approximation is made:

$$IN_{diff} = 3 \cdot K \cdot y0 \cdot L \cdot I0$$

$$IN_{rest} = 3 \cdot I0$$

The percentage of error introduced by the capacitive current will be $K \cdot y0 \cdot L$

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Example

Assuming a system with the following impedances:

Z0SL = 5 ohm
Z0SR = 8 ohm
Z0L = 12 ohm
y0 = 70 us/km
L = 10 km

K = 12 ohm

K*y0*L = 0.014

The percentage error introduced by the capacitive current will be 1.4%.

The calculation of the percentage error introduced by CTs, by communications channel asymmetry and by the relay will be the same as for the phase differential element. Said errors will be added to the error introduced by line capacitance.

The beginning of the first slope will be set to the minimum value (0 A).

2.1.11.e Positive Sequence Differential Unit

The setting criteria for the positive sequence differential unit will be the same as those described for the phase differential unit. If capacitive current compensation is enabled, it is recommended that the ***Open Pole Sensitivity*** setting be set to the same value as the ***Differential Sensitivity*** setting.

2.1.11.f Negative Sequence Differential Unit

The setting criteria of the negative sequence differential element will be the same as for the ground differential element simply by replacing the zero sequence network by the negative sequence network. The factor 3 to convert zero sequence current into ground current will not be used.

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2.1.12 Examples

2.1.12.a Example of Settings Calculation for Lines

Consider an overhead line with the following characteristics:

Length	235,7 km
Nominal Voltage	400 kV
CT ratio	1000/1 A
VT ratio	400000/110 V
Nominal Power	500MVA

$$I = \frac{P}{\sqrt{3} \cdot V} = \frac{500\ MVA}{\sqrt{3} \cdot 400\ kV} = 721.6\ A\ pri \rightarrow 0.7216\ A\ sec$$

Line parameters per kilometer	
Positive sequence resistance (R1)	0.02897 Ω
Positive sequence reactance (X1)	0.3072 Ω
Zero sequence resistance (R0)	0.2597 Ω
Zero sequence reactance (X0)	1.0223 Ω
Positive sequence susceptance (B1)	3.63 µS
Zero sequence susceptance (B0)	2.347 µS

Other parameters	
Minimum external fault current that saturates measurement transformers	5000 A
Zero sequence voltage at minimum load conditions	0.02% Vn

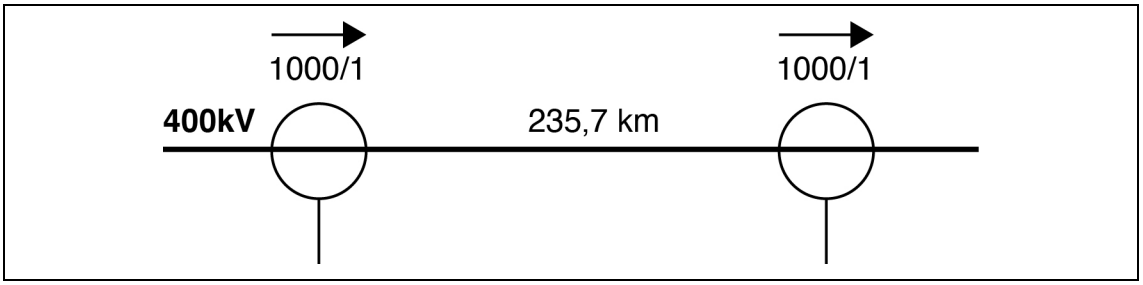


Figure 2.1.19 Example of settings calculation for an overhead line.

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General Settings	
Phase 1 CT Ratio	1000/1 = 1000
Phase 2 CT Ratio	1000/1 = 1000
Phase 3 CT Ratio	1000/1 = 1000
Ground CT Ratio	1000/1 = 1000
Phase VT Ratio	400kV/110 = 3636
Reference Angle	VA
	Minimum voltage value: 0.5 V
	Minimum current value: 0.02 A
Invert Polarity	NO

System Impedances	
Line Sections	Section E1E2: YES Section E1M1: NO Section M1E2: NO Section M1M2: NO Section M1E3: NO Section M2E2: NO
Section Impedances	Leave by default as only section E1E2 exists. It is completed in the Line Impedances section.
Line Impedances For positive sequence impedance: 0.02897 + 0.3072 j ohm/km -> 0.4222 ∟84.612° For zero sequence impedance: 0.2597 + 1.0223 j ohm/km -> 0.3127 ∟75.74° Z2/Z1 = (110·1000) / (400000·1) = 0.275 Y2/Y1 = 1/(Z2/Z1) = 3.636	
Positive sequence impedance module	0.4222 ohm/L
Positive sequence impedance angle	84.612°
Zero sequence impedance module	0.3127 ohm/L
Zero sequence impedance angle	75.74°
Positive sequence susceptance	3.63 uS/L
Zero sequence susceptance	2.347 uS/L
Line length	235.7

Fault Locator	
Length units	Kilometers
Locator units	% of length
Indication zone	Internal faults

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Line Protection	
General	
Type of tap	Automatic
Power	500 MVA
Voltage 1	400 kV
Voltage 2	400 kV
Restraint type	I1+I2-Id/2
Transformer in protection zone	NO
Capacitive current compensation	YES (long-distance HV line)
Differential current measurement	Times tap
Communications	
Local E1 Address	11
Local E2 Address	12
External synchronization	NO
Channels	
Channel 1	
Enable	SÍ
Remote end	E2
Main port	Puerto 1
Redundancy port	Puerto 2
Transmission Current Groups	I1
Receiving Current Groups	Current A: I2 Current B: None
Channel 2	
Enable	NO
Ports	
Port 1	
Connection type	Point to point
Clock data transmission type	Generated clock (the opposite end should be configured as Recovered clock).
Port 2	
Connection type	Point to point
Clock data transmission type	Generated clock (the opposite end should be configured as Recovered clock).

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Phase Differential	
Differential	
Diff Enable	YES
Sensitivity: Greater than 15% In and above the steady state capacitive current of the line. 15% In: 0.15·721.6 = 108.2 A (primary) -> 0.1082 A (secondary). I capacitive: B1·L·U = 0.00000363 · 235.7 · (400000/√3) = 197.6 A (primary) -> 0.1976 A (secondary). max (0.1082; 0.1976) = 0.1976 In rounded pu: 0.2 pu or xtap (equal to the maximum value of the capacitive current when compensation is enabled).	
Sensitivity COF: 1.5 times if capacitive compensation is enabled, 3 times if not. If the value of the capacitive current is very low with respect to 15% of In, then it can be set the same as the Sensitivity. In pu: 1.5 - 0.2 = 0.3 pu.	
Slope 1	considering CTs errors + equipment error + safety coefficient: 35
Slope 1 Start	0
Slope 2	75%
Slope 2 Start	External fault minimum current for CT saturation: 5000/721.68 ≈ 7 pu or xtap.
External Fault Block Enable	YES
Harmonic Restraint and Blocking	NO
Differential Time Delay	0 s.
Instantaneous Differential	
Enable	NO

Neutral Differential	
Sensitivity: Greater than 15% In and greater than 2 times I capacitive in neutral regime of the line. 3·400kV·0.0002·2.347µS ·235.7 = 0.132 pu Max(0.15; 2·0.132) = 0.265 pu or xtap	
Sensitivity COF: 1.5 times if capacitive compensation is enabled, 3 times if not. 1.5·0.265 = 0.4 pu or xtap	
Open Pole Sensitivity: It is not used because it has capacitive current compensation enabled.	
Slope 1: The percentage error introduced by the capacitive intensity is negligible due to the length of the line. It is adjusted, then, equal to the criterion for the phase differential. 35%.	
Slope 1 Start	0
External Fault Block Enable	YES

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Positive Sequence Differential	
Sensitivity	Same phase differential: 0,.2 pu or xtap
Sensitivity COF	Same phase differential: 0.3 pu
Open Pole Sensitivity	Same as sensitivity when capacitive current compensation is activated: 0.2 pu
Slope 1	35%
Slope 1 Start	0
External Fault Block Enable	YES

Negative Sequence Differential	
Sensitivity	Same neutral differential. 0.15 pu or xtap
Sensitivity COF	Same neutral differential. 0.225 pu or xtap
Open Pole Sensitivity	Not used because capacitive current compensation is enabled.
Slope 1	35%
Slope 1 Start	0
External Fault Block Enable	YES

External Fault Detector	
Enable	YES
Current Minimum Level	1.2. Above maximum load.
Angle for Phase Directional Comparison Unit	110º
Angle for Positive Sequence Directional Comparison Unit	110º
Blocking Logic Slope 1	2 OUT OF 3

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2.1.12.b Examples of Settings Calculation for Transformers in the Protection Zone

These examples focus on setting the protection to protect a transformer within the protection zone. The line parameters are not considered to simplify the examples.

- **Example 1**

A power transformer with two windings of 40MVA and transformer ratio of 132kV / 20kV, connection group YD11 and extreme tap of high side of 13.2kV:

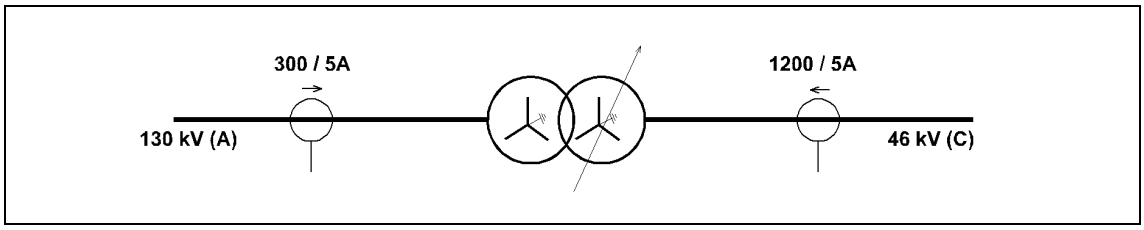


Figure 2.1.20 Example 1 of Settings Calculations for Connection Groups.

Tap Calculations

To determine the tap of the relay, calculate the primary currents corresponding to the maximum power of the machine, for each winding, using the following formula:

$$\text{Current} = \frac{\text{MaxPower(kVA)}}{\text{Voltage(kV)} \cdot \sqrt{3}}$$

Calculate the current of each winding and tap:

HV side (130 kV) (A): $IA = \frac{60{,}000\ \text{kVA}}{130\ \text{kV} \cdot \sqrt{3}} = 266.8\ \text{A}$

MV side: For this case we take the minimum, middle and maximum values.

Extreme minimum tap position: 43.7 kV (B): $IB = \frac{60{,}000\ \text{kVA}}{43.7\ \text{kV} \cdot \sqrt{3}} = 793.6\ \text{A}$

Middle tap position: 46 kV (C): $IC = \frac{60{,}000\ \text{kVA}}{46\ \text{kV} \cdot \sqrt{3}} = 754\ \text{A}$

Extreme maximum tap position: 48.3 kV (D): $ID = \frac{60{,}000\ \text{kVA}}{4.3\ \text{kV} \cdot \sqrt{3}} = 718\ \text{A}$

The ratio of the current transformers is:

HV side (130 kV): 300 / 5 A ; CT Ratio = 60
MV side (46 kV): 1200 / 5 A ; CT Ratio = 240

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The currents viewed by the relay, for the different taps, are the following:

$$Is\,(A)=\frac{266,8}{60}=4.45\ A \qquad Is\,(C)=\frac{750}{240}=3.14\ A$$

$$Is\,(B)=\frac{793.6}{240}=3.30\ A \qquad Is\,(D)=\frac{718}{240}=2.99\ A$$

Relay Tap Setting

130 kV (A) side: 4.45 A
46 kV (C) side: 3.14 A. In the tap positions for: 43.7 kV and 48.3 kV: 3.14 A

Differential Current

The difference between the setting and the value of the differential current is:

H.V. side 130 kV (A): Differential current = 4.45 - 4.45 = 0

M.V. side:

Minimum tap position: 43.7 kV (B): Differential current = 3.30 - 3.14 = 0.16 A
Middle tap position: 46 kV (C): Differential current = 3.14 - 3.14 = 0 A
Maximum tap position: 48.3 kV (D): Differential current = 3.14 - 2.99 = 0.15 A

Restraint Current

Defined as the smallest of the currents (if ***Restraint Current Type*** setting is: 1 - IRest: (I1+I2-Id)/2, within the differential element protection settings group), when they circulate in the same direction:

Minimum tap: 43.7 kV (B): 3.30 A
Middle tap: 46 kV (C): 3.14 A
Maximum tap: 48.3 kV (D): 2.99 A

Error Setting

We define this error as the quotient of the differential current and the restraint current:

Minimum tap: 43,7 kV (B): $\frac{0.16}{3.30}=0.048\,;4.8\,\%$

Middle tap: 46 kV (C): $\frac{0}{3.14}=0$

Maximum tap: 48.3 kV (D): $\frac{0.15}{2.99}=0.05\,;5\,\%$

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Calculating the Slope 1

To determine the Slope, we should consider: current transformer errors, the error in the different taps (due to the voltage regulation), and the drain current.

C.T. errors:	10% (assuming errors of 5% in each winding and opposite sign)
Drain Current:	2%
Setting error:	5%
Equipment error:	5%
Total:	22%

Recommended Setting: **25%**

Calculating the Slope 2

The Second Slope must be set based on the maximum residual current on external fault, as a result of saturation of a CT and the corresponding restraint current. A setting value of 75% is recommended.

The slope initiation will be determined by the minimum restraint current for which CTs can be saturated.

Sensitivity

It is recommended that the differential sensitivity be adjusted to 30% of the tap value of the reference winding. In the example it would be 30% of the primary winding:

This setting must be entered as times the reference tap, thus the value of said setting is directly **0.3**. This value is equivalent to a value in amps 0.3 x 4.45 A = 1.34 A.

Instantaneous Unit

An adjustment of **8 times the tap value** (of the reference winding) is recommended.

2nd and 5th Harmonic Restraint / Blocking

It is recommended to set the 2nd harmonic to 20% and the 5th harmonic to 35%.

Zero Sequence Filter

Based on the recommendations of section 2.1.11, enabling the Zero Sequence Filter would only be required if it is a three core transformer.

In case that the Zero Sequence Filter is active in both windings, the operation of the IED is not affected and will not operate under external faults.

Connection Group

The **DLF** equipment performs angle compensation internally. To do this, the connection group for each winding, the hour index and the zero sequence filter are entered:

Winding # 1		**Winding # 2**	
WYE Connection	**Y**	WYE Connection	**Y**
Zero Sequence Filter	**NO**	Hour Index	**0**
Zero Sequence Filter Type*	**0: Phase Channels**	Zero Sequence Filter	**NO**
		Zero Sequence Filter Type *	**0: Phase Channels**

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- **Example 2**

A power transformer with two windings of 40MVA and transformer ratio of 132kV / 20kV, connection group YD11 and extreme tap of high side of 13.2kV:

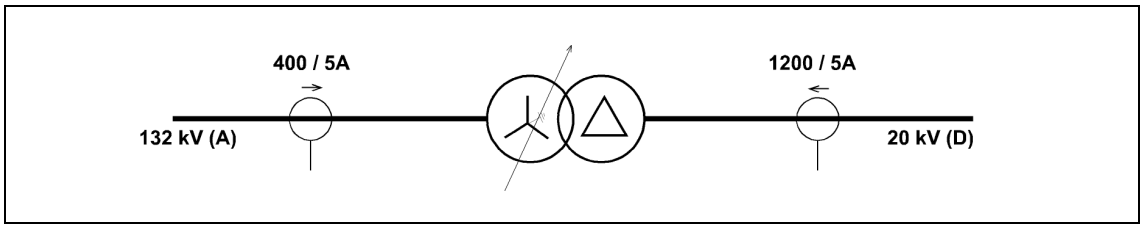


Figure 2.1.21 Example 2 of Settings Calculations for Connection Groups.

Tap Calculations

To determine the tap of the relay, calculate the primary currents corresponding to the maximum power of the machine, for each winding, using the following formula:

$$\text{Current} = \frac{\text{MaxPower(kVA)}}{\text{Voltage(kV)} \cdot \sqrt{3}}$$

In this case we take the minimum, middle, and maximum tap values:

HV side (132 kV) (A):

Middle tap position: 132 kV (A): $IA = \frac{40{,}000\ \text{kVA}}{132\ \text{kV} \cdot \sqrt{3}} = 175.16\ \text{A}$

Maximum tap position: 145.2 kV (B): $IB = \frac{40{,}000\ \text{kVA}}{145.2\ \text{kV} \cdot \sqrt{3}} = 159.23\ \text{A}$

Minimum tap position: 118.8 kV (C): $IC = \frac{40{,}000\ \text{kVA}}{118.8\ \text{kV} \cdot \sqrt{3}} = 194.24\ \text{A}$

MV side: Calculate the tap value: $ID = \frac{40{,}000\ \text{kVA}}{20\ \text{kV} \cdot \sqrt{3}} = 1154.70\ \text{A}$

The ratio of the current transformers is:

HV side (132 kV): 400 / 5 A ; CT Ratio = 80
MV side (20 kV) : 1200 / 5 A ; CT Ratio = 240

The currents viewed by the relay, for the different taps, are the following:

$\text{Is}(A) = \frac{175.16}{80} = 2.1895\ \text{A}$ (Middle tap value)

$\text{Is}(B) = \frac{159.23}{80} = 1.9903\ \text{A}$ (Maximum tap value)

$\text{Is}(C) = \frac{194.24}{80} = 2.428\ \text{A}$ (Minimum tap value)

$Is\,(D) = \frac{1154{,}70}{240} = 4.81\ A$ (M.V. side)

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Relay Tap Setting

132 kV (A) side: 2.19 A. In the tap positions for: 118.8 kV and 145.2 kV :2.19 A
20 kV (D) side: 4.81 A.

Differential Current

The difference between the setting and the value of the differential current is:

H.V. side 130 kV (A): Differential current = 4.45 - 4.45 = 0

Minimum tap position: 118.8 kV (C): Differential current = 2.428 - 2.19 = 0.238 A
Middle tap position: 132 kV (A): Differential current = 2.19 - 2.1895 = 0.0005 A
Maximum tap position: 145.2 kV (B): Differential current = 2.19 - 1.9903 = 0.197 A

M.V. side: Differential current = 4.81 - 4.81 = 0 A

Restraint Current

Defined as the smallest of the currents, when they circulate in the same direction (if ***Restraint Current Type*** setting is: 1 - IRest: (I1+I2-Id)/2, within the differential element protection settings group):

Minimum tap: 118.8 kV (C): 2.42 A
Middle tap: 132 kV (A): 2.19 A
Maximum tap: 145.2 kV (B): 1.99 A

Error Setting

We define this error as the quotient of the differential current and the restraint current:

Minimum tap: 118.8 kV (C): $\frac{0.238}{2.42} = 0.098 ; 9.8\,\%$

Middle tap: 132 kV (A): $\frac{0}{2.19} = 0$

Maximum tap: 145.2 kV (B): $\frac{0.197}{1.99} = 0.099 ; 9.9\,\%$

Calculating the Slope 1

To determine the Slope, we should consider: current transformer errors, the error in the different taps (due to the voltage regulation) and the drain current.

C.T. errors: 10%
Drain Current: 2%
Setting error: 9.9%
Equipment error: 5%

Total: 26.9%

Recommended Setting: **30%**

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Calculating the Slope 2

The Second Slope must be set based on the maximum residual current on external fault, as a result of saturation of a CT and the corresponding restraint current. A setting value of 75% is recommended.

The slope initiation will be determined by the minimum restraint current for which CTs can be saturated.

Sensitivity

It is recommended that the differential sensitivity be adjusted to 30% of the tap value of the reference winding. In the example it would be 30% of the primary winding:

This setting must be entered as times the reference tap, thus the value of said setting is directly **0.3**. This value is equivalent to a value in amps 0.3 x 2.19 A = 0.657 A

Instantaneous Unit

An adjustment of **8 times the tap value** (of the reference winding) is recommended.

2nd and 5th Harmonic Restraint / Blocking

It is recommended to set the 2nd harmonic to 20% and the 5th harmonic to 35%.

Zero Sequence Filter

During an external fault to ground, on a HV grounded wye winding and a delta secondary winding, zero sequence current will show in the phase currents of the wye winding, without zero sequence current measured on the delta side. For this reason, it is necessary to activate the Zero Sequence Filter on the side of the wye. Activating the filter avoids unwanted trips caused by "false" differential currents.

If the zero sequence filters are active in both windings, the relay operation would remain correct, not tripping in the presence of an external fault.

Connection Group

The **DLF** equipment performs angle compensation internally. To do this, the connection group for each winding, the hour index and the zero sequence filter are entered:

Winding # 1		**Winding # 2**	
WYE Connection	**Y**	DELTA Connection	**D**
Zero Sequence Filter	**YES**	Hour Index	**11**
Zero Sequence Filter Type*	**0: Phase Channels**	Zero Sequence Filter	**NO**
		Zero Sequence Filter Type*	**0: Phase Channels**

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- **Example 3**

Consider a three-winding power transformer with the following transformation ratio 220 kV / 132 / 45 kV ± 1150 V (9 taps), with the following powers associated to each winding 50 MVA / 50 MVA / 25 MVA, vector group YYY0.

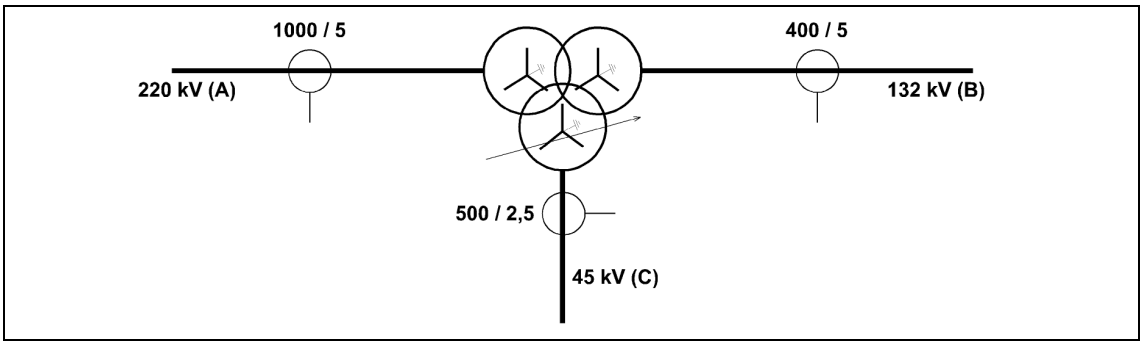


Figure 2.1.22 Example 3 of Settings Calculations for Connection Groups.

Tap Calculations

Relay taps are base secondary currents, allowing the differential unit to operate with element currents comparable to each other. Although the power of the third winding is smaller than for the other windings, calculation of the tap corresponding to said winding must be carried out using the base power considered for the tap calculation of the other windings. As a general rule, tap calculation, for any winding, must be based on the maximum power of the machine.

To determine the tap of the relay, calculate the primary currents corresponding to the maximum power of the machine, for each winding, using the following formula:

$$\text{Current} = \frac{\text{MaxPower(kVA)}}{\text{Voltage(kV)} \cdot \sqrt{3}}$$

Current calculations for each winding and tap:

220 kV Side (A): $IA = \frac{50{,}000\ \text{kVA}}{220\ \text{kV} \cdot \sqrt{3}} = 131.2\ \text{A}$

132 kV Side (B): $IB = \frac{50{,}000\ \text{kVA}}{132\ \text{kV} \cdot \sqrt{3}} = 218.7\ \text{A}$

45 kV Side (C): For this case, minimum, medium and maximum tap values will be taken:

Minimum end tap: 40.4 kV (D): $ID = \frac{50{,}000\ \text{kVA}}{40.4\ \text{kV} \cdot \sqrt{3}} = 714.5\ \text{A}$

Medium tap: 45 kV (C): $IC = \frac{50{,}000\ \text{kVA}}{45\ \text{kV} \cdot \sqrt{3}} = 641.5\ \text{A}$

Maximum end tap: 49.6 kV (E): $IE = \frac{50{,}000\ \text{kVA}}{49.6\ \text{kV} \cdot \sqrt{3}} = 582\ \text{A}$

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The ratio of the current transformers is:

220 kV Side: 1000 / 5 A ; CT Ratio = 200
132 kV Side: 400 / 5 A ; CT Ratio = 80
45 kV Side: 500 / 2.5 A ; RT.I. = 200

The currents viewed by the relay, for the different taps, are the following:

$$Is\,(A)= \frac{131.2}{200}= 0.66\ A \qquad Is\,(C)= \frac{641.5}{200}= 3.20\ A$$

$$Is\,(B)= \frac{218.7}{80}= 2.73\ A \qquad Is\,(D)= \frac{714.5}{200}= 3.57\ A$$

$$Is\,(E)= \frac{582}{200}= 2.91\ A$$

Relay Tap Setting

220 kV Side (A): 0.66 A
132 kV Side (B): 2.73 A
46 kV Side (C): 3.20 A (Middle tap position)

Differential Current

The difference between the setting and the value of the differential current is:

220 kV Side (A): Differential Current = 0.66 - 0.66 = 0
132 kV Side (B): Differential Current = 2.73 -2.73 = 0

45 kV Side (B):

Minimum tap position: 40.4 kV (D) Differential current = 3.57 - 3.20 = 0.37 A
Middle tap position: 45 kV (C): Differential current = 3.20 - 3.20 = 0 A
Maximum tap position: 145.2 kV (E): Differential current = 3.20 - 2.91 = 0.29 A

Restraint Current

Defined as the smallest of the currents, when they circulate in the same direction (if ***Restraint Current Type*** setting is: 1 - IRest: (I1+I2-Id)/2, within the differential element protection settings group):

Minimum tap: 40.4 kV (D): 3.57 A
Middle tap: 45 kV (C): 3.20 A
Maximum tap: 49.6 kV (D): 2.91 A

Error Setting

We define as the ratio between the differential current and the pass through current:

Minimum tap: 40.4 kV (B): $\frac{0.37}{3.57}= 0.103\ ;\ 10.3\,\%$

Middle tap: 45 kV (C): $\frac{0}{3.20}= 0$

Maximum tap: 49.6 kV (D): $\frac{0.29}{2.91}= 0.099\ ;\ 9.9\,\%$

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Calculating the Slope 1

To determine the Slope, we should consider: current transformer errors, the error in the different taps (due to the voltage regulation) and the drain current.

C.T. errors:	10%
Drain Current:	2%
Setting error:	10.3%
Equipment error:	5%
Total:	27.3%

Recommended Setting: **30%**

Calculating the Slope 2

The second slope must be set based on the maximum residual current on external fault, as a result of saturation of a CT and the corresponding restraint current. A setting value of 75% is recommended.

The slope initiation will be determined by the minimum restraint current for which CTs can be saturated.

Sensitivity

It is recommended that the differential sensitivity be adjusted to 30% of the tap value of the reference winding. In the example it would be 30% of the primary winding:

This setting must be entered as times the reference tap, thus the value of said setting is directly **0.3**. This value is equivalent to a value in amps 0.3 x 0.66 A = 0.198 A.

Instantaneous Unit

An adjustment of **8 times the tap value** (of the reference winding) is recommended.

2nd and 5th Harmonic Restraint / Blocking

It is recommended to set the 2nd harmonic to 20% and the 5th harmonic to 35%.

Zero Sequence Filter

The Zero Sequence Filter need not be activated as, on ground faults external to the machine, both windings being grounded Y, zero sequence current will flow through both windings. Therefore, the Differential Unit will not measure false differential current that would have caused a trip on external fault.

In any case, if zero sequence filters are active in both windings, the device operation will still be correct, and it does not trip on external fault.

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Connection Group

The **DLF** equipment performs angle compensation internally. To do this, the connection group for each winding, the hour index and the zero sequence filter are entered using the HMI:

Winding # 1	
WYE Connection	**Y**
Zero Sequence Filter	**NO**
Zero Sequence Filter Type *	**0: Phase Channels**

Winding # 2	
WYE Connection	**Y**
Hour Index	**0**
Zero Sequence Filter	**NO**
Zero Sequence Filter Type *	**0: Phase Channels**

Winding # 3	
WYE Connection	**Y**
Hour Index	**0**
Zero Sequence Filter	**NO**
Zero Sequence Filter Type *	**0: Phase Channels**

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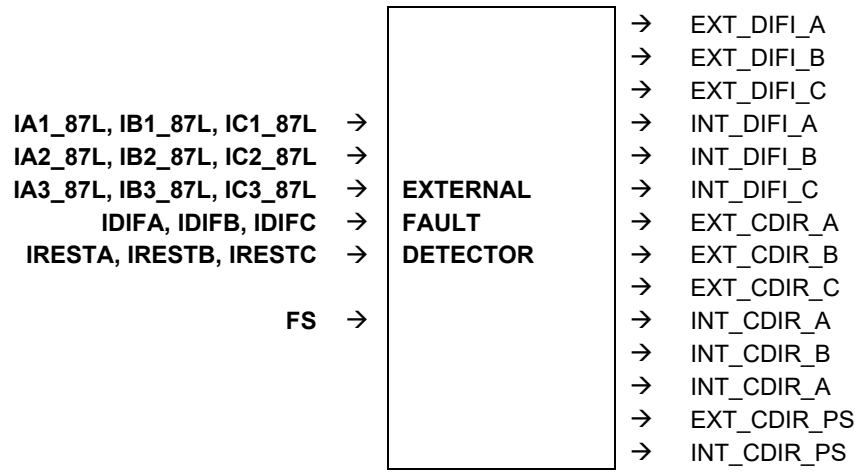
2.2 External Fault Detector

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2.2.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
External Fault Detector	EFDPDIF		

2.2.2 General Block



2.2.3 Operating Principles

A very severe saturation on a current transformer can generate, in the presence of an external fault, differential current and restraint values that trip the differential unit, despite the double slope percentage characteristic included. To increase security, the external fault detection unit allows to block the differential units. This unit is formed by three subunits:

- Differential unit with instantaneous values.
- Phase Directional Comparison unit.
- Positive Sequence Directional Comparison unit.

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2.2.4 Differential Unit with Instantaneous Values

This element compares both differential and restraint instantaneous currents. When the fault is external, and no CT is saturated, instantaneous differential current will be practically non-existent. As a consequence of CT errors, the tap changer operation, magnetization current, relay errors, etc., the geometrical position of the point (*idiff*, *irest*), where *idiff* and *irest* represent differential and restraint instantaneous currents respectively, will not be abscissa axis, but rather a gradient line equal to the error percentage introduced by the above-mentioned factors: *idiff<k*irest*, where **k** is an internal parameter (non-settable) that represents this error percentage.

When a fault takes place that saturates a CT, time will lapse, from the moment this takes place, until the CT is saturated. During this period of time, if the fault is external, the *idiff<k*irest* ratio will apply. Activation of this condition during a consecutive sampling number, will activate the signal **External Fault by Differential Unit with Instantaneous Values**. If, on the other hand, the fault is internal, the *idiff<k*irest* condition will not apply, even in the non-saturated wave section, hence the above-mentioned signal will never be activated. The differential unit with instantaneous values will operate phase by phase.

The Differential Unit with Instantaneous Values will only check the *idiff<k*irest* condition when the **Fault Start** signal is activated. On the other hand, it will only take into account those restraint current values that exceed the **Sensitivity** setting, when they are increasing.

In multi-phase faults, when the periods without CT saturation on the three phases do not coincide exactly, a false zero sequence current will be generated. The application of the zero-sequence filter generates, in those periods, an important differential current, so the *idif <k * Irest* condition is not fulfilled. The differential unit with instantaneous values must operate with the available information from the fault initiation to the first CT saturation event. Once the external fault signal has been activated, it will remain latched throughout the duration of the fault. In situations of external-internal evolutionary faults, the directional comparison units described below will be responsible for detecting that the fault is internal.

Figure 2.2.1 shows an example of an external fault in a two-winding transformer in which the CT associated with the second winding suffers a very severe saturation. Only phase A is shown. As can be seen, before the CT saturation occurs, the differential current is zero, so the idif / irest ratio is smaller than the internal constant k.

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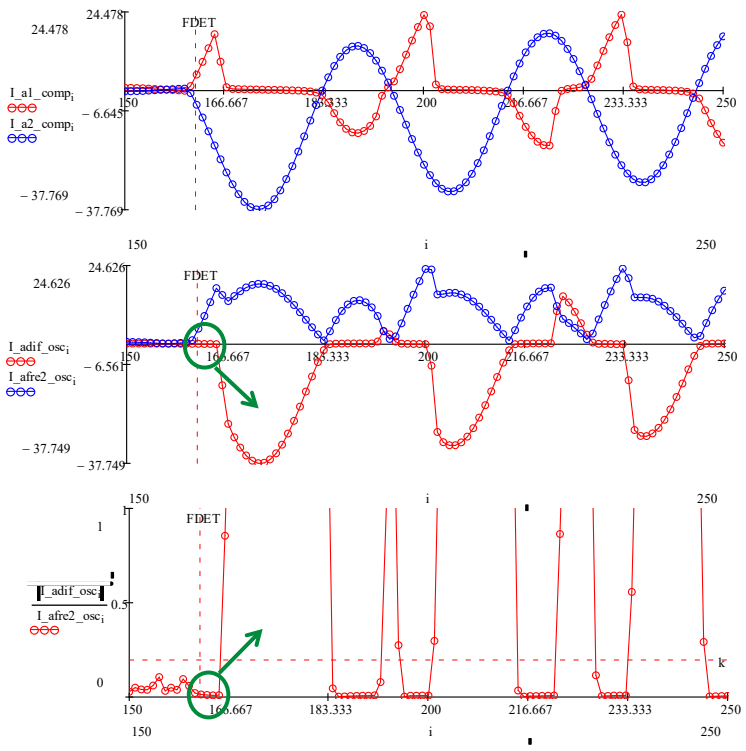


Figure 2.2.1 Example of External Fault with Saturation of the CT associated to the Input Current 1: Phase A Currents; Phase A Differential and Restraint Current; Ratio Between Phase A Differential and Restraint Current.

When the zero sequence filter is enabled, in an external single-phase fault with some CT saturation, healthy phases can trigger. External fault detection in these phases may be delayed if, at the time of fault start activation, the restraint current does not exceed the minimum threshold of 0.3 pu. To avoid this delay, logic 2 of 3 is applied (if the external fault signal is activated in two of the phases, that of the third phase will also be activated). This logic will not be activated during internal faults since the zero sequence filter generates a differential current in the two healthy phases.

In the event of an internal single-phase fault, during the saturation period of a CT, since the current samples can take almost zero values, the instantaneous zero sequence current will be very small. In that case, the differential intensity generated in the healthy phases is almost nil, which could activate logic 2 of 3. To avoid such a situation, the external fault condition will only be activated if 3 consecutive samples of at least one of the considered currents exceed the minimum threshold given by the ***Minimum Current*** setting. That is, if the following condition is met: the current rate-of-change is above Imin*root(2)*2*pi/80 for 3 consecutive samples. A replacement time of 2 samples will be applied to the previous condition (already taken into account for directional phase comparison). For the directional phase comparison, the reset time is 1.25 cycles.

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2.2.5 Phase Directional Comparison Unit

This unit compares the angle of each phase current with the angle of the sum of the rest of the currents of the same phase. That is, compare the angle of IX-n (X = A, B, C, n = 1, 2, 3) with the angle of $\sum_{i=1}^{4} \text{IX-i}$ with i ≠ n.

When the fault is external the two currents compared will be in counter-phase, while if the fault is internal both currents will tend to be in phase. The phase directional comparison unit presents the following algorithm:

External fault phase X: some IX-n current complies: $ANG_DC_PH < \arg(\text{IX-n}) - \arg(\sum_{i=1\ (i\neq n)}^{6} \text{IX-i}) < 360^{o}\text{-ANG_DC_PH}$
Internal fault phase X: some IX-n current complies: $360^{o} - ANG_DC_PH < \arg(\text{IX-n}) - \arg(\sum_{i=1\ (i\neq n)}^{3} \text{IX-i}) < \text{ANG_DC_PH}$

Where ANG_DC_PH represents the ***Phase Directional Comparison Angle*** setting.

Figure 2.2.2 shows the angular relationship between the three currents associated with a power transformer for an external fault. These three currents can represent the currents of each winding of a three-winding transformer or the currents of a two-winding transformer in which one of them is connected to a breaker and a half bay. As can be seen, I1 has 180º with respect to I2 + I3.

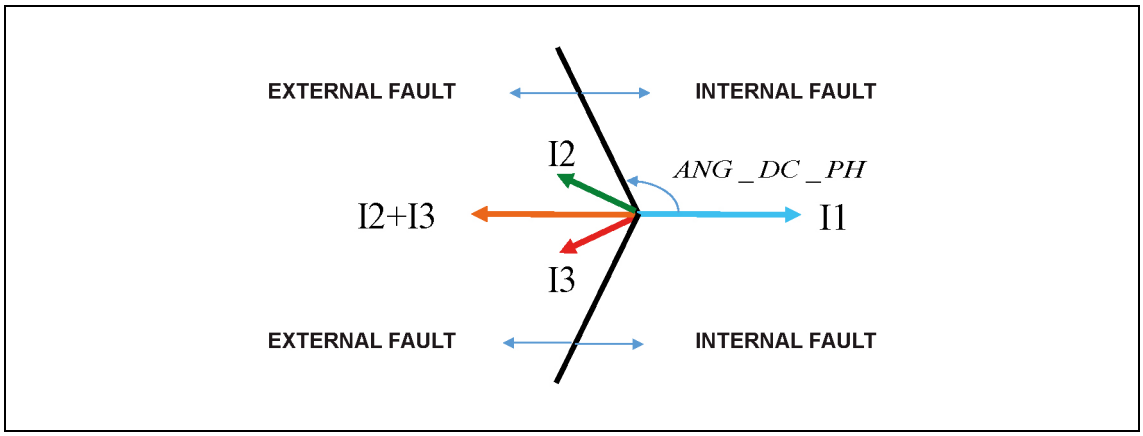


Figure 2.2.2 Angular Relationship of the Three Input Currents to the Differential Unit (Three-Winding Transformer or Two-Winding Transformer with Breaker-and-a-Half in One Side) For an External Fault.

The previous algorithm could activate the external fault signal for internal faults with outfeed (high load faults and weak source at the load receiving end). To avoid the previous situation, there is a minimum threshold for a current to be considered in the directional criterion. This threshold is set by the ***Current Minimum Level*** setting, which must take values above the maximum load that can circulate through the transformer.

If the saturation detector is not activated at either end, the angle used for the directional comparison unit will be the ***Phase Directional Comparison Angle*** setting increased by 20º.

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The phase directional comparison unit will only operate when the **Fault Initiate** signal is activated.

For external faults with very severe saturation of some CT, because of the enabling of the zero sequence filters, it may happen that the directional comparison unit associated with any of the healthy phases activates the internal fault signal. To avoid this condition, when a zero-sequence filter is enabled, applied from the phase currents, the directional comparison unit operates with a logic **2 of 3**: if two phases activate the signal of external fault, the third phase will also activate it, although the comparison of angles indicates otherwise. It should be noted that, for internal single-phase faults, the zero sequence filter will lead to the activation of the internal fault signal in some of the healthy phases, which will prevent the logic **2 of 3** being fulfilled.

The phase directional comparison unit operates with compensated currents, based on the ***Tap***, ***Connection Group*** and ***Zero Sequence Filter*** settings.

2.2.6 Positive Sequence Directional Comparison Unit

The positive sequence directional comparison unit may use the following currents depending on the circumstances of the system:

- Under normal conditions, positive sequence current of pure fault, once the pre-fault current has been subtracted.
- Under anomalous conditions, i.e. when the positive sequence pre-fault current is below the threshold marked by the ***Open Pole Current*** setting, the negative sequence fault current will be used when there is no open pole condition. Otherwise, it will use pure fault negative sequence currents.
- Under zero sequence conditions, the neutral fault current will be used when no open pole condition exists. Otherwise, it will use pure fault neutral currents.

- **Directional Comparison with Positive Sequence Currents**

This unit compares the angles of the pure-fault positive sequence currents measured by all three-phase input channels with the differential unit (I1-1, I1-2, I1-3). To obtain the pure fault component of said current, the relay eliminates the pre-fault current, stored two cycles before the activation of the ***Fault Start*** signal (see Fault Detectors). The use of pure fault currents eliminates the influence of the load, which allows to generate correct directional decisions for internal faults with outfeed.

The pure fault positive sequence component calculation requires the storage of the pre-fault current, which is not available in situations of closing onto fault. The external fault detector will monitor the magnitude of all stored pre-fault currents. If the pre-fault current magnitude of each of the three inputs to the differential unit is below the corresponding ***Open Pole Current*** setting (both local and remote), the directional comparison will be calculated with negative sequence currents. This last algorithm has the limitation of not being able to act on three-phase faults.

Note: the currents of the remote poles can be configured in the Open Pole Unit.

Of all the currents considered by the positive sequence directional comparison unit (positive sequence of pure fault or negative sequence, depending on the conditions) those whose magnitude does not exceed a minimum threshold will be discarded.

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The Positive Sequence Directional Comparison Unit will activate the **External Fault** signal when any of the currents considered by the algorithm are in opposition to the rest. To do this, it must form an angle greater than the ***Positive Sequence Directional Angle*** setting and less than **360º - Positive Sequence Directional Comparison Angle** with respect to the rest. If all the currents considered in the directional criterion tend to be in phase (phase shifts between them greater than **360º -** ***Positive Sequence Directional Comparison Angle*** and less than ***Positive Sequence Directional Comparison Angle***), the unit will activate the internal fault condition.

If the saturation detector is not activated at either end, the angle used for the directional comparison unit will be the ***Positive Sequence Directional Comparison Angle*** setting increased by 20º.

The Positive Sequence Directional Comparison Unit operates with compensated currents, based on the of ***Tap***, ***Connection Group*** and ***Zero Sequence Filter*** settings.

In close onto fault conditions, the Positive Sequence Directional Comparison Unit will not act upon invalidation of the pre-fault direct sequence currents. In that case, the Negative Sequence Directional Comparison Unit shall be used. The closing on fault condition will be detected when the current of all the inputs to the differential unit is below the threshold defined by the ***Minimum Current*** setting of the open pole detector (local and remote currents), one of the mentioned currents exceeds the corresponding threshold.

- **Directional Comparison with Negative Sequence Currents**

If it is not possible to use the positive sequence currents (close onto fault, current magnitude lower than ***Open Pole Current*** setting), the unit will compare the angles of the local and remote negative sequence currents. Since the negative sequence current is pure fault, its use eliminates the influence of the load, allowing correct directional decisions to be generated in the event of internal faults with outfeed.

This directional comparison using inverse sequence currents will only operate if there is no three-phase fault condition (including a reset time of 10 ms) and the three phase currents do not exceed 2*Inom. Whenever the Module of the pre-fault currents of each of the three inputs to the differential unit is below the corresponding ***Open Pole Current*** setting, the pure fault direct sequence currents will be replaced with the inverse sequence currents.

In open pole conditions (single-phase reclosing cycle) the **DLF** equipment eliminates the pre-fault inverse sequence current in order to continue cancelling the effect of the load. To do this, the devices store the negative sequence current 2 cycles before the activation of the **Fault Start** signal.

- **Directional Comparison with Neutral Currents**

The directional neutral comparison is intended to protect lines that have a dominant zero sequence current. Therefore, this comparison will only operate if the phase selector indicates ground fault and I0LINES/I1LINES>1.25 and I0LINES/I2LINES>1.25. Then the pure fault positive sequence currents will be replaced with the neutral currents. This condition requires that the ***Transformer in Protection Zone*** setting be set to NO.

Under open pole conditions (single-phase reclosing cycle) the **DLF** equipments remove the pre-fault neutral current in order to continue to override the load effect. To do this, they store the neutral current 2 cycles before the activation of the **Fault Start** signal.

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- **Blocking Logic of the Phase Differential Unit**

The ***Blocking Logic*** setting indicates the source of the differential units blocking signal, restrained and unrestrained. If the setting is **2 out of 3**, at least two of the three units described above need to activate their external fault condition to generate the blocking signal to the differential units. If the setting is **3 out of 3**, three units need to activate their external fault condition for the blocking signal to become active.

Once the external fault detector output blocking signal has been generated, it will only block the phase differential units if the corresponding settings for ***Ext Fault Block Enable*** are set to YES.

Note: Most of the automatic tests carried out by test sets to test the performance of a restraint differential characteristic, apply currents in two 180 ° phase-shifted windings. This test would continuously activate the external fault signals generated by the directional comparison units, so if the differential unit block enable by external fault detector is set to YES, the relay could never trip. The faults injected by the test set correspond to internal faults (since they generate differential current) with outfeed effect. The phase directional comparison unit would not detect the external fault condition if an appropriate current threshold is chosen. However, the positive sequence directional comparison unit would continuously activate the external fault signal. This would not happen if the test injected a pre-fault value consistent with the fault current (that which generates pure fault currents in both windings practically in phase). If no pre-fault is injected or an unreal pre-fault value is injected, for an internal fault, with respect to the fault value, the differential unit block enable by External Fault Detector must be disabled.

- **Blocking Logic of the Neutral, Positive and Negative Sequence Differential Units (NPQ)**

The blocking logic of the neutral, positive and negative sequence differential units will depend on the ***Zero Sequence Filter*** setting. When this filter is set to "NO", 3 out of 3 of the different units (instantaneous, phase directional and positive sequence values) will be necessary to activate the external fault blocking with the following activation requirements for each unit:

- Phase Directional Comparison: OR of external fault in A, B, C.
- Positive Sequence Directional Comparison: external fault.
- Differential Unit with instantaneous values: external fault OR in A, B, C.

When the ***Zero Sequence Filter*** is set to "YES":

- Phase Directional Comparison: 2 of 3 of external fault in A, B, C.
- Positive Sequence Directional Comparison: external fault.
- Differential Unit with instantaneous values: 2 of 3 of external fault in A, B, C.

As long as no internal fault is activated by directional phase comparison, the blocking signal for the neutral, positive and negative sequence differential units will be generated. Once the output blocking signal is generated from the external fault detector for NPQ differential units, it will only block the neutral, positive and negative sequence differential units if the corresponding ***Ext Fault Block Enable*** setting of each unit are set to YES.

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2.2.7 Differential Unit Blocking Logic

The ***Blocking Logic*** setting indicates the source of the differential units blocking signal, restrained and unrestrained. If the setting is **2 out of 3**, at least two of the three units described above need to activate their external fault condition to generate the blocking signal to the differential units. If the setting is **3 out of 3**, three units need to activate their external fault condition for the blocking signal to become active.

Once the external fault detector output blocking signal has been generated, it will only block the differential units if the corresponding settings for ***Block Enabled by External Fault Detector*** are set to YES.

Note: Most of the automatic tests carried out by test sets to test the performance of a restraint differential characteristic, apply currents in two 180 ° phase-shifted windings. This test would continuously activate the external fault signals generated by the directional comparison units, so if the differential unit block enable by external fault detector is set to YES, the relay could never trip. The faults injected by the test set correspond to internal faults (since they generate differential current) with outfeed effect. The phase directional comparison unit would not detect the external fault condition if an appropriate current threshold is chosen. However, the positive sequence directional comparison unit would continuously activate the external fault signal. This would not happen if the test injected a pre-fault value consistent with the fault current (that which generates pure fault currents in both windings practically in phase). If no pre-fault is injected or an unreal pre-fault value is injected, for an internal fault, with respect to the fault value, the differential unit block enable by External Fault Detector must be disabled.

2.2.8 Setting Ranges

External Fault Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	External Fault Det	PEFD1.LNInSvc	YES / NO		YES
Current Minimum Level	Min. Curr. Level	PEFD1.BlkValA	0.1 - 20 pu	0.01	1.2
Angle for Phase Directional Comparison	Angle for phase DC	PEFD1.PhDirAng	1 - 180º	1º	110º
Angle for Positive-Sequence Directional Comparison	Angle for phase PS	PEFD1.PSeqDirAng	1 - 180º	1º	110º
Blocking Logic	Blocking Logic	PEFD1.BlkLogic	2 out of 3 3 out of 3		3 out of 3

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2.2.9 Analog Inputs to the Unit

The mapping of the physical channels to the protection unit's analog inputs is configurable.

Table 2.2-1: Analog Inputs of the External Fault Detector Module

Name	Description	IEC 61850
IA1_87L	Phase A Current Input 1	MMXU1.AWdg1.phsA
IB1_87L	Phase B Current Input 1	MMXU1.AWdg1.phsB
IC1_87L	Phase C Current Input 1	MMXU1.AWdg1.phsC
IA2_87L	Phase A Current Input 2	MMXU1.AWdg2.phsA
IB2_87L	Phase B Current Input 2	MMXU1.AWdg2.phsB
IC2_87L	Phase C Current Input 2	MMXU1.AWdg2.phsC
IA3_87L	Phase A Current Input 3	MMXU1.AWdg3.phsA
IB3_87L	Phase B Current Input 3	MMXU1.AWdg3.phsB
IC3_87L	Phase C Current Input 3	MMXU1.AWdg3.phsC

2.2.10 Digital Inputs

Table 2.2-2: Digital Inputs to the External Fault Detector Module

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_EXTFLT	Enabling commands	PEFD1.Mod	External Fault Detector Enable Input		Activation of this input puts the External fault Detector into service. It can be assigned to digital inputs by level or to a commands from the communications protocol or from the HMI. The default value of this logic input signals is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.2.11 Auxiliary Outputs and Events of the External Fault Detector Module

Table 2.2-3: Auxiliary Outputs and Events of the External Fault Detector Module

Name	Group	IEC 61850	Description	Vis.	Function
EXT_DIFI_A	Generic Outputs of Protection	PEFD1.OpInstVal	External Fault by Phase A Differential Unit with Instantaneous Values.	I	External fault condition in phase A / B / C detected by differential unit with instantaneous values.
EXT_DIFI_B		PEFD1.OpInstVal	External Fault by Phase B Differential Unit with Instantaneous Values	I	
EXT_DIFI_C		PEFD1.OpInstVal	External Fault by Phase C Differential Unit with Instantaneous Values.	I	
EXT_CDIR_PS		PEFD1.OpPSeqDir	External Fault by Positive-Sequence Directional Comparison Unit.	I	External fault condition detected by the positive-sequence directional comparison unit.
INT_CDIR_PS		PEFD1.IntPSeqDir	Internal Fault by Positive-Sequence Directional Comparison Unit.	I	Internal fault condition detected by the positive-sequence directional comparison unit.
EXT_CDIR_A		PEFD1.OpPhDir	External Fault by Phase A Directional Comparison Unit	I	External fault condition in phase A / B / C detected by the phase directional comparison unit.
EXT_CDIR_B		PEFD1.OpPhDir	External Fault by Phase B Directional Comparison Unit	I	
EXT_CDIR_C		PEFD1.OpPhDir	External Fault by Phase C Directional Comparison Unit	I	
INT_CDIR_A		PEFD1.IntPhDir	Internal Fault by Phase A Directional Comparison Unit	I	Internal fault condition in phase A / B / C detected by the phase directional comparison unit.
INT_CDIR_B		PEFD1.IntPhDir	Internal Fault by Phase B Directional Comparison Unit	I	
INT_CDIR_C		PEFD1.IntPhDir	Internal Fault by Phase C Directional Comparison Unit	I	
BLK_Ext_A		PEFD1.PhsOp	External Fault – Block Differential Unit Phase A	I	Phase Differential (A / B / C) External fault blocking.
BLK_Ext_B		PEFD1.PhsOp	External Fault – Block Differential Unit Phase B	I	
BLK_Ext_C		PEFD1.PhsOp	External Fault – Block Differential Unit Phase C	I	
BLK_Ext_DIF_NPQ		PEFD1.GndOp	External Fault – Block Differential Units Ground and Sequence	I	87NPQ Differential External fault blocking.
BlkLogic2outof3		PEFD1.BlkNPreFlt	External Fault - Block in logic 2 out of 3 - unit positive sequence comparison not used	I	External Fault Block in logic 2 out of 3. Positive sequence comparison unit disabled.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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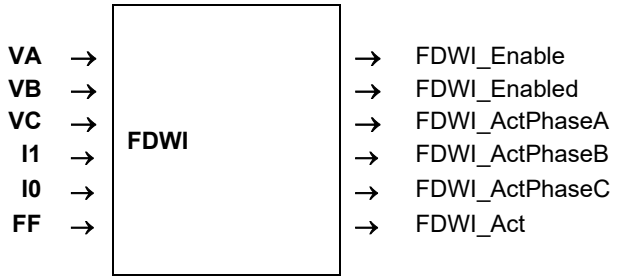
2.3 Weak Infeed Fault Detector

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2.3.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Weak Infeed Fault Detector	WEIRFLO1		

2.3.2 General Block



LEGEND
FF =Fuse Failure

2.3.3 Fault Detector in Weak Infeed Conditions

In weak infeed conditions, the Fault Detector described above may be disabled because the positive and zero sequence current level will be lower than the minimum operating level of the fault detector (0.02*In and Level_I0 respectively). Therefore, a new module called Weak Infeed Fault Detector will be implemented, which will be enabled by the corresponding ***Enable*** setting. In addition to the setting, this module will only work when the following conditions are met (both at the same time):

- The positive sequence current is less than level 0.02*In.
- The zero sequence current is lower than the setting ***Level_I0*** (Phase Selector setting).

If both conditions are met, supervision will be based on the activation of three undervoltage units (one per phase), whose starting level is given by the ***WI Undervoltage Level*** setting (Phase Selector settings). If any of the three phases has a voltage level lower than the setting, the FDWI_ACT signal will be activated, as long as the phase or phases with undervoltage do not have their corresponding open poles or there is no blocking due to a fuse failure. These undervoltage units shall be reset when the voltage level of the phase(s) is 1.05 times higher than the ***WI Undervoltage Level*** setting.

On the other hand, the signals FDWI_ActPhaseA, FDWI_ActPhaseB and FDWI_ActPhaseC will be used as phase selector, in case of weak infeed, for the neutral, positive and negative sequence differential units .

This fault-detection by weak infeed will only affect the differential units and in no case will it affect the distance units.

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2.3.4 Setting Ranges

Weak Infeed Fault Detector Module					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Enable	WEIRFLO1.LnInSvc	YES / NO		NO

2.3.5 Analog Inputs to the Unit

Table 2.3-1: Analog Inputs to the Fault Detector Module (based on Differential and Restraint Currents)

Name	Description	IEC 61850
VA	Phase A Voltage	
VB	Phase B Voltage	
VC	Phase C Voltage	

2.3.6 Digital Inputs

Table 2.3-2: Digital Inputs to the External Fault Detector Module

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_FDWI	Enabling commands	WEIRFLO1.Mod	Fault Detector Weak Infeed Enable Input	I	Activation of this input puts the Fault Weak Infeed Detector into service. It can be assigned to digital inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signals is a "1."

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2.3.7 Auxiliary Outputs and Events

Table 2.3-3: Auxiliary Outputs and Events of the Fault Detector (based on Differential and Restraint Currents)

Name	Group	IEC 61850	Description	Vis.	Function
FDWI_ENBLD	Generic Outputs of Protection	WEIRFLO1.Mod	Weak Infeed Fault Detector Enabled	I	Indicates that the Fault Detector in weak infeed conditions is enabled.
FDWI_ACTFASEA		WEIRFLO1.Op	Phase A Weak Infeed Fault Detector	I	Indicates weak infeed activation phase A
FDWI_ACTFASEB		WEIRFLO1.Op	Phase B Weak Infeed Fault Detector	I	Indicates weak infeed activation phase B
FDWI_ACTFASEC		WEIRFLO1.Op	Phase C Weak Infeed Fault Detector	I	Indicates weak infeed activation phase C
FDWI_ACT		WEIRFLO1.Op	Weak Infeed Fault Detector Activated	I	Indicates weak infeed detector activation

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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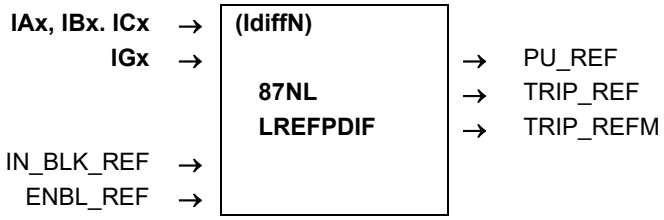
2.4 Restricted Earth Faults Unit

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2.4.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Restricted Earth Fault winding 1 Unit	LREFPDIF1	dIoLo1>	**87NL**
Restricted Earth Fault winding 2 Unit	LREFPDIF2	dIoLo2>	**87NL**
Restricted Earth Fault winding 3 Unit	LREFPDIF3	dIoLo3>	**87NL**

2.4.2 General Block



X= independently by winding (1, 2 or 3).

2.4.3 Operation Principles

The Restricted Earth Fault unit (87NL) is used to detect ground faults in transformers, reactances and rotating machines (generators and motors). This detection requires star-connected windings and with the neutral grounded or delta-connected windings with an artificial grounding (i.e zig-zag transformer).

The Restricted Earth Fault unit (87NL) is a ground differential unit which provides higher sensibility than the Phase Differential unit, mainly when the neutral point is connected to ground through an impedance.

The Restricted Earth Fault unit calculates the differential current as the vector sum of the neutral current of the winding (IA + IB + IC) and the grounding current of the winding itself (IG) according to the following expression

$$\bar{I}_{diffN} = \frac{\bar{I}_A + \bar{I}_B + \bar{I}_C}{t_N} + \bar{I}G = \frac{3\bar{I}_0}{t_N} + \bar{I}G$$

Where:

$\bar{I}_{diffN}$ is the RMS value of the neutral differential current of the winding.
For the winding1 assigned to ground current 1 (IG-1) it is called IGN1, for the winding2 and assigned to ground current 2 (IG-2) it is called IGN2 and for the winding3 and assigned to ground current 3 (IG-3) it is called IGN3.

$\bar{I}_A$, $\bar{I}_B$, $\bar{I}_C$ are the phase currents of the winding.

$\bar{I}G$ Is the winding ground current measured by the CT.

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t_N is the division of the CT transformation ratio of the winding earthing (CTIG), between the transformation ratio of the phase CTs of the same winding (CTPhase). By means of this parameter, the neutral current is normalized to secondary values comparable to those of the earth current.

$$t_N = \frac{CTIG}{CTPhase}$$

The value of **CTIG** corresponds to the following relay settings:

Gnd 1 CT Ratio for winding 1.
Gnd 2 CT Ratio for winding 2.
Gnd 3 CT Ratio for winding 3.

The value of **CTPhase** corresponds to the following relay settings:

Winding 1 Ratio for winding 1
Winding 2 Ratio for winding 2
Winding 3 Ratio for winding 3

Next are detailed the phase and ground channels of the equipment, assigned to each of the windings of the transformer:

87NL Winding1 unit	87NL Winding2 unit	87NL Winding3 unit
IA1	IA2	IA3
IB1	IB2	IB3
IC1	IC2	IC3
IG1	IG2	IG3

As an example of application of the unit, Figure 2.4.1 shows the flow of the fault current, in situation of external fault and internal fault, in a two winding (wye-delta) transformer. For the external fault, due to the phase and ground CTs polarity (both CTs looking towards the protected winding), the secondary currents, neutral and ground, already scaled, in ideal conditions, will be equal and 180º phase-shifted. Therefore:

$$IdifN = IGs + \frac{(IAs + IBs + ICs)}{t_N} = 0 .$$

In an internal fault, the mentioned currents will be 0º phase-shifted, therefore:

$$IdifN = IGs + \frac{(IAs + IBs + ICs)}{t_N} \neq 0$$

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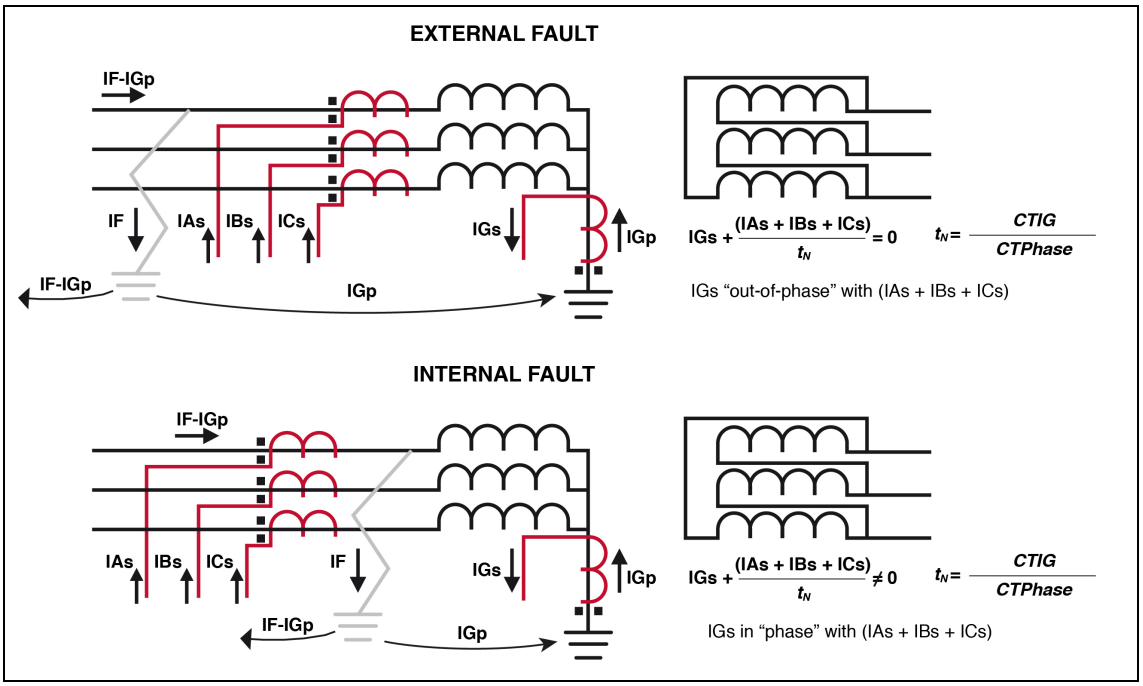


Figure 2.4.1 External and Internal Faults to a Power Transformer.

The Restricted Earth Fault Unit provides higher sensibility than the Phase Differential unit because the relation between the differential current and the distance from the fault location to the neutral point is linear; whereas for the phase differential unit this relation is quadratic. Figure 2.4.2 shows a fault located in a wye winding at a distance to the neutral point given by "n", value in per unit with regard to the total winding turns. In order to simplify the explanation, the breaker of the wye winding is supposed open, therefore ground differential current will be **IGN=IG** and phase differential current **IPHDIFF=IPH**.

The neutral differential current will be equal to:

$$\mathrm{IG}=\frac{n \cdot V_r}{Zn},$$

where Vr represents the rated voltage of the wye winding.

While the phase differential current will be equal to:

$$\mathrm{IPH}=\frac{IG \cdot n \cdot N2}{N1}=\frac{n^2 \cdot V_r \cdot N2}{Zn \cdot N1} \cdot \frac{1}{\sqrt{3}}$$

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The variation of the mentioned differential currents as a function of the distance from the fault location to the neutral point, “n”, is shown in the plot of Figure 2.4.3. As it can be observed, the magnitude of the phase differential current is lower than the corresponding magnitude of the neutral differential current. Even by removing the √3 factor, derived from the transformation between the wye and delta windings, the phase differential current would be lower than the neutral differential current.

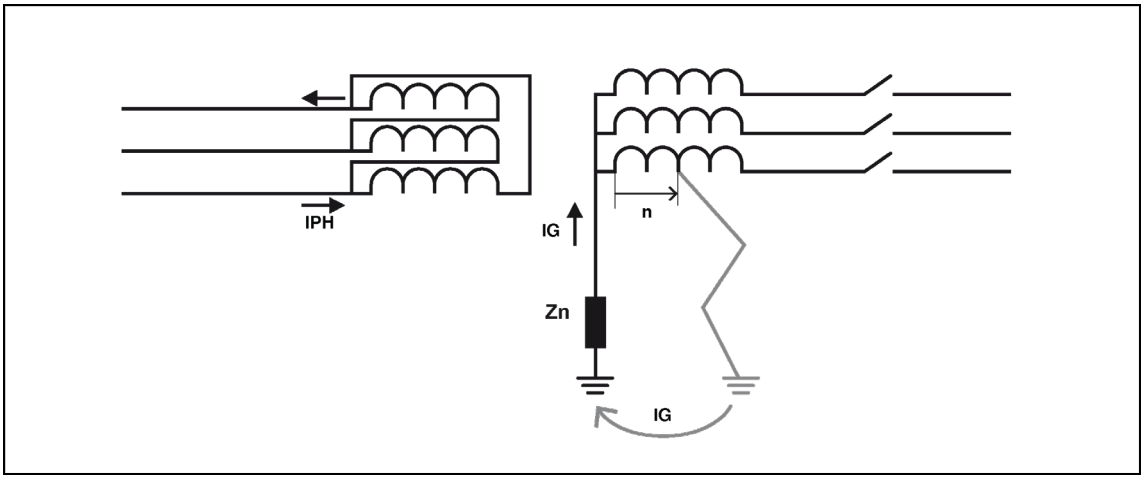


Figure 2.4.2 Ground Fault in a Wye Winding Located at a Distance “n” from the Neutral Point.

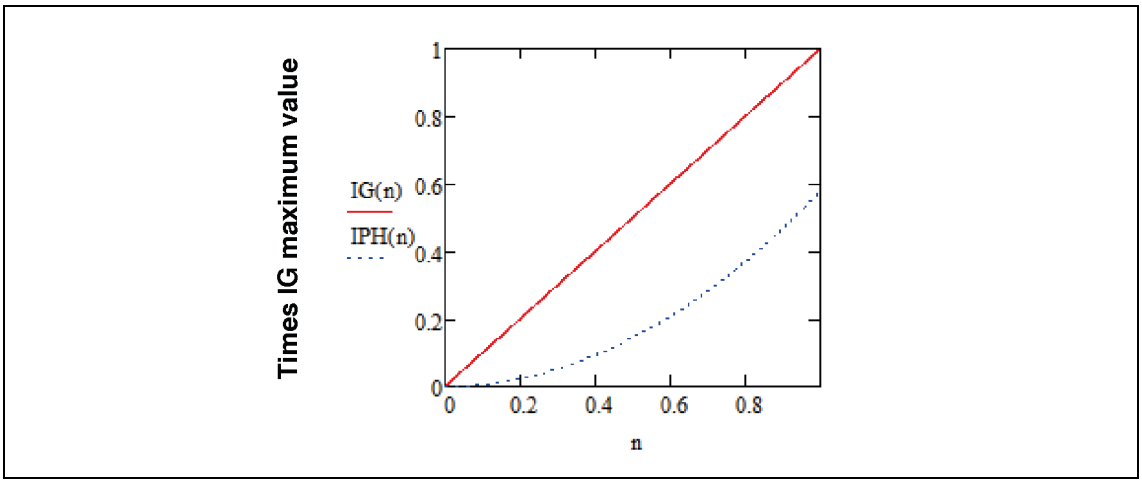


Figure 2.4.3 Variation of the Neutral and Phase Differential Currents with the Distance “N” from the Fault Location to the Neutral Point.

When the neutral point of the wye winding is solidly grounded, the magnitude of the ground current mainly depends on the winding leakage reactance. As such reactance is very low for faults close to the neutral point, the ground current will be high for these faults. Therefore, in solidly grounded neutrals, the Restricted Earth Fault unit will practically cover faults in the 100% of the winding.

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2.4.4 Percentage Restraint Characteristic

In order to take into account the CT errors, the Restricted Earth Fault unit includes a percentage restraint characteristic. The restraint current is calculated independently by is winding as:

$$I_{restN} = \frac{\max(I_A, I_B, I_C)}{t_N}$$

$$t_N = \frac{CTIG}{CTPhase}$$

The restraint based on the maximum phase current allows the stabilization of the Restricted Earth Fault unit during non-grounded faults which generate a false neutral current due to CT saturation. This false neutral current will directly create a false differential current.

Restricted Earth Fault unit is provided with a settable timer for time delayed trips if required.

The unit pickup takes place at 100% of the operate characteristic value and resets at 80% of this value.

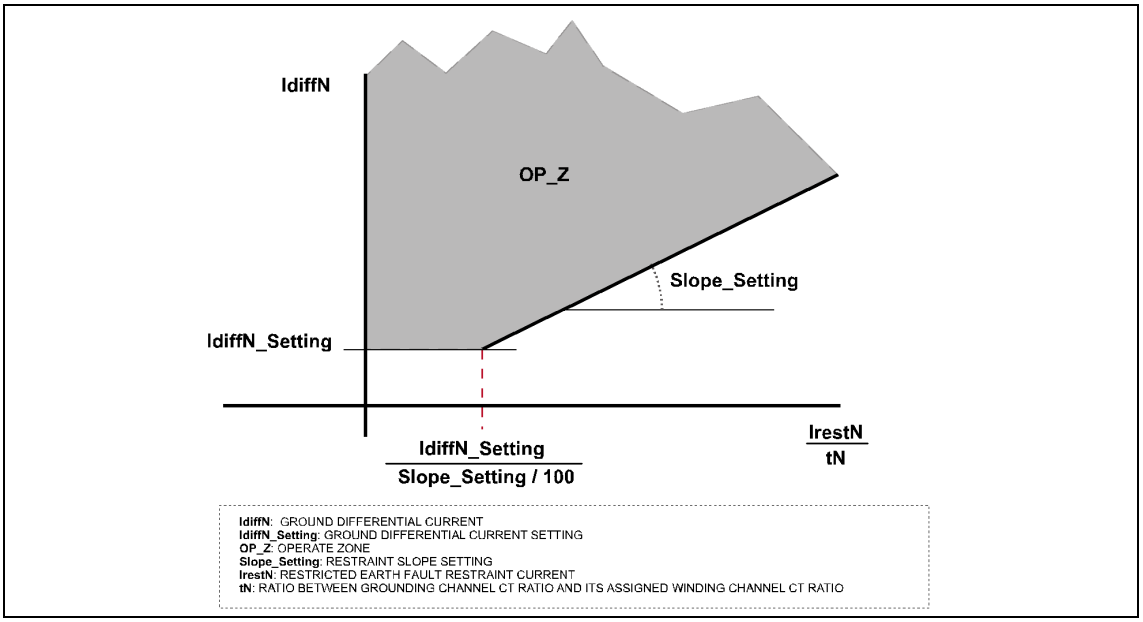


Figure 2.4.4 Percentage Restraint Characteristic for Differential Unit.

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2.4.5 Blocking by Directional Comparison Unit

To increase the security during external faults with CT saturation, the Restricted Earth Fault unit includes a Directional Comparison unit, which compares the angle between the ground current (IGx) and the neutral current (INx) corresponding to the same winding, whenever there is polarization. When this angle higher than the setting ***Angle for Directional Comparison REF Channel n*** (n=1, 2, 3) the directional comparison unit will activate the external fault condition (signal **External Fault Restricted Earth Fault Channel n** (n=1, 2, 3)). If the angle, in absolute value, is lower than the setting, the directional comparison unit will activate the internal fault condition (signal **External Fault Restricted Earth Fault Channel n** (n=1, 2, 3)). The Restricted Earth Fault unit will only operate when the directional comparison unit activates the internal fault condition.

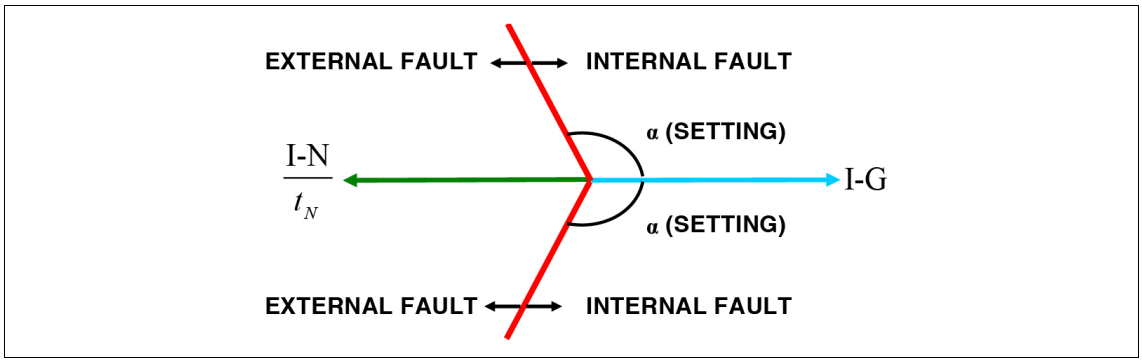


Figure 2.4.5 Directional Comparison Unit.

In order for the directional comparison unit to polarize (it can reliably compare the angle of IN/tN and IG) it is necessary that both neutral (IN/tN) and ground (IG) currents exceed minimum thresholds:

- IGx must be higher than the setting **Minimum Level IG Current Channel** n (n=1, 2, 3) **AND,** besides that:
- INx / t_N must be higher than the 90% of the setting **Minimum Level IG Current Channel n (n=1, 2, 3)** and at least one phase intensity (IAx, or IBx or ICx) must be higher than **14 mA (*)**

(*) When the three-phase currents of the corresponding winding are below **14 mA**, the neutral current considered for the calculation of the neutral differential current will be 0 A.

In case of lack of **IG** polarization, the unit will never act. Equipment models with protection digit X27+X28 = 26 or higher include the ***Minimum Level IG Supervision Enable*** setting, which enables/disables the IG minimum threshold supervision function. If the ***Minimum Level IG Supervision Enable*** setting is set to **NO**, internal fault will be signaled even if IG is below the minimum level.

In case of lack of **IN/tN** polarization, **IG** polarization is enough to always signal internal fault. Clear cases of application would be, for example, internal faults without neutral current, such as a close-onto-fault with the breaker of the other winding open (figure 2.4.2), or internal faults with zero load in the transformer.

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The supervision of a minimum IG threshold (setting ***Minimum Level IG Supervision Enable*** = **YES**), will prevent the operation of the Restricted Earth Fault unit in external fault situations that do not involve ground and that generate a false neutral current (thus causing a false differential current), as a consequence of the saturation of the phase CTs. In such faults there will be no ground current, so IGx will be lower than the threshold.

The Restricted Earth Fault unit will have permission to trip if the signal **Internal Fault Restricted Earth Fault channel n (n=1, 2, 3)** is activated during one cycle. This time-delay is included to filter transient activations of the internal fault condition.

The setting **Minimum Level IG Current Channel n (n=1, 2, 3)** must be higher than the maximum ground current flowing under load conditions, as a result of system unbalances. A value between 5% and 10% of the transformer rated current is recommended.

The directional comparison unit allows distinguishing internal and external faults with CT saturation whenever the saturation free time is higher than 3.5 ms at 60 Hz (4 ms at 50 Hz).

2.4.6 Blocking by Neutral Current Level

The Restricted Earth Fault unit is designed to detect internal faults to the winding that generate a reduced current, for which the phase differential current does not provide enough sensitivity. For this reason the restricted ground fault unit can be blocked in faults with high current. In this way, the operation with external faults with CT saturation is avoided.

If IN / t_N is higher than the setting ***Blocking Level IN REF Channel n*** (n=1, 2,3), the Restricted Earth Fault unit will be blocked. This setting must be above the maximum neutral current for an internal fault divided by t_N.

When the Restricted Earth Fault unit is blocked by Neutral current level, the signal **External Fault Restricted Earth Fault Channel n** is activated.

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2.4.7 Restricted Earth Fault with Autotransformers

The application of Restricted Earth Fault Unit in the case of autotransformers requires different calculations. These are applied when the setting ***Autotransformer***, inside the field **Connection Groups** is set to **YES**.

Consider the electric diagram for an autotransformer shown in Figure 2.4.6 Due to the CT polarity, in secondary values, if the CT ratios were equal, we would have IN1s+IN2s+IGs=0.

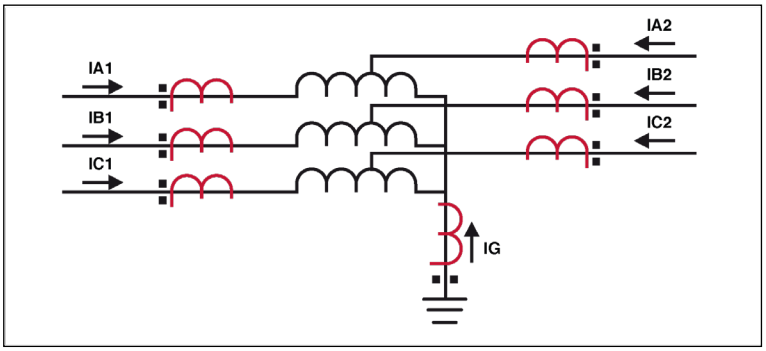


Figure 2.4.6 Electric Diagram of an Autotransformer.

The Restricted Earth Fault Unit adds the neutral current (IN) and the ground current (IG). In the case of autotransformers, the IN value used is as follows:

$$IN_{\text{AUTOTRANSFORMER}} = \frac{IN_1}{t_{N1}} + \frac{IN_2}{t_{N2}}$$

where IN_1 is the neutral current of winding 1 and IN_2 is the neutral current of winding 2.

$$t_{N1} = \frac{CTIG1}{CTPhase1} \text{ and } t_{N2} = \frac{CTIG2}{CTPhase2}$$

2.4.8 Blocking Inputs

These units have the possibility to program **Trip Blocking** inputs, which prevents the operation of these units if the corresponding inputs are activated before the trip is generated. If they are activated after the trip, it is reset. In order to use this blocking logic, the inputs defined as **Restricted Earth Fault Trip Blocking** must be programmed for each of the four available units.

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2.4.9 Application

The Restricted Earth Fault unit, as it presents greater sensitivity to internal earth faults than the phase unit (the neutral differential current is greater than the phase differential current), allows the protection of transformers and generators against this type of faults, in which the sensitivity of the phase differential unit would have to be greatly reduced in order to detect them.

For example, this unit has a clear application in transformers with a delta winding to detect internal earth faults occurring in WYE (Yn) or ZIGZAG (Zn) windings connected to earth.

In these cases, the fault current will circulate through the grounding of the winding generating a flow of zero sequence current that will circulate both through the fault winding and within the delta-connected winding.

This zero sequence current is eliminated from the phase differential current by the zero sequence filter. As the phase differential current decreases, the sensitivity of the unit to this type of fault also decreases, being able in some cases to prevent its detection and subsequent clearing.

As a solution, the Restricted Earth Fault unit provides greater sensitivity to internal earth faults, at the same time as it is immune to the zero sequence filter, as this only applies to the phase differential unit.

It is important to point out that the zero sequence filter must be enabled in this type of transformers, to eliminate the homopolar current, which in external faults generates a differential current that could cause the equipment to trip erroneously.

Ground faults can be also detected through Sensitive Ground Directional Overcurrent Element (only available in feeder protection). Nevertheless, this could result in not being responsive enough, e.g. for faults near the machine neutral, and fast enough.

Restricted Earth Faults Elements are used to quickly detect ground faults internal to the transformer or generator, even for faint faults. In any case, a detail analysis must be carried out both of the winding ground resistance and the measurement transformers, to prevent any problems caused by saturation. This is why, for an element to operate correctly, machine neutral current must be limited by a ground resistor and measurement transformers with turn ratios as close as possible to each other must be used.

Said element can also be used with delta connected large power transformers, for faster and more sensitive operation, working as an unbalance element.

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2.4.10 Example of Settings Calculation

This example considers a 60 MVA two winding power transformer, transformation ratio of 130 kV / 46 kV, connection group ΔY1. The ground CT ratio in the 2nd winding is 300/1A. Earth resistor is 15 Ω.

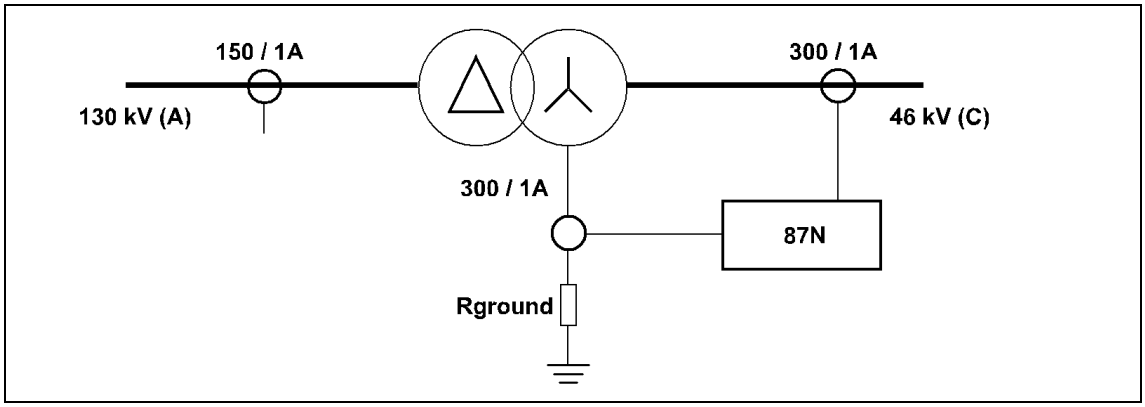


Figure 2.4.7 Example of Calculating the Restricted Earth Fault Unit Settings.

- **Calculating the maximum grounding current, fault current and zero sequence current**

Nominal current on winding 2 for the maximum power value:

$$\text{Current} = \frac{\text{MaximumPower(kVA)}}{\text{Voltage(kV)} \cdot \sqrt{3}} = \frac{60000\text{kVA}}{46 \cdot \sqrt{3}} = 753.06\,A$$

The current flowing through the grounding of the transformer is limited with a resistance in that ground. The magnitude of this resistance permits knowing the position of the fault in the winding with respect to ground, based on the measured current value.

Maximum current is:

$$\text{MaxGroundCurrent} = \frac{\text{Voltage (V)}}{\text{EarthResistor}(\Omega) \cdot \sqrt{3}} = \frac{46000}{15 \cdot \sqrt{3}} = 1770.54\,A$$

This means that ground current in transformer will be maximum 1770.54A; or 5.901A as secondary value for a CT ratio of 300/1A. Under this situation, a fault located at 7% from the neutral would cause:

$$\textit{Fault Current} = 7\% \cdot \textit{Max Ground Current (A)} = 0.07 \cdot 1770.54\ \ A = 123.94\ A$$

The increasing of the phase currents is near zero and therefore the calculated ground current will also be considered as zero.

IN=3Io=0A

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- **Calculating Settings**

1- **Pickup** setting in secondary values will be:

$$Diff.\ Current = \left| 3{\cdot}I0 + IG \right| = \left| 0 + Fault\ Current/CTIG \right| = \left| 0 + 123.94 / 300 \right| = 0.4131\ A$$

2- **Slope** setting is obtained from the minimum ratio between the differential current for the fault to be detected and the nominal current:

$$Slope = \frac{123.94\,A}{753.06\,A} \cdot 100 = 16.46 \rightarrow 16.46\%$$

3- **Time Delay**: a time-delay of half-cycle is recommended in order to filter transient activations

2.4.11 Setting Ranges

Winding1 / Restricted Earth Faults					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
REF Enable	R Earth Enable	LREFPDIF[1].LNInSvc	YES / NO		NO
REF Pickup	REF Pickup	LREFPDIF[1].StrVal	0.05-50 A	0.01 A	0.05 A
REF Restraint Slope	R Earth Restraint	LREFPDIF[1].RstPct	0-100 %	1 %	20 %
REF Delay	R Earth Delay	LREFPDIF[1].OpDlTmms	0.00-300 s	0.01 s	0.01 s
Minimum level IG Current	Minimum IG curr	LREFPDIF[1].MinValA	0.02 A-10 A	0.01 A	0.05 A
Minimum level IG supervision Enable	Min IG Curr Ena	LREFPDIF[1].MinValAEna	YES / NO		NO
Blocking level IN REF	Block level IN	LREFPDIF[1].BlkValA	10 A-160 A	1A	30 A
Angle for Directional Comparison REF	Angle dir com	LREFPDIF[1].DirAng	0º-180º	1º	120º

Winding2 / Restricted Earth Faults					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
REF Enable	R Earth Enable	LREFPDIF[2].LNInSvc	YES / NO		NO
REF Pickup	REF Pickup	LREFPDIF[2].StrVal	0.05-50 A	0.01 A	0.05 A
REF Restraint Slope	R Earth Restraint	LREFPDIF[2].RstPct	0-100 %	1 %	20 %
REF Delay	R Earth Delay	LREFPDIF[2].OpDlTmms	0.00-300 s	0.01 s	0.01 s
Minimum level IG Current	Minimum IG curr	LREFPDIF[2].MinValA	0.02 A-10 A	0.01 A	0.05 A
Minimum level IG supervision Enable	Min IG Curr Ena	LREFPDIF[2].MinValAEna	YES / NO		NO
Blocking level IN REF	Block level IN	LREFPDIF[2].BlkValA	10 A-160 A	1A	30 A
Angle for Directional Comparison REF	Angle dir com	LREFPDIF[2].DirAng	0º-180º	1º	120º

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Winding3 / Restricted Earth Faults					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
REF Enable	R Earth Enable	LREFPDIF[3].LNInSvc	YES / NO		NO
REF Pickup	REF Pickup	LREFPDIF[3].StrVal	0.05-50 A	0.01 A	0.05 A
REF Restraint Slope	R Earth Restraint	LREFPDIF[3].RstPct	0-100 %	1 %	20 %
REF Delay	R Earth Delay	LREFPDIF[3].OpDlTmms	0.00-300 s	0.01 s	0.01 s
Minimum level IG Current	Minimum IG curr	LREFPDIF[3].MinValA	0.02 A-10 A	0.01 A	0.05 A
Minimum level IG supervision Enable	Min IG Curr Ena	LREFPDIF[3].MinValAEna	YES / NO		NO
Blocking level IN REF	Block level IN	LREFPDIF[3].BlkValA	10 A-160 A	1A	30 A
Angle for Directional Comparison REF	Angle dir com	LREFPDIF[3].DirAng	0º-180º	1º	120º

2.4.12 Analog Inputs to Restricted Earth Faults Unit

Table 2.4-1: Analog Inputs to Restricted Earth Fault Unit		
Name	**Description**	**IEC 61850**
IA1	Winding 1 Phase A Current	A1MMXU1.A.phsA
IB1	Winding 1 Phase B Current	A1MMXU1.A.phsB
IC1	Winding 1 Phase C Current	A1MMXU1.A.phsC
IG1	Winding 1 Ground Current	A1MMXU1.A.neut
IGN1	Winding 1 Ground Differential Current (I_{diffN})	LREFPDIF[1].DifACIc
IA2	Winding 2 Phase A Current	A2MMXU1.A.phsA
IB2	Winding 2 Phase B Current	A2MMXU1.A.phsB
IC2	Winding 2 Phase C Current	A2MMXU1.A.phsC
IG2	Winding 2 Ground Current	A2MMXU1.A.neut
IGN2	Winding 2 Ground Differential Current (I_{diffN})	LREFPDIF[2].DifACIc
IA3	Winding 3 Phase A Current	A3MMXU1.A.phsA
IB3	Winding 3Phase B Current	A3MMXU1.A.phsB
IC3	Winding 3Phase C Current	A3MMXU1.A.phsC
IG3	Winding 3Ground Current	A3MMXU1.A.neut
IGN3	Winding 3Ground Differential Current (I_{diffN})	LREFPDIF[3].DifACIc

$$I_{GN} = I_{diffN} = \frac{\bar{I}_A + \bar{I}_B + \bar{I}_C}{t_N} + \bar{I}_G = \frac{3\bar{I}_0}{t_N} + \bar{I}_G$$

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2.4.13 Digital Inputs to the Restricted Earth Faults Unit

Table 2.4-2:Digital Inputs to the Restricted Earth Faults Unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INBLK_REF_1	Logic inputs to Protection	LREFPDIF[1].Mod	Restricted Earth Fault unit 1 blocking input		Activation of input before trip generation blocks unit operation. If activated after tripping, trip resets.
INBLK_REF_2		LREFPDIF[2].Mod	Restricted Earth Fault unit 2 blocking input		
INBLK_REF_3		LREFPDIF[3].Mod	Restricted Earth Fault unit 3 blocking input		
ENBL_REF_1	Enabling / Disabling Commands		Restricted Earth Fault unit 1 enable input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_REF_2			Restricted Earth Fault unit 2 enable input	I	
ENBL_REF_3			Restricted Earth Fault unit 3 enable input	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.4.14 Auxiliary Outputs and Events of the Restricted Earth Faults Unit

Table 2.4-3: Auxiliary Outputs and Events of the Restricted Earth Faults Unit

Name	Group	IEC 61850	Description	Vis.	Function
PU_REF_1	Pickup Protection Outputs	LREFPDIF[1].Str	Restricted Earth Fault unit 1 pickup	I,F	Unit pickup and timing start.
PU_REF_2		LREFPDIF[2].Str	Restricted Earth Fault unit 2 pickup	I,F	
PU_REF_3		LREFPDIF[2].Str	Restricted Earth Fault unit 3 pickup	I,F	
TRIP_REF_11	Trip Protection Outputs	LREFPDIF[1].Op	Restricted Earth Fault unit 1 trip	I,F	Trip of the unit.
TRIP_REF_12		LREFPDIF[2].Op	Restricted Earth Fault unit 2 trip	I,F	
TRIP_REF_21		LREFPDIF[3].Op	Restricted Earth Fault unit 3 trip	I,F	
TRIP_REFM_1	Masked Trip		Restricted Earth Fault unit 1 masked trip		Unit trip affected by trip mask.
TRIP_REFM_2			Restricted Earth Fault unit 2 masked trip		
TRIP_REFM_3			Restricted Earth Fault unit 3 masked trip		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 2-4.3: Auxiliary Outputs and Events of the Restricted Earth Faults Unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
EXTFLT_REF_1	Others	LREFPDIF[1].ExtFlt	External Fault Restricted Earth Fault 1	I	Internal and external fault condition generated by the REF directional comparison unit.
INTFLT_REF_1		LREFPDIF[1].IntFlt	Internal Fault Restricted Earth Fault 1	I	
EXTFLT_REF_2		LREFPDIF[2].ExtFlt	External Fault Restricted Earth Fault 2	I	
INTFLT_REF_2		LREFPDIF[2].IntFlt	Internal Fault Restricted Earth Fault 2	I	
EXTFLT_REF_3		LREFPDIF[3].ExtFlt	External Fault Restricted Earth Fault 3	I	
INTFLT_REF_3		LREFPDIF[3].IntFlt	Internal Fault Restricted Earth Fault 3	I	
REF_ENBLD_1		LREFPDIF[1].Mod	Restricted Earth Fault unit 1 enabled		Indication of enabled or disabled status of the unit.
REF_ENBLD_2		LREFPDIF[2].Mod	Restricted Earth Fault unit 2 enabled		
REF_ENBLD_3		LREFPDIF[3].Mod	Restricted Earth Fault unit 3 enabled		
INBLK_REF_1		LREFPDIF[1].Mod	Restricted Earth Fault unit 1 blocking input		The same as for the Digital Inputs.
INBLK_REF_2		LREFPDIF[2].Mod	Restricted Earth Fault unit 2 blocking input		
INBLK_REF_3		LREFPDIF[3].Mod	Restricted Earth Fault unit 3 blocking input		
ENBL_REF_1		LREFPDIF[1].Mod	Restricted Earth Fault unit 1 enable input	I	The same as for the Digital Inputs.
ENBL_REF_2		LREFPDIF[2].Mod	Restricted Earth Fault unit 2 enable input	I	
ENBL_REF_3		LREFPDIF[3].Mod	Restricted Earth Fault unit 3 enable input	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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2.4.15 Restricted Earth Fault Unit Test

The test is performed to each of the 3 Restricted Earth Fault Units, according to the tests described below.

- **Settings**

Relay settings to be as per Table 2.4-4 below:

Table 2.4-4: Restricted Earth Fault Units Test (Settings)

Setting Label	Value
Settings\General Trafo\ Number of Windings	3
Settings \ General \ Phase n CT Ratio (n=1, 2, 3)	300
Settings \ General \ Gnd n CT Ratio (n=1, 2, 3)	300
Settings \ Protection \ Winding 1 \ Restricted Earth Faults \ REF Enable.	YES
Settings \ Protection \ Winding 2 \ Restricted Earth Faults \ REF Enable.	YES
Settings \ Protection \ Winding 3 \ Restricted Earth Faults \ REF Enable.	YES
Settings \ Protection \ Winding 1 \ Restricted Earth Faults \ REF Pickup.	2A
Settings \ Protection \ Winding 2 \ Restricted Earth Faults \ REF Pickup.	2 A
Settings \ Protection \ Winding 3 \ Restricted Earth Faults \ REF Pickup.	2 A
Settings \ Protection \ Winding 1 \ Restricted Earth Faults \ REF Restraint Slope.	2%
Settings \ Protection \ Winding 2 \ Restricted Earth Faults \ REF Restraint Slope.	2%
Settings \ Protection \ Winding 3 \ Restricted Earth Faults \ REF Restraint Slope.	2%
Settings \ Protection \ Winding 1 \ Restricted Earth Faults \ REF Delay.	5s
Settings \ Protection \ Winding 2 \ Restricted Earth Faults \ REF Delay.	5s
Settings \ Protection \ Winding 3 \ Restricted Earth Faults \ REF Delay.	5s
Settings \ Inputs Outputs \ Outputs \ Slot A \ Digital Output 1	Trip Protection outputs\ Protection 1 activation
Settings \ Inputs Outputs \ Outputs \ Slot A \ Digital Output 2	Trip Protection outputs\ Protection 2 activation
Settings \ Inputs Outputs \ Outputs \ Slot A \ Digital Output 3	Trip Protection outputs\ Protection 3 activation
Other unit settings and Settings of the other units	VALUE BY DEFAULT

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- **Unit Sensitivity**

Apply current only to ground (IG) and in one phase (at 0º) and check that Restricted Earth Fault Unit picks up and resets, for all pickup settings, when said current is within the margin indicated in Table 2.4-5.

Table 2.4-5: Restricted Earth Fault Element Test (Element Sensitivity)		
Pickup setting	Pickup	Reset
2 A	0.97 - 1.03 A	0.776 - 0.824 A
1 A	0.485 - 0.515 A	0.3288 - 412 A
0.04 A	0.0194 - 0.0206 A	0.014 - 0.017 A

Check that upon unit activation a trip occurs activating all trip contacts.

- **Element Timer**

Apply a current 2.5 A to ground channel and check that trip occurs within the margin ±1% o ±45ms (whichever is greater) of the timer setting value. Bear in mind that operate time for a 0 ms setting is between 1 and 2 cycles.

- **Unit Characteristic**

One of the Restricted Earth Fault units should be set as:

Setting Label	Value
Unit Pickup	0.2 A
Unit Restraint Slope	20 %
Unit Delay	0 s

Apply currents on phase A, B and the corresponding ground channel of such winding. Phase current will be constant (restraint current) and current to be injected to grounding channel for the element to operate shall be measured.

When opposite polarity sign, test will be started with ground channel value equal to phase value and then step down, keeping the phases constant. For 0º out of phase, test will start with ground channel to 0 A and then step up.

Check that operate current is within the margin stated in Table 2.4-6.

Table 2.4-6: Restricted Earth Fault Element Test (Element Characteristic)			
A-Phase	B-Phase	Ground Channel - Pickup	
1 A (0º)	-	180º	Never
1 A (0º)	-	0º	0.048 A - 0.052 A
2 A (0º)	-2 A (180º)	0º	0.388 A - 0.412 A
3.2 A (0º)	3.2 A (180º)	0º	0.621 - 0.659 A

Repeat the test using B and C phases.

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Chapter 3.

Distance Protection Units

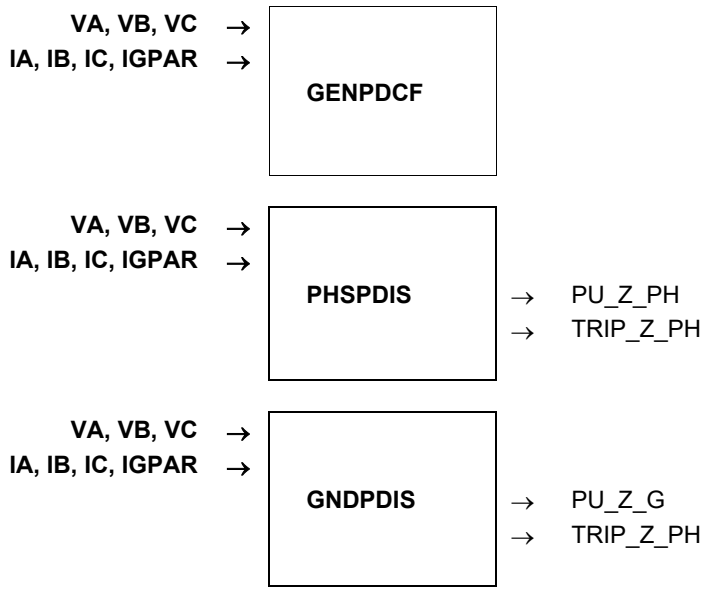
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3.1.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
(8) Reversible Distance Zones	PDIS		**21/21N**

3.1.2 General Block



3.1.3 Operation

DLF relays are provided with eight independent protection zones. The direction of operation for each zone is selected using the Zone Direction setting.

The direction of the zone designated as direction reverse zone (**Zone 4** or **Zone 5** as a function of ***Direction Reverse Zone*** setting) behaves differently than the other zones. When the selected protection scheme is either **Directional Comparison Blocking** or if **Weak Infeed** logic ("echo" or "echo + trip" signals) and ***Transient Reverse Overcurrent Blocking*** is enabled, Zone 4 or Zone 5 will operate as **Reverse Looking** even if the setting is forward-looking. Therefore, when either of these schemes is in use, it is not necessary to adjust the Zone 4 or Zone 5 direction.

Each zone is provided with six independent metering elements (one for each fault type), which comprise one operation phasor and one polarization phasor derived from the elemental voltage and current phasors and the settings specific to the characteristics of the line to be protected.

Ground fault metering elements make reverse-looking impedance compensation so as to assess an impedance directly proportional to the line positive sequence impedance. Said compensation is made based on factor K0 defined as:

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K0 = Z0 / Z1 where Z0 and Z1 are the zero sequence and positive sequence impedances respectively, associated to each distance zone.

Each zone is provided with ***Reach*** settings (positive sequence impedance) and ***Zero Sequence Compensation*** (K0 = Z0 / Z1), both in modulus and argument, independent from the other zones. Said independence provides higher precision of metering elements for mixed lines. On the other hand, zones have separate **Reach** and **Resistive Limit** settings for phase and ground elements (in case quadrilateral characteristic is selected).

Ground fault measurement elements can compensate the zero sequence mutual coupling in parallel lines. To this avail, the setting ***Distance Mutual Coupling Enable***, corresponding to distance elements (there is a separate setting for the Fault Locator), must be set to **YES**. The mutual coupling compensation is made through the term **K0M*(INPAR/3)** where:

- **K0M=Z0M/Z1** is the mutual coupling factor (**Z0M** is the zero sequence mutual impedance and **Z1** is the positive sequence impedance of the line).
- **INPAR** is the ground current of the parallel line.

Zero sequence mutual coupling compensation will only be made if the ratio I0/I0PAR (zero sequence current of the protected line / zero sequence current of the parallel line) exceeds the setting ***Factor I0/I0PAR***. The purpose of this setting is to prevent the mutual coupling compensation from being enabled for faults in the parallel line with a high I0PAR value. In that case, this compensation will produce a great overreach that might cause the relay to trip on said external fault. Provided both parallel lines share the same source, a fault in the parallel line will generate an I0PAR greater than I0 so that **I0/I0PAR<Factor I0/I0PAR**.

Distance characteristic can be adjusted separately for between-phase and earth faults, through ***Ground Characteristic*** and ***Phase Characteristic*** settings respectively, which have the following options:

- Quadrilateral characteristic.
- Mho characteristic.
- Mho and Quadrilateral.
- Mho or Quadrilateral.

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3.1.4 Quadrilateral Characteristic

Quadrilateral characteristics comprise three elements:

- Reactance Element.
- Directional Element.
- Resistive Limiter.

3.1.4.a Reactance Element

DLF Reactance elements are polarized by a phasor that, in homogeneous systems, is parallel to the current through the fault impedance. This type of polarization compensates for the influence of the load, avoiding the overreach and underreach of the relay produced by the load on resistive faults with remote-end feeding of the fault, by introducing a phase difference between local and remote currents.

A system that is not homogeneous introduces an additional phase difference between local and remote currents, and may also lead to overreach and underreach that cannot be compensated by the use of the polarization phasor. To avoid this situation, the **DLF** introduces compensation in the phase comparator of zone 1 reactance characteristic, based on the impedances of the system. This compensation is equivalent to a tilt in the characteristic, which is defined as tilt angle, and is only applied when the characteristic is set to forward looking and during an adjustable time (***Tilt Time***) after the fault occurs; when the time is out, the characteristic returns to the original position.

Next table shows the operation and polarization phasors involved in each of the **Reactance** metering elements, as well as the applied operation criteria.

Table 3.1-1: Reactance Characteristic

Unit	Fop	Fpol	Criteria
AG	$\left[Ia + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)*\right] \cdot Z1n - Va$	Ia2 or Ia - Iapf	$0^o \le \left[\arg\left(\text{Fop}\right) - \arg\left(\text{Fpol}\right)\right] \le 180^o$
BG	$\left[Ib + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)*\right] \cdot Z1n - Vb$	Ib2 or Ib - Ibpf	
CG	$\left[Ic + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)*\right] \cdot Z1n - Vc$	Ic2 or Ic - Icpf	
AB	$Iab \cdot Z1n - Vab$	*Iab - Iabpf*	
BC	$Ibc \cdot Z1n - Vbc$	*Ibc - Ibcpf*	
CA	$Ica \cdot Z1n - Vca$	*Ica - Icapf*	

*** The term is only applied if the distance element setting "Distance Mutual Coupling Enable" is set to YES and I0/I0PAR> I0/I0PAR factor.**

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Where:

Ia, Ib, Ic	Phase currents
$Iapf, Ibpf, Icpf$	Phase current during pre-fault (load)
Iab, Ibc, Ica	Line currents (Ia-Ib), (Ib-Ic), (Ic-Ia)
$Iabpf, Ibcpf, Icapf$	Line currents during pre-fault (Iapf-Ibpf), (Ibpf-Icpf), (Icpf-Iapf)
$Ia2, Ib2, Ic2$	Negative sequence phase currents
$I0$	Zero sequence currents
$I0PAR$	Zero sequence current of the parallel line (ground current INPAR divided by 3).
Va, Vb, Vc	Phase voltages
Vab, Vbc, Vca	Line voltages (Va-Vb), (Vb-Vc), (Vc-Va)
$Z1n$	Positive sequence reach impedance associated to zone n
$Z0n$	Zero sequence reach impedance associated to zone n
$K0n = \frlvert Z0n \frrvert / \frlvert Z1n \frrvert$	Zero sequence compensation factor for zone n
$K0M = Z0M / Z1L$	Negative Sequence Mutual Coupling Factor
$Z0M$	Negative Sequence Mutual Impedance
$Z1L$	Line Positive Sequence Impedance

Pre-fault currents are stored two cycles before the time of activation of the Fault Detector. The values of said currents are compared percentage wise with the values of fault currents, to ascertain that the stored magnitudes come from a load condition. Pre-fault magnitudes are only considered as long as the **Fault Detector** is activated and the **Power Swing Blocking** signal is not active.

Ground fault **Reactance** metering elements are normally polarized by negative sequence current it being parallel to the current through the fault resistance. Nevertheless, said parallelism may not be guaranteed under certain conditions, such as the opening of one pole (single-phase reclosing cycle), or two-phase ground faults (when a single-phase element has been allowed to operate, whether ***Phase Lag*** setting is set to **Yes** or any AG, BG or CG element enable input has been activated. See Distance Element activation). In those cases, the negative sequence current is replaced by fault phase current (load component removed), which will be in phase with the voltage drop through the fault resistance.

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Figures 3.1.1 and 3.1.2 show a voltage diagram where a ground fault **Reactance** line associated to zone 1 has been included.

Figure 3.1.1 shows a **Reactance** line for a homogeneous system with load. The point **F** indicates where the fault occurs, and point **F'** indicates where the relay locates the fault. As shown, both points do not coincide due to **IF·RF** vector, which represents the voltage drop in the fault impedance. Under no load conditions, this vector would be horizontal, and **F'** would be located on the horizontal line passing through **F**.

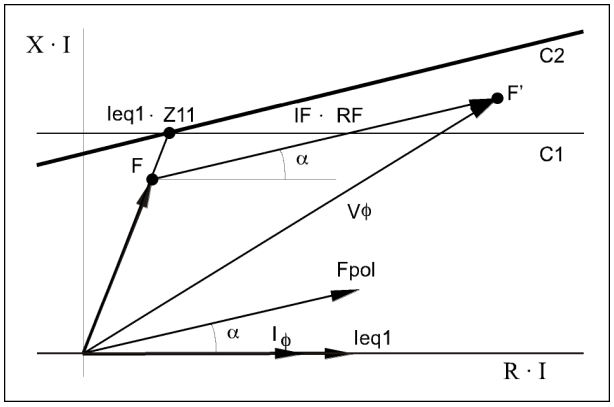


Figure 3.1.1 Reactance Characteristic Diagram for Ground Faults (I).

However, the remote end feeding creates a rotation α moving the point **F'** to the place shown in the figure (a load feed from the remote end has been considered).

C1 characteristic (represented under the condition of no feed from the other end) turns into **C2**, with a rotation by an angle α that keeps **F'** within the operation zone. The tilt of the **Reactance** characteristic tends to compensate for the voltage drop through the fault impedance, as seen by the relay, avoiding both overreach and underreach.

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Figure 3.1.2 shows a **Reactance** characteristic under a no load but not homogeneous system (no phase difference between local and remote sources).

In this case the voltage drop at the fault is seen by the relay to be rotated an angle γ due to the lack of homogeneity on the system. The tilt angle changes the characteristic from C1 to C2, avoiding the overreach of the relay during the preset tilt time (starting from the activation of the fault detector), allowing adjacent protection elements to clear the fault. Angle γ is calculated by the **DLF** from the line, source and equivalent parallel impedances.

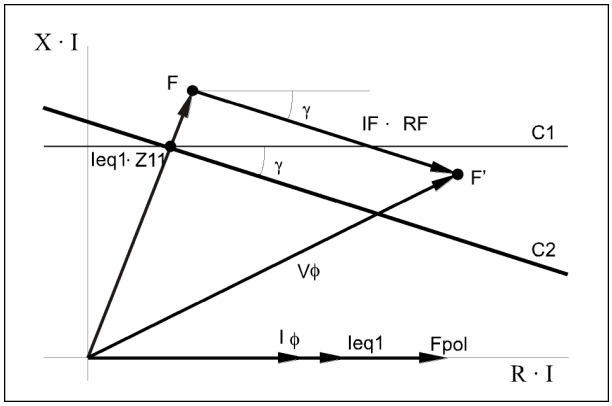


Figure 3.1.2 Reactance Characteristic Diagram for Ground Faults (II).

The value of the tilt angle γ is calculated from the impedances of the line, the source and the equivalent parallel circuit. This angle depends on the setting ***Compensation Angle Type***. If this setting takes the value **Direct**, γ equals the setting ***Compensation Angle***. If the setting ***Compensation Angle Type*** takes the value **Calculated**, the value of γ will be calculated from the impedances of the equivalent system.

$I\phi$	Phase current
$Ieq1$	Equivalent current associated to zone 1: $Ieq1 = I\phi + I0 \cdot (K01 - 1) + (I0PAR \cdot K0M)^*$
$V\phi$	Phase voltage
RF	Ground fault resistance
IF	Current through ground fault resistance
$Fpol$	Polarization phasor for single-phase reactance $Fpol = I\phi 2$ or $I\phi - I\phi pf$
$Z11$	Zone n reach impedance

*** The term is only applied if the distance element setting "Distance Mutual Coupling Enable" is set to YES and I0/I0PAR> I0/I0PAR factor.**

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Figures 3.1.3 and 3.1.4 show a voltage diagram where a **Reactance** line for faults between phases associated to zone 1 has been included.

Figure 3.1.3 shows the **Reactance** line for a homogeneous system with load. Similarly to the case above, for single-phase ground faults, the reactance line undergoes an angle of rotation to compensate for the underreach as a consequence of remote end feeding.

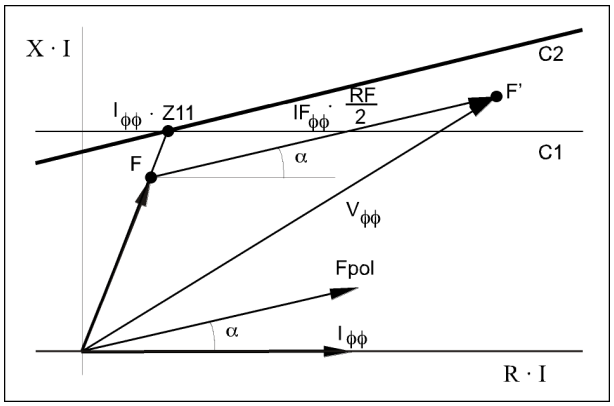


Figure 3.1.3 Reactance Characteristic Diagram for Faults between Phases (I).

Figure 3.1.4 shows a **Reactance** characteristic under a no load system that is not homogeneous. Similarly to single-phase ground faults, it can be seen the rotation of the reactance line by a tilt angle calculated internally, this way avoiding the overreach of the relay during the preset tilt time.

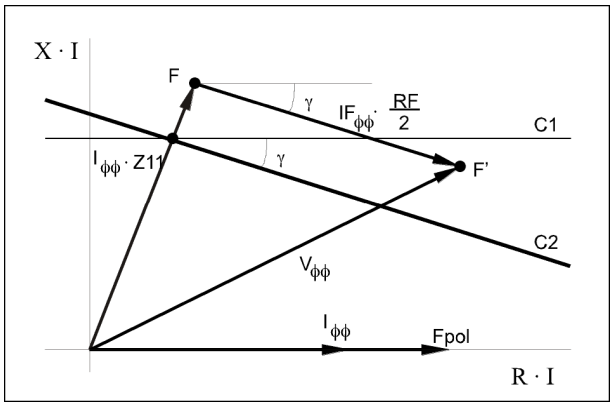


Figure 3.1.4 Reactance Characteristic Diagram for Faults between Phases (II).

Where:

$I\phi\phi$	Current phase-to-phase (Ia-Ib, Ib-Ic, Ic-Ia)
$V\phi\phi$	Voltage phase-to-phase (Va-Vb, Vb-Vc, Vc-Va)
RF	Phase-to-phase fault resistance
$IF\phi\phi$	Phase-to-phase current through fault resistance (IFa-IFb, IFb-IFc, IFc-IFa)
$Fpol$	Polarization phasor for two-phase reactance $Fpol = I\phi\phi - I\phi\phi pf$
$Z11$	Zone n reach impedance

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3.1.4.b Directional Element

DLF equipment features directional elements for each type of fault, common to all zones.

The directional and counter-directional signals to be used for the quadrilateral characteristics are generated by the Positive Sequence, Negative Sequence and Distance Directional units.

If the ***Torque Control Type*** setting is set to **Normal**, only the directional distance unit is used.

If the setting is set to **Advanced**:

- If the **Blocking Condition by Power Swing** (**CBPS**) signal is active, the Positive Sequence Directional unit is used if the phase selector indicates three-phase fault, and the Negative Sequence Directional unit is used otherwise
- In the rest of the cases the Distance Directional Unit is used.

3.1.4.c Resistive Limiter

The **DLF** features six resistive limiter elements (one for each type of fault) per zone. The reach of resistive limiters for ground faults and phase-to-phase faults are independent from each other, each zone having its own adjustment. The following table shows the operation and polarization phasors of the resistive limiters, as well as the applied operating criteria.

Table 3.1-2: Resistive Limiter

Axis R>0 Characteristic			
Unit	**Fop**	**Fpol**	**Criteria**
AG	$Ia \cdot \mathrm{RGn} - \mathrm{Va}$	$Ia \cdot \mathrm{RGn}$	$-(180 - \theta bucn) \le [\arg(Fop) - \arg(Fpol)] \le \theta bucn$
BG	$Ib \cdot \mathrm{RGn} - \mathrm{Vb}$	$Ib \cdot \mathrm{RGn}$	
CG	$Ic \cdot \mathrm{RGn} - \mathrm{Vc}$	$Ic \cdot \mathrm{RGn}$	
Axis R<0 Characteristic			
AG	$-Ia \cdot \mathrm{RGn} - \mathrm{Va}$	$-Ia \cdot \mathrm{RGn}$	$-(180 - \theta bucn) \le [\arg(Fop) - \arg(Fpol)] \le \theta bucn$
BG	$-Ib \cdot \mathrm{RGn} - \mathrm{Vb}$	$-Ib \cdot \mathrm{RGn}$	
CG	$-Ic \cdot \mathrm{RGn} - \mathrm{Vc}$	$-Ic \cdot \mathrm{RGn}$	

Axis R>0 Characteristic			
Unit	**Fop**	**Fpol**	**Criteria**
AB	$Iab \cdot \mathrm{RPn} - \mathrm{Vab}$	$Iab \cdot \mathrm{RPn}$	$-(180^{\circ} - \theta n) \le [\arg(Fop) - \arg(Fpol)] \le \theta n$
BC	$Ibc \cdot \mathrm{RPn} - \mathrm{Vbc}$	$Ibc \cdot \mathrm{RPn}$	
CA	$Ica \cdot \mathrm{RPn} - \mathrm{Vca}$	$Ica \cdot \mathrm{RPn}$	
Axis R<0 Characteristic			
AB	$-Iab \cdot \mathrm{RPn} - \mathrm{Vab}$	$-Iab \cdot \mathrm{RPn}$	$-(180^{\circ} - \theta n) \le [\arg(\mathrm{Fop}) - \arg(\mathrm{Fpol})] \le \theta n$
BC	$-Ibc \cdot \mathrm{RPn} - \mathrm{Vbc}$	$-Ibc \cdot \mathrm{RPn}$	
CA	$-Ica \cdot \mathrm{RPn} - \mathrm{Vca}$	$-Ica \cdot \mathrm{RPn}$	

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Where:

Ia, Ib, Ic	Phase currents
Iab, Ibc, Ica	Phase-to-phase currents (Ia-Ib), (Ib-Ic), (Ic-Ia)
Va, Vb, Vc	Phase voltages
Vab, Vbc, Vca	Phase-to-phase voltages
RGn	Resistive reach for ground faults corresponding to zone n
RPn	Resistive reach for phase-to-phase faults corresponding to zone n
θn	Positive sequence reach impedance angle corresponding to zone n
$\theta bucn$	Loop impedance angle for zone n: $\theta bucn = \theta n - \left[\arg(\mathrm{Ia}) - \arg(\mathrm{Ieqn})\right]$

Resistive limiters for ground faults use phase current as polarization phasor, as it is normally closer to the current going through the fault resistance than the equivalent current.

Figure 3.1.5 represents **Resistive limiters** for ground faults associated to zone 1.

Both C4 and C5 characteristics are at an angle to the phase current axis equal to the loop impedance for zone 1, so that they will be at an angle to the equivalent current axis equal to the positive sequence reach impedance for said zone.

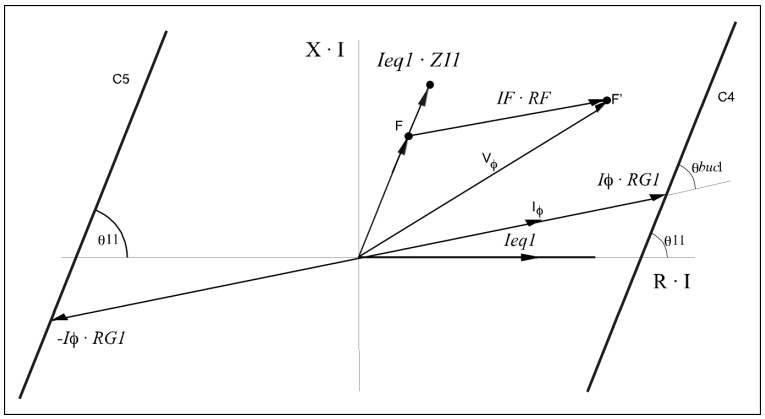


Figure 3.1.5 Resistive Limiters Diagram for Ground Faults.

In Figure 3.1.5 the voltage drop through the fault resistance has been considered parallel to the phase current.

Figure 3.1.6 shows **Resistive limiters** for phase-to-phase faults associated to zone 1.

Both C4 and C5 characteristics are at an angle to the phase-to-phase current axis equal to the positive sequence reach impedance for zone 1.

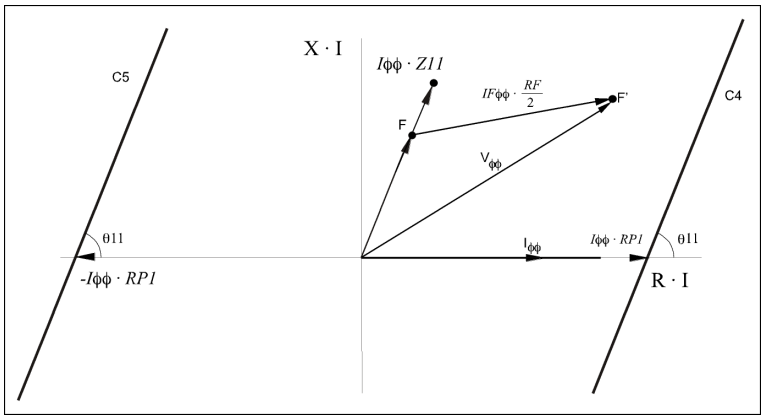


Figure 3.1.6 Resistive Limiter Diagrams for Phase-to-Phase Faults.

The resistive limiter tilt provides the same resistive coverage along the whole line length included in each zone.

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3.1.4.d Graphic Representation

Figure 3.1.7 shows the quadrilateral characteristic for ground faults in the voltage plane referred to the equivalent current. In order to change to the impedance plane, all vectors must be divided by said current value.

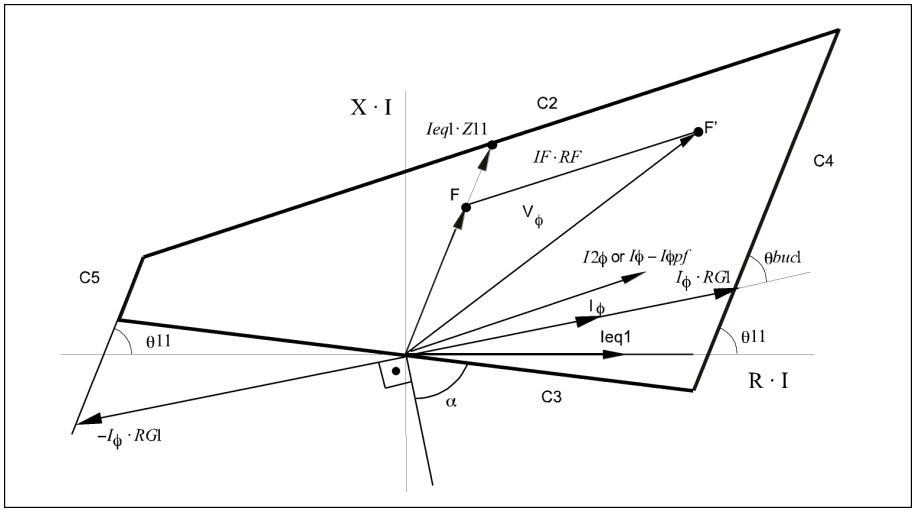


Figure 3.1.7 Quadrilateral Characteristic Diagram for Ground Faults.

An homogeneous system has been considered (thus, the tilt effect has not been included), although, on the other hand, one case has been selected where none of the vectors $I\phi$, Ieq and $I2\phi$ (or $I\phi - I\phi pf$) are parallel. The phase difference between $I\phi$ and $I2\phi$ is a function of the load flow, whereas the possible phase difference between $I\phi$ and Ieq will be a function of the zero sequence current (which will be greatly affected by the type of fault: single-phase or two-phase ground fault) as well as the zero sequence compensation factor. The phase difference between the phase current and the equivalent current in cables is normally high because of the angle difference between positive sequence and zero sequence impedances.

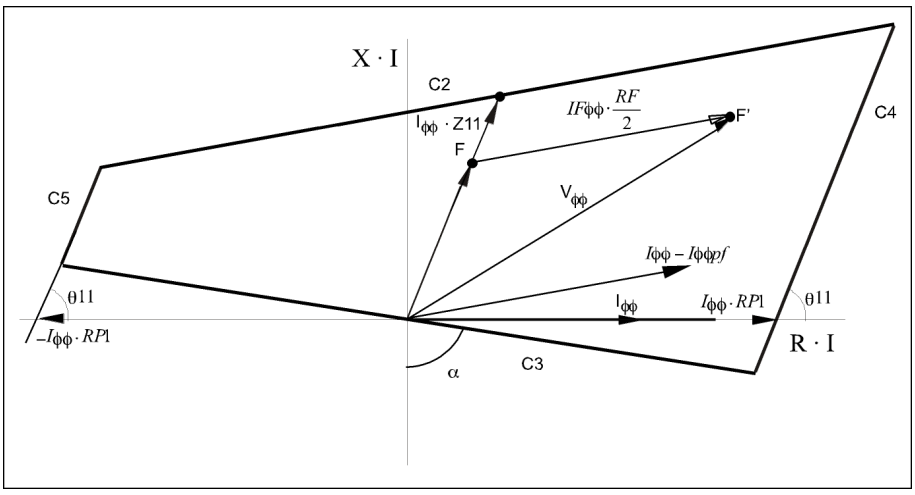


Figure 3.1.8 Quadrilateral Characteristic Diagram for Phase-to-Phase Faults.

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3.1.5 Mho Characteristic

The **DLF Mho** characteristic is polarized by the positive sequence voltage (with memory, when required) of the corresponding phase or phases. This polarization produces a behavior with the following characteristics:

- **Variable**: the use of positive sequence voltage makes the characteristic to expand backwards, when the fault is forward looking, proportional to the local source impedance value. The reason for said behavior is that positive sequence voltage involves the undamaged phase or phases.
- **Dynamic**: the use of voltage memory makes a temporary backwards expansion (as a function of said memory duration) of the characteristic, when the fault is forward looking, also proportional to the local source impedance value.

Said behavior allows the **Mho** characteristic for a correct operation under very close faults (with very low voltage) and under voltage reversals likely to occur in lines with series compensation.

The memorized voltage is used when voltage memory logic so dictates.

The following table shows the operation and polarization phasors of the **Mho** characteristic measuring elements, as well as the applied operational criteria.

Table 3.1-3:Mho Characteristic

Unit	Fop	Fpol	Criteria
AG	$\left[Ia + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)^{*}\right] \cdot Z1n - Va$	$Va1M$	$-90^{o} \le \left[\arg\left(\mathrm{Fop}\right) - \arg\left(\mathrm{Fpol}\right)\right] \le 90^{o}$
BG	$\left[Ib + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)^{*}\right] \cdot Z1n - Vb$	$Vb1M$	
CG	$\left[Ic + I0 \cdot \left(K0n - 1\right) + (I0PAR \cdot K0M)^{*}\right] \cdot Z1n - Vc$	$Vc1M$	
AB	$Iab \cdot Z1n - Vab$	$Vab1M$	
BC	$Ibc \cdot Z1n - Vbc$	$Vbc1M$	
CA	$Ica \cdot Z1n - Vca$	$Vca1M$	

*** The term is only applied if the distance element setting "Distance Mutual Coupling Enable" is set to YES and I0/I0PAR> I0/I0PAR factor.**

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Where:

Ia, Ib, Ic	Phase currents
Iab, Ibc, Ica	Line currents (Ia-Ib), (Ib-Ic), (Ic-Ia)
$I0$	Zero sequence currents
$I0PAR$	Zero sequence current of the parallel line (ground current INPAR divided by 3).
Va, Vb, Vc	Phase voltages
Vab, Vbc, Vca	Line voltages (Va - Vb), (Vb - Vc), (Vc - Va)
$Va1M, Vb1M, Vc1M$	Positive sequence voltages referred to each phase
$Vab1M, Vbc1M, Vca1M$	Positive sequence voltages referred to each phase pair
$Z1n$	Positive sequence reach impedance associated to zone n
$Z0n$	Zero sequence reach impedance associated to zone n
$\mathrm{K0n} = \frac{\lvert \mathrm{Z0n} \rvert}{\lvert \mathrm{Z1n} \rvert}$	Zero sequence compensation factor for zone n
$K0M = \frac{Z0M}{Z1L}$	Negative Sequence Mutual Coupling Factor
$Z0M$	Negative Sequence Mutual Impedance
$Z1L$	Line Positive Sequence Impedance

Figures 3.1.9 and 3.1.10 show the phase-to-ground fault **Mho** characteristics. Due to the polarization used, the diameter of the characteristic is the vector addition of the adjusted reach and a vector function of the local source impedance. This effect allows tripping under very close forward looking faults, with very low voltage values (located very close to the origin) or even under forward looking faults in lines with series compensation appearing in the third quadrant by the effect of the capacitors negative reactance.

It is again important to highlight that the above going effect does not imply loss of directionality, as for reverse direction faults the **Mho** characteristic is displaced forward, following a vector proportional to the sum of line and remote source impedances. Said displacement is shown in figure 3.1.11.

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Figure 3.1.9 shows the **Mho** characteristic at the moment when a forward looking fault occurs, the positive sequence voltage previous to the fault being applied as polarization voltage by effect of the memory. It is apparent that the expansion undergone by said characteristic is given by the vector:

$$ZSL \cdot (Ieq - I\phi load)$$

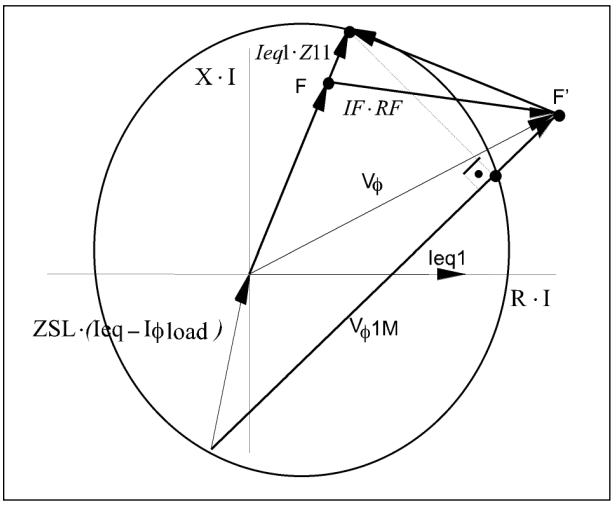


Figure 3.1.9 Phase-to-Ground Fault Mho Characteristic (I).

Figure 3.1.10 shows the **Mho** characteristic after memory update during a stationary state fault. Said characteristic undergoes a displacement given by the vector:

$$ZSL \cdot (Ieq - I1\phi)$$

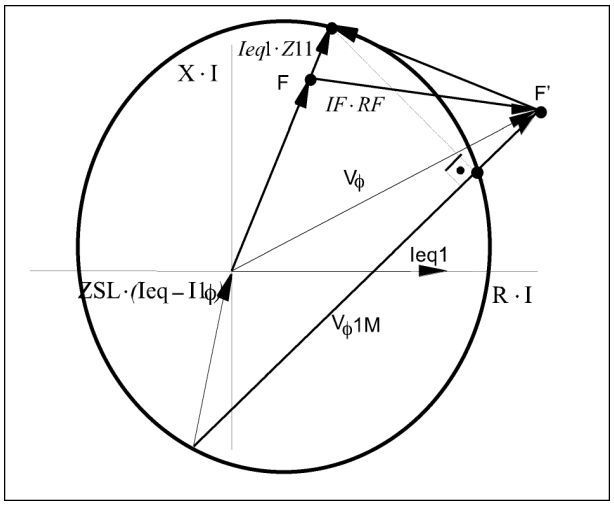


Figure 3.1.10 Phase-to-Ground Fault Mho Characteristic (II).

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Figure 3.1.11 shows the **Mho** characteristic at the moment when a reverse looking fault occurs. By effect of the memory said characteristic undergoes a displacement upwards given by the vector:

$$(ZL + ZSR) \cdot (Ieq - I\phi load)$$

After memory update by the effect of the positive sequence voltage, during the duration of the fault, the **Mho** characteristic will keep an upward displacement given by the vector:

$$(ZL + ZSR) \cdot (Ieq - I1\phi)$$

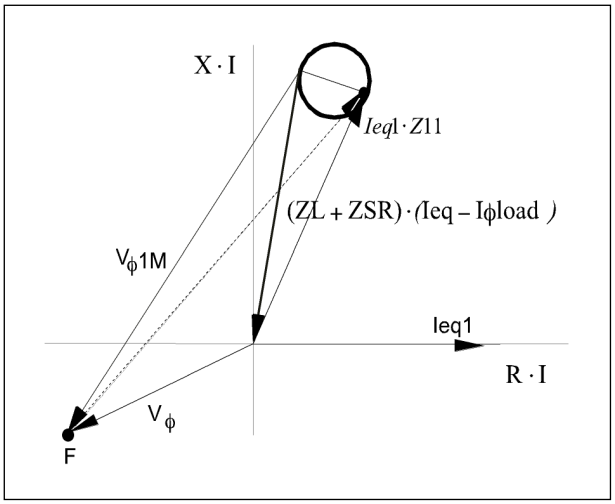


Figure 3.1.11 Phase-to-Ground Fault Mho Characteristic (III).

Where:

ZSL	Local source positive sequence impedance (located behind the relay)
ZL	Line positive sequence impedance
ZSR	Remote source positive sequence impedance
$Z11$	Reach impedance for zone 1
Ieq	Equivalent current (common to line, local source and remote source)*
$I\phi(Ia, Ib, Ic)$	Phase current
$I1\phi$	Positive sequence fault current
$I\phi load$	Load current, previous to fault
$V\phi$	Phase voltage
$V\phi 1$	Positive sequence voltage

(*) Above described displacement vectors have been figured out considering that compensation factors associated to the line, local source and remote source are equal.

Figures 3.1.12 and 3.1.13 show the phase-to-phase fault Mho characteristics. These figures have been drawn for a forward-looking fault current. In the case of a reverse-looking fault current, the **Mho** characteristic would be displaced upwards, with an arrangement similar to that drawn in figure 3.1.11, corresponding to a single-phase fault.

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Figure 3.1.12 shows a characteristic at the instant of a fault. The expansion by the effect of the memory is given by vector:

$$ZSL \cdot (I\phi\phi - I\phi\phi load)$$

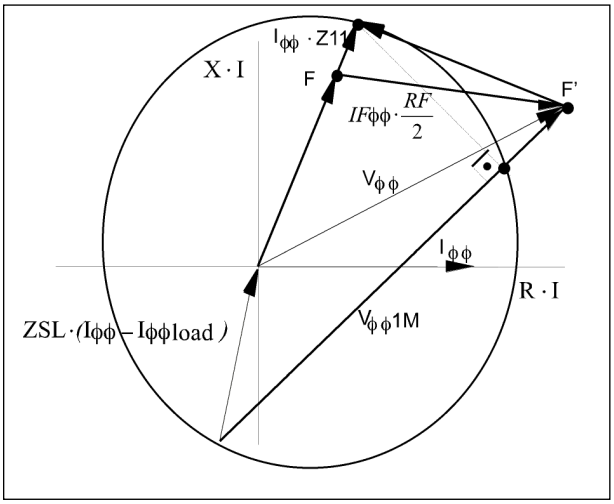


Figure 3.1.12 Mho Characteristic Diagram for Phase-to-Phase Faults (I).

Figure 3.1.13 shows the characteristic once the buffer for the voltage memory effect has been updated. The expansion undergone by said characteristic under a steady state of the fault is given by the vector:

$$ZSL \cdot (I\phi\phi - I\phi\phi 1)$$

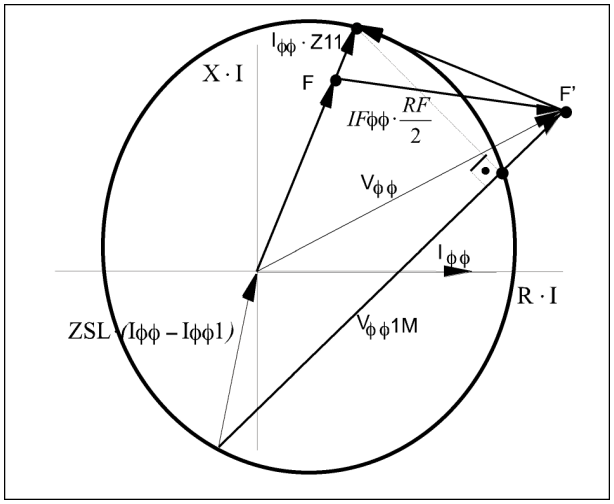


Figure 3.1.13 Mho Characteristic Diagram for Phase-to-Phase Faults (II).

Where:

ZSL	Local source positive sequence impedance
$I\phi\phi(Iab, Ibc, Ica)$	Phase-to-phase current (fault)
$I1\phi\phi$	Positive sequence fault current (phase-to-phase)
$I\phi\phi load$	Load current (phase-to-phase), previous to fault
$V\phi\phi$	Phase-to-phase voltage
$V\phi\phi 1$	Positive sequence voltage (phase-to-phase)

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3.1.6 Distance Characteristic Activation

Figures 3.1.14 and 3.1.15 show the activation logic of distance characteristics AG and AB, respectively, for a zone n, as a function of outputs generated by the elements hitherto described and selected characteristic setting.

When a zone is set as backward looking, **Mho** and **Reactance** elements will reverse the direction of the current used in their operation algorithm, whereas the directional element, which always watch forward looking faults, will disable its output.

If the **Characteristic** selection setting, either for **ground faults** or **phase-to-phase faults**, is set with the **Mho and Quadrilateral** option, both characteristics need to be active in order to pick up the distance function. However, if this setting has the **Mho or Quadrilateral** option, the activation of only one of these characteristics will be enough to pick up the distance function.

Distance characteristic outputs will be introduced into the distance element activation logic.

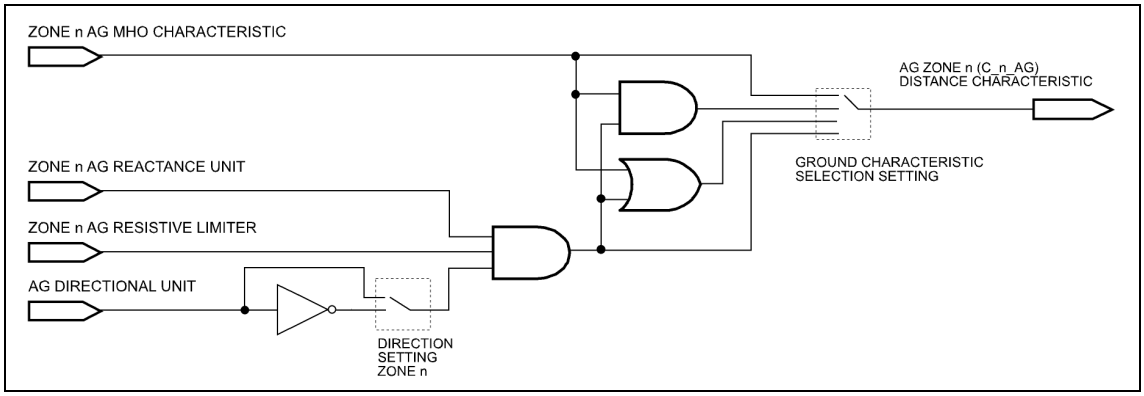


Figure 3.1.14 AG Distance Characteristic Activation Logic.

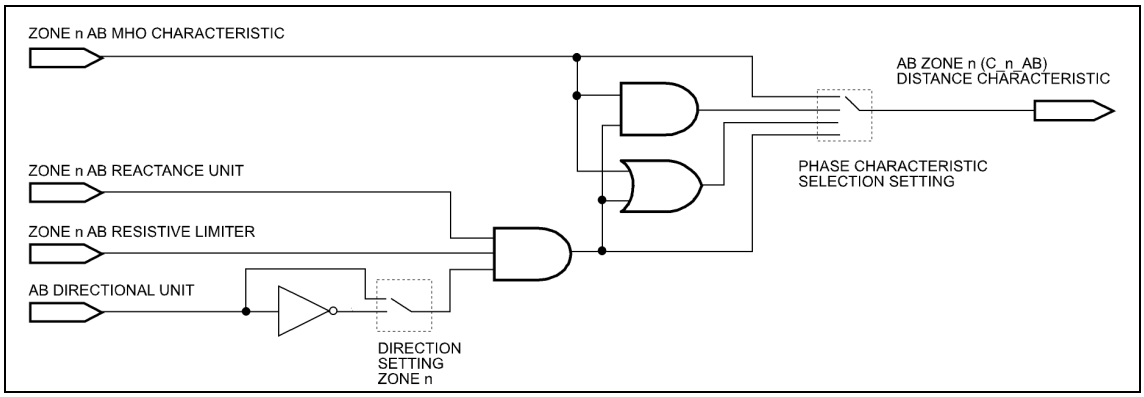


Figure 3.1.15 AB Distance Characteristic Activation Logic.

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3.1.7 Voltage Memory Logic

Storage of positive sequence voltage memory takes place two cycles before the moment the fault detector activates.

The use of the voltage memory will depend on the ***Series Compensation Logic Enable*** setting. However, no matter said setting, the positive sequence voltage with memory is only used if its value is above 20 V (with the purpose of preventing using it at the moment when the switch is closed in a position with the voltage transformer on the line side, which will not allow the trip) and while the fault detector is active. Said memory duration, from the moment it is latched, will be given by the setting ***Memory Duration***.

If ***Series Compensation Logic Enable*** setting is **NO** (which means that **DLF** is not applied to a line with series compensation), voltage memory would only be necessary for clearing three-phase faults with voltage below the minimum threshold to polarize distance elements (***Voltage Threshold*** configuration setting). Thus, voltage memory is only used if positive sequence voltage (corresponding to the phase or phases considered) is below **50 V**.

If ***Series Compensation Logic Enable*** is set to **YES** no threshold is supervised, as the purpose of voltage memory is to allow correct actions not only under near zero voltage faults but also under voltage reversal, which can take place with relatively high fault voltage.

Memory Duration setting can take the maximum value (100 cycles) if faults with positive sequence voltage below the minimum to polarize distance elements in zone 2 or zone 3 are expected (provided the time delay associated to said zones is below 80 cycles). This situation could take place under three-phase faults in very short lines, with very high SIR (ratio between the source impedance and line impedance).

Regarding lines with series compensation, voltage reversal is unlikely for faults in zone 2, as the existing inductive reactance from the relay to zone 1 reach is normally greater than the introduced capacitive reactance (however, the comparison ought to be done). Thus, voltage memory during zone 2 times is not required for clearing correctly forward looking faults. On the other hand, ***Series Compensation Logic Enable*** allows acting correctly under reverse looking faults using a minimum voltage memory time.

If the line features series compensation, the voltage reversal problem, as previously stated, is solved with small voltage memory time, although the possibility of positive sequence voltage reversal or very low values of said voltage for faults in zone 2 ought to be studied. However, voltage memory is used whenever the fault detector is activated, thus avoiding its continuous use under no fault conditions.

No matter the above, the memory voltage will be used for a maximum of 4 cycles when the signal **Power Swing Blocking Condition** is active.

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3.1.8 Distance Elements Combinations

Distance elements AG, BG, CG, AB, BC and CA pickup outputs of zone 1, 2, 3, 4, 5, 6, 7 and 8 are obtained combining outputs generated by the already described Mho and Quadrilateral characteristics with outputs from the following elements:

- Supervision Elements.
- Phase Selector.
- Open Pole Detector.
- Fuse Failure Detector.
- Load Encroachment.
- Harmonic Blocking.

The **Start Timers** setting indicates whether the start of the timer for each zone starts with the start of the zone in question or with the start of any zone.

3.1.8.a Single-Phase Elements Activation

Figure 3.1.21 shows the logic diagram associated to the pickup of elements AG, for a zone n set as forward looking. If said zone were set to “Reverse looking” direction the diagram would be similar but using the element reverse looking supervision output.

Apart from single-phase faults, single-phase elements can operate on two phase ground faults provided the following conditions are met:

1) When any of the **AG, BG or CG Element Enable** inputs is activated. Said inputs are of application in dual circuits, when a two phase ground fault occurs affecting both circuits in different phases (faults known as “cross-country”).

   Figure 3.1.21 shows one fault of this type affecting phases A and B. The DLF-2 phase selector, at the line end closest to the fault, will indicate **AG Fault**, whereas the DLF-1 phase selector, at the other end, will indicate **ABG Fault**. If a protection scheme via communications has been configured, the DLF-1 high speed tripping will always be three-phase, as a two phase element will be operating (AB in this case). To prevent said **DLF** tripping three-phase (provided single-phase tripping on single-phase fault philosophy has been selected), the relay must receive from the remote end, apart from the signal **Transmission Distance Channel**, the **Type of Fault** signal (AG in this case). This last signal could be used, on the one hand, to allow the operation of the single-phase element associated to the faulted phase of the protected line, by means of the above mentioned single-phase element enable inputs, and, on the other hand, to block the two phase element. In this way, the trip generated will always be single-phase.

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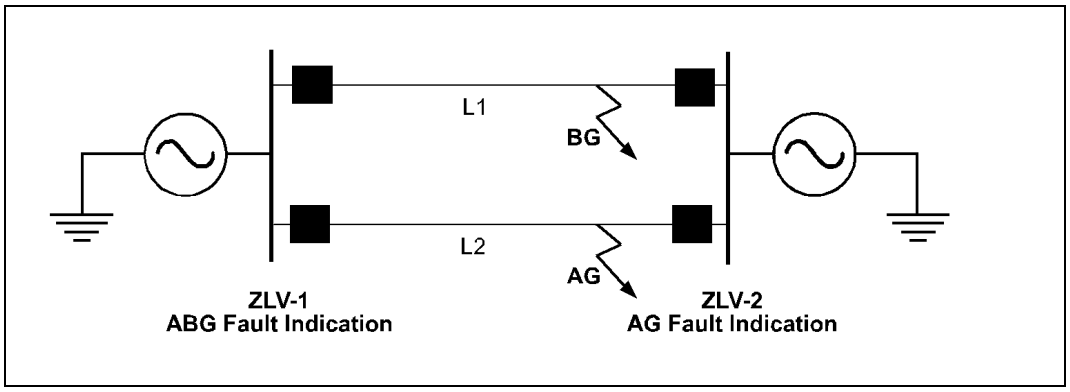


Figure 3.1.16 Simultaneous Single-Phase Faults AG and BG in Dual Circuit.

However, it must be born in mind that a cross-country fault is a two phase ground fault, generally with a resistance between the common point of the two faulted phases and ground, which will produce underreach and overreach effects on the single-phase elements associated to the lagging and leading phases respectively. If the faulted phase of the protected line is the leading phase, the operation of the single-phase element will not have negative results, as the indication of single-phase fault coming from the other end will only be given if the fault is internal to the line. The overreach effect of the single-phase element will ensure, in this case, an instant trip (high speed tripping by overreach zone or even direct by zone 1). However, if the faulted phase of the protected line is the lagging phase, the above mentioned underreach effect can disable the pickup of the single-phase element associated to the overreach zone (as a function of the reach of this zone and the ground fault resistance). In that case blocking the two phase element might not be recommended. In order for the trip generated to be still single-phase, using single breaker pole block inputs and three-phase trip preparation block input, as described in Single-phase / Three-phase Trip Logic.

2) When ***Phase Lag Enable*** setting is set to **YES**, which allows, for any two phase fault, the operation of the single-phase element associated to the lagging phase.

Under a two-phase ground fault, the single-phase lagging element will undergo an underreach provided a fault resistance exists between the junction of the two phases and ground. The greater the ground resistance the greater said underreach. In this case, the two-phase element will be in charge of tripping the fault correctly. However, for two-phase ground faults with zero resistance between the junction of the two phases and ground, as is the case for simultaneous single-phase faults, the lagging single-phase element will actuate correctly, supporting the two-phase element clearing the fault.

When high resistance ground faults are expected (compared to line impedance) and the Quadrilateral characteristic is selected only for single-phase faults, it is advisable to adjust said setting to **YES**. The two-phase **Mho** characteristic will operate correctly under most of two-phase ground faults, as normally the resistance between phases is not high (electric arc resistance). However, underreach may be obtained under simultaneous single-phase faults in view of the high resistance between phases. In this case, the single-phase quadrilateral characteristic will be in charge of clearing the fault.

In accordance with the above considerations, setting ***Phase Lag Enable*** to **YES** will only be justified when a quadrilateral characteristic for ground faults has been selected.

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Single-phase elements will produce single-phase trips provided a preparation for a three-phase trip is not generated (Single-Phase / Three-Phase Tripping Logic).

With one pole open (single phase trip), the operation of any unit (single-phase or double-phase) containing the open pole phase will be disabled.

If the ***Harmonic Blocking*** enable setting is enabled (value set to "YES") the single phase unit will be blocked by the activation of the harmonic blocking signal of its corresponding phase.

Single-phase elements associated to a given zone can only operate when the **Ground Element Enable Input** corresponding to said zone is active, default value being 1.

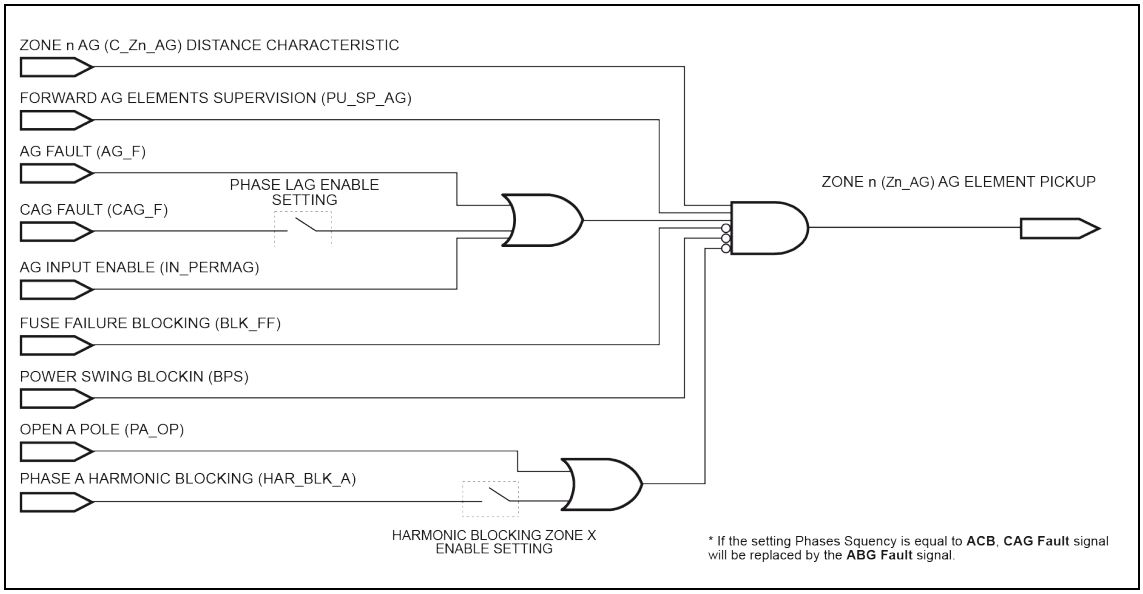


Figure 3.1.17 Pickup Logic of AG Elements.

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3.1.8.b Two-phase Elements Activation

Figure 3.1.18 shows the logic diagram associated to the pickup of elements AB, for a zone n set as “Forward” looking. If said zone were set to “Reverse” looking direction the diagram would be similar but using the element reverse looking supervision output.

Two-phase elements will never activate under single-phase faults in view of the preparation to three-phase trip always generated by said elements (see 3.25, Single-Phase / Three-Phase Tripping Logic).

With one pole open (single phase trip), the operation of any unit (single-phase or two-phase) containing the open pole phase will be disabled.

If the ***Harmonic Blocking*** enable setting is enabled (value set to "YES") the two-phase unit will be blocked by the activation of any of the harmonic blocking signals corresponding to the same phases.

Two-phase elements associated to a given zone can only operate when the **Phase Element Enable Input** corresponding to said zone is active, default value being 1.

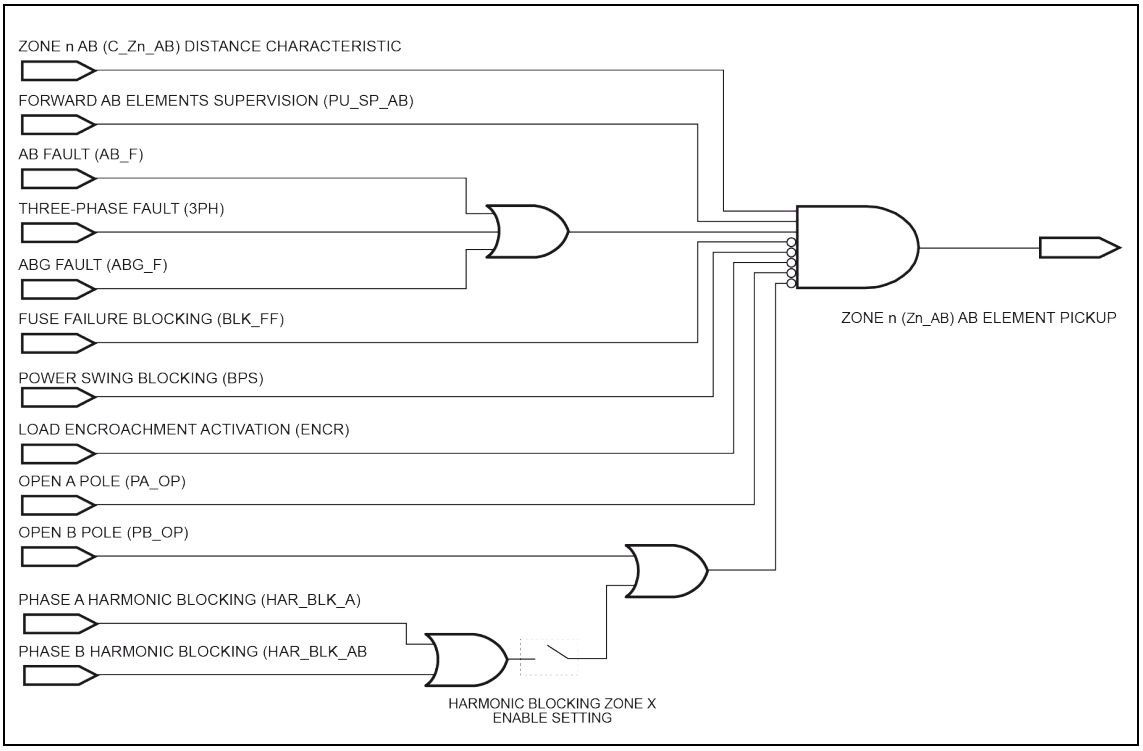


Figure 3.1.18 Pickup Logic of AB Elements.

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3.1.9 Zone Pickup and Trip

Figure 3.1.19 shows the logic diagram associated to the pickup of a zone n.

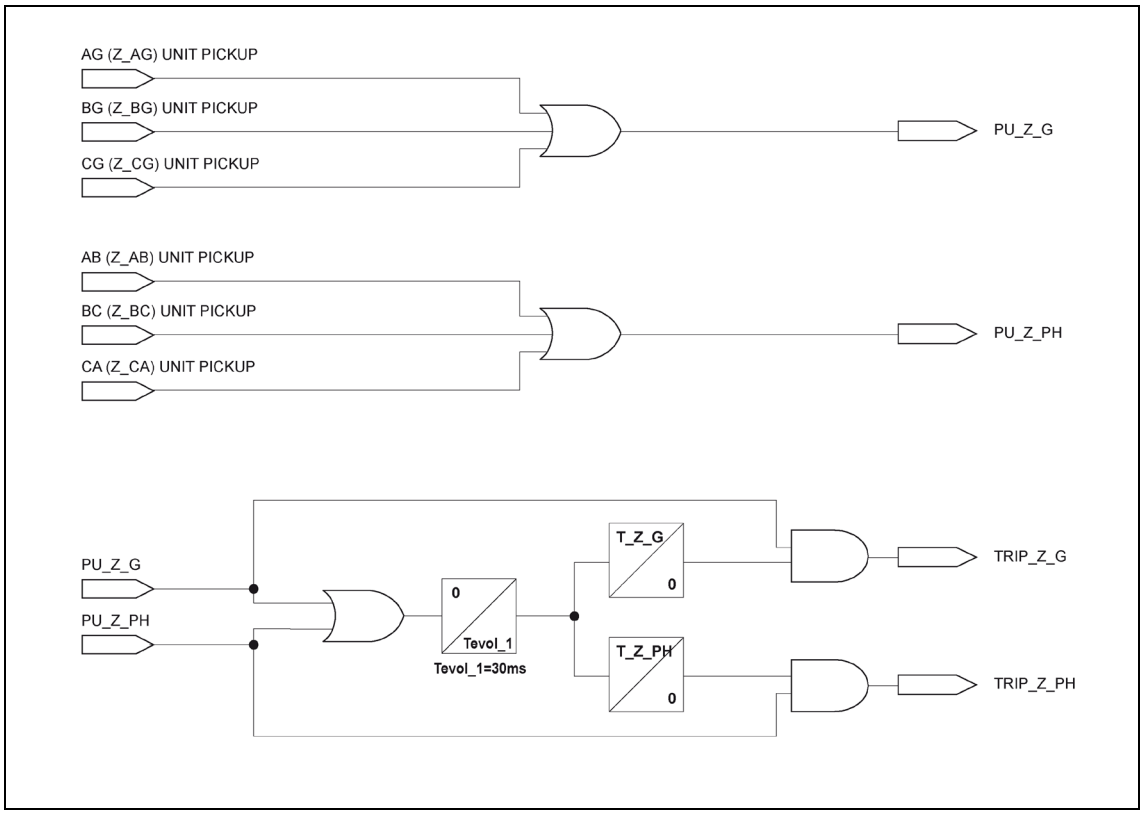


Figure 3.1.19 Diagram Associated to the Pickup of a Zone n.

LEGENG	
PU_Z_G: n Ground Units Pickup	T_Z_G: Ground fault time delay
PU_Z_PH: n Phase Units Pickup	T_Z_PH: Phase-to-phase fault time delay
TRIP_Z_G: n Ground Units Trip	
TRIP_Z_PH: n Phase Units Trip	

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3.1.10 Setting Ranges

System Impedances					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Line Impedance	Line Impedance				
Positive sequence magnitude	Pos. Seq Magnitude		0.01-500 Ω	0.01 Ω	1.25 Ω
Positive sequence angle	Pos. Seq. Angle		5 - 90º	1º	75º
Zero sequence magnitude	Zero Seq Magnitude		0.01-500 Ω	0.01 Ω	1.25 Ω
Zero sequence angle	Zero Seq. Angle		5 - 90º	1º	75º
Parallel Line Impedance					
Mutual coupling factor (*)	Mutual Coupl. Factor		0 - 10	0.01	0
Mutual coupling angle (angle of Z0M)	Mutual Coupl. Angle		5 - 90º	1º	25º
I0/I0PAR factor	Factor I0/I0PAR		0.3 - 1	0.01	0.95
Equivalent Parallel Impedance	Paralell Equiv. Imp.				
Positive sequence magnitude	Pos. Seq Magnitude		0.01-50000 Ω	0.01 Ω	1.25 Ω
Positive sequence angle	Pos. Seq. Angle		5 - 90º	1º	75º
Zero sequence magnitude	Zero Seq Magnitude		0.01-50000 Ω	0.01 Ω	1.25 Ω
Zero sequence angle	Zero Seq. Angle		5 - 90º	1º	75º

System Impedances					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Local Source Impedance	Local Source Imp.				
Positive sequence magnitude	Pos. Seq Magnitude		0.01 - 500 Ω	0.01 Ω	1.25 Ω
Positive sequence angle	Pos. Seq. Angle		5 - 90º	1º	75º
Zero sequence magnitude	Zero Seq Magnitude		0.01 - 500 Ω	0.01 Ω	1.25 Ω
Zero sequence angle	Zero Seq. Angle		5 - 90º	1º	75º

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System Impedances					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Remote Source Impedance	Remote Source Imp.				
Positive sequence magnitude	Pos. Seq Magnitude		0.1 - 500 Ω	0.01 Ω	1.25 Ω
Positive sequence angle	Pos. Seq. Angle		5 - 90º	1º	75º
Zero sequence magnitude	Zero Seq Magnitude		0.01 - 500 Ω	0.01 Ω	1.25 Ω
Zero sequence angle	Zero Seq. Angle		5 - 90º	1º	75º

(*) K0 = zero sequence magnitude / positive sequence magnitude
(**) K0M = Z0M / Z1L (module of the zero sequence mutual impedance / module of the positive sequence impedance of the line).

Distance Protection / Distance					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Ground Fault Characteristics	Gnd Characteristic				
Element type			Quadrilateral. Mho. Quadrilateral and MHO. Quadrilateral or Mho.		MHO
Phase-to-Phase Characteristics	Ph Characteristic				
Element type			Quadrilateral. Mho. Quadrilateral and MHO. Quadrilateral or Mho.		MHO
Directional Element Type	Directional Type				
Directional element Type	Directional Type		Standard Advanced		Standard
Start Timers	Timers Pickup				
Start Type	Start type		Zone Pick Up Distance Pick Up		Zone Pick Up
Phase Lag Enable	Act. Mono FaultBG				
Phase Lag Enable (Two-phase-to-ground fault)	Lagging Phase		YES / NO		NO
Voltage Memory	Voltage Memory				
Memory duration	Memory Duration		2 - 100 cycles	1 cycle	2 cycles
Voltage threshold	Voltage Threshold		0.1 - 5 V	0.1 V	1 V
Parallel Line Coupling	Paralel L Coupling				
Mutual Coupling Enable	Dis Mut Cou Enable		YES / NO		NO

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Distance Protection / Zone Units					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Zone 1, 2, 3, 4, 5, 6, 7 and 8 units (independent settings for each zone)					
Ground Fault Enable	Enable N Zone		YES / NO		YES
Phase-to-phase Fault Enable	Enable PH Zone		YES / NO		YES
Direction	Direction		Reverse Forward		Forward
Ground fault reach	Ground Reach		0.01 - 500 Ω	0.01 Ω	
Phase-to-phase fault reach	Phase Reach		0.01 - 500 Ω	0.01 Ω	
Ground fault resistive limit	Grnd Resist Limit		0.01 - 500 Ω	0.01 Ω	
Phase-to-phase fault resistive limit	Phase Resist Limit		0.01 - 500 Ω	0.01 Ω	
Ground fault time delay	Ground Time		0.00-300.00 s	0.01 s	
Phase-to-phase fault time delay	Phase Time		0.00-300.00 s	0.01 s	
Positive sequence angle	Pos. Seq. Angle		5 - 90º	1º	75º
Zero sequence angle	Zero Seq. Angle		5 - 90º	1º	75º
K0 Factor (*) (zero sequence comp.)	k0 Factor		0.50 - 10.00	0.01	2
Tilt Time	Tilt Time		0.00 - 0.50s	0.01 s	0 s
Tilt Angle Type	Tilt Angle Type		Calculated Direct		Calculated
Tilt Angle	Tilt Angle		-90º - 90º	1	0º
Z Pow. Swing Block	Z Block		YES / NO		NO
Harm. Blocking Zn	Harmonic Blocking Zn		YES / NO		NO

(*) K0 = zero sequence magnitude / positive sequence magnitude

3.1.11 Analog Inputs to the Unit

Table 3.1-4: Analog Inputs of the Distance Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
IGPAR	Parallel Line Ground Current	
V1	Positive Sequence Calculated Voltage	MSQI1.SeqV.c1

$$|V_1| = \left| \frac{V_A + V_B \cdot 1\angle 120° + V_C \cdot 1\angle 240°}{3} \right|$$

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3.1.12 Digital Inputs to the Distance Modules

Table 3.1-5: Digital Inputs to the Distance Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_ZIG			Ground element enable input zone 1		Its activation puts ground elements into operation. They can be assigned to digital inputs on level or commands from the communications protocol or from the HMI. Default value is "1".
ENBL_ZIIG			Ground element enable input zone 2		
ENBL_ZIIIG			Ground element enable input zone 3		
ENBL_ZIVG			Ground element enable input zone 4		
ENBL_ZVG			Ground element enable input zone 5		
ENBL_ZVIG			Ground element enable input zone 6		
ENBL_ZVIIG			Ground element enable input zone 7		
ENBL_ZVIIIG			Ground element enable input zone 8		
ENBL_ZIP			Phase element enable input zone 1		Its activation puts phase elements into operation. They can be assigned to digital inputs on level or commands from the communications protocol or from the HMI. Default value is "1".
ENBL_ZIIP			Phase element enable input zone 2		
ENBL_ZIIIP			Phase element enable input zone 3		
ENBLZIVP			Phase element enable input zone 4		
ENBL_ZVP			Phase element enable input zone 5		
ENBL_ZVIP			Phase element enable input zone 6		
ENBL_ZVIIP			Phase element enable input zone 7		
ENBL_ZVIIIP			Phase element enable input zone 8		
IN_PERMAG			AG element enable input		Its activation puts single-phase elements into operation no matter phase selector outputs.
IN_PERMBG			BG element enable input		
IN_PERMCG			CG element enable input		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.1.13 Auxiliary Outputs and Events of the Distance Modules

Table 3.1-6: Auxiliary Outputs and Events of the Distance Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
C_ZI_AG			Zone 1 AG Characteristic		Distance characteristic activation for different zones.
C_ZI_BG			Zone 1 BG Characteristic		
C_ZI_CG			Zone 1 CG Characteristic		
C_ZI_AB			Zone 1 AB Characteristic		
C_ZI_BC			Zone 1 BC Characteristic		
C_ZI_CA			Zone 1 CA Characteristic		
C_ZII_AG			Zone 2 AG Characteristic		
C_ZII_BG			Zone 2 BG Characteristic		
C_ZII_CG			Zone 2 CG Characteristic		
C_ZII_AB			Zone 2 AB Characteristic		
C_ZII_BC			Zone 2 BC Characteristic		
C_ZII_CA			Zone 2 CA Characteristic		
C_ZIII_AG			Zone 3 AG Characteristic		
C_ZIII_BG			Zone 3 BG Characteristic		
C_ZIII_CG			Zone 3 CG Characteristic		
C_ZIII_AB			Zone 3 AB Characteristic		
C_ZIII_BC			Zone 3 BC Characteristic		
C_ZIII_CA			Zone 3 CA Characteristic		
C_ZIV_AG			Zone 4 AG Characteristic		
C_ZIV_BG			Zone 4 BG Characteristic		
C_ZIV_CG			Zone 4 CG Characteristic		
C_ZIV_AB			Zone 4 AB Characteristic		
C_ZIV_BC			Zone 4 BC Characteristic		
C_ZIV_CA			Zone 4 CA Characteristic		
C_ZV_AG			Zone 5 AG Characteristic		
C_ZV_BG			Zone 5 BG Characteristic		
C_ZV_CG			Zone 5 CG Characteristic		
C_ZV_AB			Zone 5 AB Characteristic		
C_ZV_BC			Zone 5 BC Characteristic		
C_ZV_CA			Zone 5 CA Characteristic		
C_ZVI_AG			Zone 6 AG Characteristic		
C_ZVI_BG			Zone 6 BG Characteristic		
C_ZVI_CG			Zone 6 CG Characteristic		
C_ZVI_AB			Zone 6 AB Characteristic		
C_ZVI_BC			Zone 6 BC Characteristic		
C_ZVI_CA			Zone 6 CA Characteristic		
C_ZVII_AG			Zone 7 AG Characteristic		
C_ZVII_BG			Zone 7 BG Characteristic		
C_ZVII_CG			Zone 7 CG Characteristic		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 3.1-6: Auxiliary Outputs and Events of the Distance Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
C_ZVII_AB			Zone 7 AB Characteristic		Distance characteristic activation for different zones.
C_ZVII_BC			Zone 7 BC Characteristic		
C_ZVII_CA			Zone 7 CA Characteristic		
C_ZVIII_AG			Zone 8 AG Characteristic		
C_ZVIII_BG			Zone 8 BG Characteristic		
C_ZVIII_CG			Zone 8 CG Characteristic		
C_ZVIII_AB			Zone 8 AB Characteristic		
C_ZVIII_BC			Zone 8 BC Characteristic		
C_ZVIII_CA			Zone 8 CA Characteristic		
ZI_AG			Zone 1 AG Element Pickup		Pickup of the distance elements for each Zone.
ZI_BG			Zone 1 BG Element Pickup		
ZI_CG			Zone 1 CG Element Pickup		
ZII_AG			Zone 2 AG Element Pickup		
ZII_BG			Zone 2 BG Element Pickup		
ZII_CG			Zone 2 CG Element Pickup		
ZIII_AG			Zone 3 AG Element Pickup		
ZIII_BG			Zone 3 BG Element Pickup		
ZIII_CG			Zone 3 CG Element Pickup		
ZIV_AG			Zone 4 AG Element Pickup		
ZIV_BG			Zone 4 BG Element Pickup		
ZIV_CG			Zone 4 CG Element Pickup		
ZV_AG			Zone 5 AG Element Pickup		
ZV_BG			Zone 5 BG Element Pickup		
ZV_CG			Zone 5 CG Element Pickup		
ZVI_AG			Zone 6 AG Element Pickup		
ZVI_BG			Zone 6 BG Element Pickup		
ZVI_CG			Zone 6 CG Element Pickup		
ZVII_AG			Zone 7 AG Element Pickup		
ZVII_BG			Zone 7 BG Element Pickup		
ZVII_CG			Zone 7 CG Element Pickup		
ZVIII_AG			Zone 8 AG Element Pickup		
ZVIII_BG			Zone 8 BG Element Pickup		
ZVIII_CG			Zone 8 CG Element Pickup		
ZI_AB			Zone 1 AB Element Pickup		
ZI_BC			Zone 1 BC Element Pickup		
ZI_CA			Zone 1 CA Element Pickup		
ZII_AB			Zone 2 AB Element Pickup		
ZII_BC			Zone 2 BC Element Pickup		
ZII_CA			Zone 2 CA Element Pickup		
ZIII_AB			Zone 3 AB Element Pickup		
ZIII_BC			Zone 3 BC Element Pickup		
ZIII_CA			Zone 3 CA Element Pickup		
ZIV_AB			Zone 4 AB Element Pickup		
ZIV_BC			Zone 4 BC Element Pickup		
ZIV_CA			Zone 4 CA Element Pickup		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 3.1-6: Auxiliary Outputs and Events of the Distance Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ZV_AB			Zone 5 AB Element Pickup		Pickup of the distance elements for each Zone.
ZV_BC			Zone 5 BC Element Pickup		
ZV_CA			Zone 5 CA Element Pickup		
ZVI_AB			Zone 6 AB Element Pickup		
ZVI_BC			Zone 6 BC Element Pickup		
ZVI_CA			Zone 6 CA Element Pickup		
ZVII_AB			Zone 7 AB Element Pickup		
ZVII_BC			Zone 7 BC Element Pickup		
ZVII_CA			Zone 7 CA Element Pickup		
ZVIII_AB			Zone 8 AB Element Pickup		
ZVIII_BC			Zone 8 BC Element Pickup		
ZVIII_CA			Zone 8 CA Element Pickup		
PU_ZI_G			Zone 1 Ground element pickup		
PU_ZI_PH			Zone 1 Phase element pickup		
PU_ZII_G			Zone 2 Ground element pickup		
PU_ZII_PH			Zone 2 Phase element pickup		
PU_ZIII_G			Zone 3 Ground element pickup		
PU_ZIII_PH			Zone 3 Phase element pickup		
PU_ZIV_G			Zone 4 Ground element pickup		
PU_ZIV_PH			Zone 4 Phase element pickup		
PU_ZV_G			Zone 5 Ground element pickup		
PU_ZV_PH			Zone 5 Phase element pickup		
PU_ZVI_G			Zone 6 Ground element pickup		
PU_ZVI_PH			Zone 6 Phase element pickup		
PU_ZVII_G			Zone 7 Ground element pickup		
PU_ZVII_PH			Zone 7 Phase element pickup		
PU_ZVIII_G			Zone 8 Ground element pickup		
PU_ZVIII_PH			Zone 8 Phase element pickup		
TRIP_ZI_G			Zone 1 Ground element trip		
TRIP_ZI_PH			Zone 1 Phase element trip		
TRIP_ZII_G			Zone 2 Ground element trip		
TRIP_ZII_PH			Zone 2 Phase element trip		
TRIP_ZIII_G			Zone 3 Ground element trip		
TRIP_ZIII_PH			Zone 3 Phase element trip		
TRIP_ZIV_G			Zone 4 Ground element trip		
TRIP_ZIV_PH			Zone 4 Phase element trip		
TRIP_ZV_G			Zone 5 Ground element trip		
TRIP_ZV_PH			Zone 5 Phase element trip		
TRIP_ZVI_G			Zone 6 Ground element trip		
TRIP_ZVI_PH			Zone 6 Phase element trip		
TRIP_ZVII_G			Zone 7 Ground element trip		
TRIP_ZVII_PH			Zone 7 Phase element trip		
TRIP_ZVIII_G			Zone 8 Ground element trip		
TRIP_ZVIII_PH			Zone 8 Phase element trip		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 3.1-6: Auxiliary Outputs and Events of the Distance Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ZIG_ENBLD			Ground elements zone 1 enabled		Indication of the enabled or disabled condition of the corresponding zone ground elements.
ZIIG_ENBLD			Ground elements zone 2 enabled		
ZIIIG_ENBLD			Ground elements zone 3 enabled		
ZIVG_ENBLD			Ground elements zone 4 enabled		
ZVG_ENBLD			Ground elements zone 5 enabled		
ZVIG_ENBLD			Ground elements zone 6 enabled		
ZVIIG_ENBLD			Ground elements zone 7 enabled		
ZVIIIG_ENBLD			Ground elements zone 8 enabled		
ZIP_ENBLD			Phase elements zone 1 enabled		Indication of the enabled or disabled condition of the corresponding zone phase elements.
ZIIP_ENBLD			Phase elements zone 2 enabled		
ZIIIP_ENBLD			Phase elements zone 3 enabled		
ZIVP_ENBLD			Phase elements zone 4 enabled		
ZVP_ENBLD			Phase elements zone 5 enabled		
ZVIP_ENBLD			Phase elements zone 6 enabled		
ZVIIP_ENBLD			Phase elements zone 7 enabled		
ZVIIIP_ENBLD			Phase elements zone 8 enabled		
UD_A			Direction of AG distance elements		Operation of the directional elements associated to the quadrilateral characteristic. Their activation is produced in forward faults.
UD_B			Direction of BG distance elements		
UD_C			Direction of CG distance elements		
UD_AB			Direction of AB distance elements		
UD_BC			Direction of BC distance elements		
UD_CA			Direction of CA distance elements		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.1.14 Distance Element Test

Before running the test, those elements that are not being tested must be deactivated and the distance element activated with the following settings:

Table 3.1-7:Test Settings for the Distance Unit*	
System Impedances	
Positive sequence magnitude. Line impedance	1.20 Ω
Positive sequence angles. Zones 1, 2, 3, 4 and 5 line impedance	75º
Zero sequence angles. Zones 1, 2, 3, 4 and 5 line impedance	75º
K0, K02, K03, K04 and K05 factors	3.00
Positive sequence magnitude. Local source impedance	1.00 Ω
Positive sequence angle. Local source impedance	75º
Zero sequence magnitude. Local source impedance	1.00 Ω
Zero sequence angle. Local source impedance	75º
Positive sequence magnitude. Remote source impedance	1.00 Ω
Positive sequence angle. Remote source impedance	75º
Zero sequence magnitude. Remote source impedance	1.00 Ω
Zero sequence angle. Remote source impedance	75º
Positive sequence magnitude. Equivalent parallel impedance	1.00 Ω
Positive sequence angle. Equivalent parallel impedance	75º
Zero sequence magnitude. Equivalent parallel impedance	1.00 Ω
Zero sequence angle. Equivalent parallel impedance	75º
Distance Elements	
Ground distance characteristic	Quadrilateral
Phase-to-phase characteristic	Quadrilateral
Zone 1 direction	Forward
Zone 2 direction	Forward
Zone 3 direction	Forward
Zone 4 direction	Forward
Zone 5 direction	Forward
Zone 1 reach	1.00 Ω
Zone 2 reach	2.00 Ω
Zone 3 reach	4.00 Ω
Zone 4 reach	5.00 Ω
Zone 5 reach	6.00 Ω
Zone 1 resistive limit	2.00 Ω
Zone 2 resistive limit	4.00 Ω
Zone 3 resistive limit	8.00 Ω
Zone 4 resistive limit	10.00 Ω
Zone 5 resistive limit	12.00 Ω
Zone 1 phase-to-phase resistive limit	2.00 Ω
Zone 2 phase-to-phase resistive limit	4.00 Ω
Zone 3 phase-to-phase resistive limit	8.00 Ω
Zone 4 phase-to-phase resistive limit	10.00 Ω
Zone 5 phase-to-phase resistive limit	12.00 Ω

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Distance Elements (cont.)	
Ground element zone 1 pickup time	0 s
Ground element zone 2 pickup time	0.5 s
Ground element zone 3 pickup time	1 s
Ground element zone 4 pickup time	1.5 s
Ground element zone 5 pickup time	2 s
Phase element zone 1 pickup time	0 s
Phase element zone 2 pickup time	0.5 s
Phase element zone 3 pickup time	1 s
Phase element zone 4 pickup time	1.5 s
Phase element zone 5 pickup time	2 s
Compensation time	0 s
Directional element characteristic angle. Reactance characteristic	75º
Phase lag enable. (Two-phase-to-ground fault)	No
Voltage memory duration	2 cycles

*** For an In = 5 A.**

3.1.14.a Ground Fault Characteristics

- **Reactance Characteristic**

This test will check the reactance element, as well as the resistive limiter.

Apply a three-phase balanced input of voltages, with an input of 65 Vac and inductive angles of 0º, 120º and 240º to phases A, B and C, respectively.

In the phase under test, apply a current of 5 A, with the inductive angles (related to the voltage of the same phase) shown in Table 3.1-8.

Slowly decrease the voltage of the phase under test. Each zone should activate within the voltage ranges indicated in Table 3.1-8.

Activation of each zone will be displayed in the **Information** - **Status** - **Measuring Elements** - **Step Distance** screen, or in the **Status** (**Status** - **Elements** - **Step Distance**) screen of the ***ZIVercomPlus***® software. Also, the verification can be made configuring the activation in auxiliary outputs and verifying the status.

Table 3.1-8: Reactance Characteristic Test for Single Phase Faults

Zone	Voltage Trip (V)						
	Res. Limit R>0		Reactance			Res. Limit R<0	
	Phase I=0º	Phase I=15º	Phase I=45º	Phase I=75º	Phase I=105º	Phase I=150º	Phase I=165º
1	9.7-10.3	10.82-11.49	11.04-11.73	8.08-8.58	8.08-8.58	9.7-10.3	9.37-9.95
2	19.4-20.6	21.64-22.98	22.08-23.45	16.17-17.17	16.17-17.17	19.4-20.6	18.74-19.9
3	38.8-41.2	43.28-45.95	44.17-46.9	32.33-34.33	32.33-34.33	38.8-41.2	37.48-39.8
4	48.5-51.5	54.09-57.44	55.21-58.63	40.42-42.92	40.42-42.92	48.5-51.5	46.85-49.74
5	58.2-61.8	64.91-68.93	66.25-70.35	48.50-51.50	48.50-51.50	58.20-61.80	56.22-56.69

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This test uses the relationship between the voltage **V**, which trips the unit by the **Reactance** characteristic, for a given current **I** in the test phase; provided the current difference of the other phases to that of the test phase current yields 0 Aac. This relationship is given by the following equation:

$$V = \frac{1}{3} \cdot I \cdot Z1n \cdot \frac{sen(a + \theta 1n)}{sen(\alpha)} \cdot \left| 2 + K0n \cdot e^{j \cdot (\theta 0n - \theta 1n)} \right|$$

Use the following equation to determine the operating points of the **Resistive limiter** (R>0):

$$V = \frac{I \cdot RGn \cdot sen(\theta bn)}{sen(\theta bn - \alpha)}$$

And the following equation to determine the operating points of the **Resistive limiter** (R<0):

$$V = \frac{I \cdot RGn \cdot sen(\theta bn)}{sen(\alpha - \theta bn)}$$

Where:

$Z1n$	Positive sequence reach impedance of the zone n
RGn	Resistive limiter reach impedance in Ω, for ground faults of the zone n
$\theta 1n$	Positive sequence reach impedance angle of the zone n
$\theta 0n$	Zero sequence reach impedance angle of the zone n
θbn	Impedance angle of the loop for zone n In case that the sound phases are null θbn = θ1n+a
$K0n = \frac{\lvert Z0n \rvert}{\lvert Z1n \rvert}$	Zero sequence compensation factor of the zone n
I	Effective value of the phase current
α	Inductive angle of the phase current with respect to the phase voltage
a	Phase shift between the equivalent current and the phase current, i.e., $a = \arg\left(2 + K0n \cdot e^{j \cdot (\theta 0n - \theta 1n)}\right)$ in case that the sound phases are null

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- **MHO Characteristic**

The test will be carried out in the same manner as previously, on adjusting the **Characteristic for Ground Fault** as **MHO**. The results obtained will be the following:

Table 3.1-9: Mho Characteristic Test for Single Phase Faults						
Zone	**Voltage Trip (V)**					
	Phase I=0º	**Phase I=30º**	**Phase I=60º**	**Phase I=75º**	**Phase I=90º**	**Phase I=120º**
1	2.09-2.22	5.72-6.07	7.81-8.29	8.08-8.58	7.81-8.29	5.72-6.07
2	4.18-4.44	11.43-12.14	15.62-16.58	16.17-17.17	15.62-16.58	11.43-12.14
3	8.37-8.89	22.86-24.28	31.23-33.16	32.33-34.33	31.23-33.16	22.86-24.28
4	10.46-11.11	28.58-30.35	39.04-41.45	40.42-42.92	39.04-41.45	28.58-30.35
5	12.55-13.33	34.29-36.41	46.84-49.74	48.5-51.5	46.84-49.74	34.29-36.41

This test uses the relationship between the voltage **V**, which trips the unit by the Mho characteristic, for a given a current **I** in the test phase; provided the current difference of the other phases to that of the test phase current yields 0 A ac. This relationship is given by the following equation:

$$V = \frac{1}{3} \cdot I \cdot Z1n \cdot \cos\left(\theta 1n - \alpha + a\right) \cdot \left| 2 + K0n \cdot e^{j \cdot (\theta 0n - \theta 1n)} \right|$$

Where:

$Z1n$	Positive sequence reach impedance of the zone n
$\theta 1n$	Positive sequence reach impedance angle of the zone n
$\theta 0n$	Zero sequence reach impedance angle of the zone n
$K0n = \frac{\lvert Z0n \rvert}{\lvert Z1n \rvert}$	Zero sequence compensation factor of the zone n
I	Effective value of the phase current
α	Inductive angle of the phase current with respect to the phase voltage
a	Phase shift between the equivalent current and the phase current, i.e., $a = \arg\left(2 + K0n \cdot e^{j \cdot (\theta 0n - \theta 1n)}\right)$ in case that the sound phases are null

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- **Zone Times**

Prepare the system to measure the time between the application of current to the test phase and the close of the corresponding trip contact.

Begin with a three-phase balanced voltage system, with an input of 65 Vac and inductive angles of 0º, 120º and 240º in the A, B and C phases, respectively; and a balanced three-phase current, with an input of 0 Vac and inductive angles of 75º, 195º and 315º in the A, B and C phases, respectively.

The voltage of the phase under test will be reduced to the values for each zone, as indicated in Table 3.1-10.

Raise the effective value of the current of the phase under test until it reaches 5 A ac, measuring the time between the application of the current and the close of the trip contact of the phase under test.

Table 3.1-10 also indicates the ranges of trip times for each zone.

Table 3.1-10: Zone Times (single-phase faults)

Zone	Applied Voltage (V)	Minimum Time (s)	Maximum Time (s)
1	5.00	-	0.045
2	12.00	0.475	0.525
3	20.00	0.950	1.050
4	36.00	1.425	1.575
5	42.00	1.9	2.1

3.1.14.b Characteristic for Faults between Phases

- **Reactance Characteristic for Faults between Phases**

This test will check the **Reactance element**, as well as the **Resistive limiter**.

For this test, two phases will be used (pairs AB, BC or CA). Initially, 65 Vac will be applied with 0º to the first phase, and a voltage of 65 Vac and 180º to the second phase and a voltage of 65 Vac and 90º to the third.

A current of 5 A ac will be applied to the first phase, with an angle (inductive) as indicated in Table 3.1-11. A current of 5 A ac will be applied to the second phase and an angle 180º out of phase to that of the first phase.

The voltages of the phases under test should be gradually and simultaneously reduced, and the characteristics of the different zones should activate within the voltage ranges that are shown in Table 3.1-11.

The activation of each zone can be viewed on the display (**Information** - **Status** - **Measuring Units** - **Step Distance**), or in the status screen of the ***ZIVercomPlus***® software program (**Status** - **Elements** - **Step Distance**). The verification can also be made configuring the activations in auxiliary outputs and verifying the status.

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Table 3.1-11: Reactance Characteristic Test for Faults Between Phases							
Zone	Voltage Trip (V)						
	Res. Limit R>0		Reactance			Res. Limit R<0	
	Phase I=0º	Phase I=15º	Phase I=45º	Phase I=75º	Phase I=105º	Phase I=150º	Phase I=165º
1	9.7-10.3	10.82-11.49	6.63-7.03	4.85-5.15	4.85-5.15	9.7-10.3	9.37-9.95
2	19.4-20.6	21.64-22.98	13.25-14.07	9.7-10.3	9.7-10.3	19.4-20.6	18.74-19.9
3	38.8-41.2	43.28-45.95	26.5-28.14	19.4-20.6	19.4-20.6	38.8-41.2	37.48-39.8
4	48.5-51.5	54.09-57.44	33.13-35.18	24.25-25.75	24.25-25.75	48.5-51.5	46.85-49.74
5	58.2-61.8	64.91-68.92	39.75-42.21	29.1-30.9	29.1-30.9	Reactance breaking	46.84-49.74

This test uses the relationship between the value of the phase voltage **V** (with angles of 0° and 180º), which trips the unit by the Reactance characteristic for faults between phases and the corresponding phase current, for a given current **I** (with angles of 0° and 180º plus a phase difference with respect to the voltage). This relationship is given by the following equation:

$$V = \left(I \cdot Z1n\right) \cdot \frac{sen\left(\theta 1n\right)}{sen\left(\alpha\right)}$$

Use the following equation to determine the operating points of the **Resistive limiter** (R>0):

$$V = \frac{I \cdot RPn \cdot sen(\theta 1n)}{sen(\theta 1n - \alpha)}$$

And the following equation to determine the operating points of the **Resistive limiter** (R<0):

$$V = \frac{I \cdot RPn \cdot sen(\theta 1n)}{sen(\alpha - \theta 1n)}$$

Where:

$Z1n$	Positive sequence reach impedance of the zone n
$\theta 1n$	Positive sequence reach impedance angle of the zone n
I	Effective value of the phase current
α	Inductive angle of the currents with respect to the voltages
RPn	Resistive limiter reach impedance in Ω, for faults between phases of the zone n

In general, this equation shows the relationship between the voltage and current equivalents for a given pair of phases that establishes the corresponding point of the Reactance characteristic for a fault between phases.

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- **Mho Characteristic for Faults between Phases**

For this test, two phases will be used (pairs AB, BC or CA). Initially, 65 Vac will be applied with 0º to the first phase, a voltage of 65 Vac and 180º to the second phase and a voltage of 65 Vac and 90º to the phase not involved in the fault.

A current of 5 A ac will be applied to the first phase, with an angle as indicated in Table 3.1-12. A current of 5 A ac will be applied to the second phase and an angle 180º out of phase to that of the first phase.

The voltages of the phases under test should be gradually and simultaneously reduced, and the characteristics of the different zones should activate within the voltage ranges that are shown in Table 3.1-12.

The activation of each zone can be viewed on the display (**Information** - **Status** - **Measuring Units** - **Step Distance**) or in the status screen of the ***ZIVercomPlus***® software program (**Status** - **Elements** - **Step Distance**). The verification can also be made configuring the activations in auxiliary outputs and verifying its status.

Table 3.1-12: Mho Characteristic Test for Faults Between Phases

Zone	Voltage Trip (V)					
	Phase I=0º	Phase I=30º	Phase I=60º	Phase I=75º	Phase I=90º	Phase I=120º
1	1.26-1.33	3.43-3.64	4.69-4.97	4.85-5.15	4.69-4.97	3.43-3.64
2	2.51-2.67	6.86-7.28	9.37-9.95	9.7-10.3	9.37-9.95	6.86-7.28
3	5.02-5.33	13.72-14.57	18.74-19.9	19.4-20.6	18.74-19.9	13.72-14.57
4	6.28-6.66	17.15-18.21	23.42-24.87	24.25-25.75	23.42-24.87	17.15-18.21
5	7.53-7.99	20.57-21.85	28.10-29.85	29.1-30.9	27.93-29.66	20.57-21.84

This test uses the relationship between the value of the phase voltage **V** (with angles of 0° and 180º), which trips the unit by the MHO characteristic for faults between phases and the corresponding phase current, for a given current **I** (with angles of 0° and 180º plus a phase difference with respect to the voltage). This relationship is given by the following equation:

$$V = I \cdot Z1n \cdot \cos\left(\theta 1n - \alpha\right)$$

Where:

$Z1n$	Positive sequence reach impedance of the zone n
$\theta 1n$	Positive sequence reach impedance angle of the zone n
I	Effective value of the phase current
α	Inductive angle of the currents with respect to the voltages

In general, this equation shows the relationship between the voltage and current equivalents for a given pair of phases that establishes the corresponding point of the MHO characteristic for a fault between phases.

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- **Zone Times**

Prepare the system to measure the time between the application of current and the close of the corresponding trip contact.

Two phases will be used for this test. A voltage of 65 Vac and 0º will be applied to one phase, a voltage of 65 Vac and 180º will be applied to the second and in the voltage not involved in the fault 65 Vac and 90º.

A current of 7.5 A ac and an angle of 75º will be applied to the first phase. To the second phase, a current of 7.5 A ac and an angle 180º out of phase to that of the first phase will be applied.

The effective values of the voltages of the phases under test will be reduced to a different value for each zone, according to the values shown in Table 3.1-13.

Table 3.1-13 also indicates the resulting ranges of the trip times for each zone.

Table 3.1-13: Zone Times (Faults between Phases)

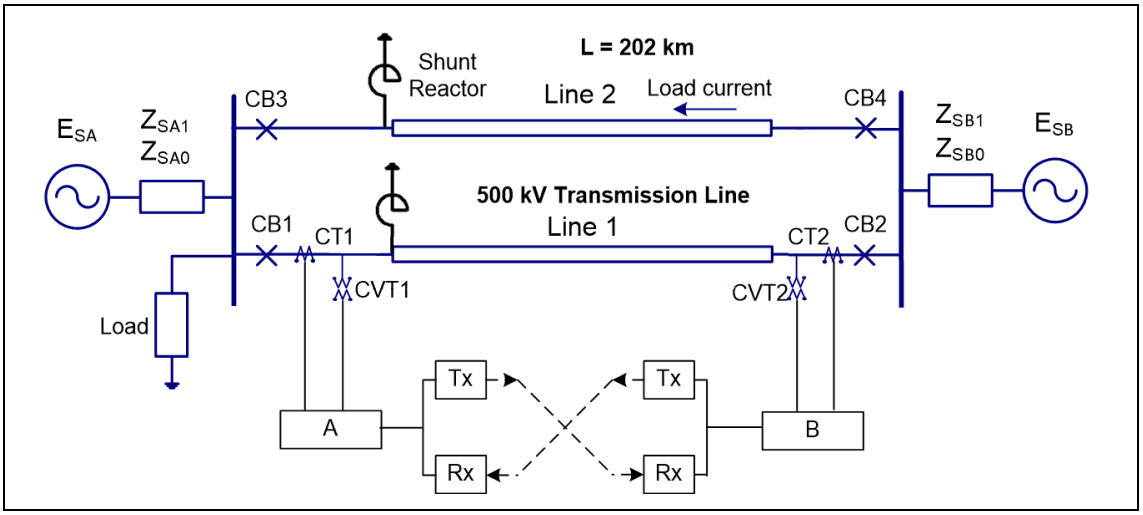
Zone	Applied Voltage (V)	Minimum Time (s)	Maximum Time (s)
1	5.00	-	0.045
2	12.00	0.475	0.525
3	20.00	0.950	1.050
4	36.00	1.425	1.575
5	42.00	1.9	2.1

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3.1.15 Application Example

3.1.15.a Initial Data

Consider an overhead line with the following characteristics:



POWER SYSTEM PARAMETER

AC INPUT RATING

	"A" SIDE		"B" SIDE	
CT RATIO (A)	2000	1	2000	1
VT RATIO (V)	500000	100	500000	100
Frequency	50Hz			

SYSTEM CONSTANT

"A" SOURCE (Ω)		
Zs (Ω)	Zp1	5,5+35.5j
	Zp0	14+76.75j

"B" SOURCE (Ω)		
Zs (Ω)	Zp1	5+40.25j
	Zp0	17.25+82.75j

LINE TRANSMISSION IMPEDANCES (Ω) LINE LENGTH 202 KM			
ZL (Ω) LINE IMPEDANCE	ZL1	5,221+58.406j	0.116 L 85º Ω/L
	ZL0	36.421+175.219j	0.354 L 78º Ω/L
	ZL0M	32.2319+103.8959j	0.215 L 73º Ω/L

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3.1.15.b System Impedances

First, the impedances must be changed to the polar form (module and argument) and referenced to the secondary side of the CT. Therefore, the general setting and system impedances will be:

GENERAL SETTINGS		
SETTING	VALUE	UNITS
Phase CT Ratio	2000	-
Parallel CT Ratio	2000	-
Phase VT Ratio	5000	-
Capacitive VT	YES	-
Phase Sequence	ABC	-

LINE IMPEDANCE		
SETTING	VALUE	UNITS
Positive Seq. Impedance Module	0.116	Ω/L
Positive Seq. Impedance Angle	85	º
Zero Seq. Impedance Module	0.354	Ω/L
Zero Seq. Impedance Angle	78	º
Positive Seq. Susceptance	10.97	µS/L
Zero Seq. Susceptance	7.117	µS/L
Line Length	202	-
LOCAL SOURCE IMPEDANCE		
SETTING	VALUE	UNITS
Positive-Sequence Magnitude	14.37	Ω
Positive-Sequence Angle	81	º
REMOTE SOURCE IMPEDANCE		
SETTING	VALUE	UNITS
Positive-Sequence Magnitude	16.22	
Positive-Sequence Angle	83	º
PARALLEL LINE IMPEDANCE		
SETTING	VALUE	UNITS
Mutual Coupling Factor	1.85	
Mutual Coupling Angle	73	º
Factor I0/I0PAR	0.95	

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The local and remote source impedances and the equivalent parallel impedance are set with the values taken from the example data, however they are not used either in the fault locator or in the zone 1 reactance line. These impedances are used to compensate for the non-homogeneity of the system. In this case the system is quite homogeneous.

The setting in the fault locator “non-homogeneity compensation” is set to NO. On the other hand, the tilt angle for the reactance line is set to 0º. In case the system impedances are not known precisely, a -5º angle is recommended to avoid overreaching. The setting “Tilt Angle Type” should be put to “Direct”. The tilting time can be set equal to a breaker failure time: 0.2 to 0.4 s.

The non-homogeneity of the system is calculated with the following formula:

$$\gamma := \arg\left[\frac{\left[(ZA1 + ZB1)\cdot\left(1 + \frac{ZL1}{ZP1}\right) + ZL1\right]}{ZB1}\right]$$

Where:

- ZA1 is the positive-sequence local source impedance.
- ZB1 is the positive-sequence remote source impedance.
- ZP1 is the positive-sequence equivalent parallel circuit impedance.
- ZL1 is the positive-sequence line impedance.

The angle calculated for the line ends is -0.125º and 1.875º, respectively. This means that the system is practically homogeneous, so no actions to compensate for non-homogeneity are required.

The KM0 (mutual coupling factor) can be calculated as ZLM0/ZL1 and is introduced to compensate for the zero-sequence mutual coupling when there is a parallel line. This compensation is done with the measurement of the ground current coming from the parallel line by means of the analog channel INPAR. Three-phase currents from the parallel line CT must be short-circuited to compose INPAR current and wired to the relay.

The factor I0/I0PAR avoids the use of mutual compensation in the healthy line, which can lead to overreaching, especially if I0PAR is much higher than I0. In the healthy line, if the parallel lines share the same source, the zero-sequence current will be lower than in protected line, therefore I0/I0PAR will be very low. The mutual compensation will only be made if I0/I0PAR is above the setting.

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3.1.15.c Common Settings for Distance Units

Due to the limited coverage of the Mho characteristic a Quadrilateral characteristic is chosen. Directional type is set to normal. Lagging phase operation is not enabled. The memory voltage time is set to the maximum time (100 cycles). Series compensation logic is not enabled and the parallel line mutual coupling compensation for the distance units is enabled.

COMMON SETTINGS		
SETTING	VALUE	UNITS
Ground Characteristic	Quadrilateral	-
Phase Characteristic	Quadrilateral	-
Directional Type	Normal	-
Start Type	Zone Pickup	-
Lagging Phase	No	-
Memory Duration	100	Cycles
Voltage Threshold	1	V
Series Comp. Enable	No	-
Distance Units Mutual Coupling Compensation	Yes	-

3.1.15.d Zone Settings

Zone 1 reach is set to 80% of the positive-sequence line impedance. The resistive reach is normally set to a value of 3 to 4 times the impedance reach if it allows for a correct setting of Zone 3 and the Power Swing Detector zones. A more accurate value could be obtained with the following formulas:

$$RG := \frac{|ZL1| \cdot [(Z1_reach + overreach) \cdot (1 - m) \sin(\theta L - \arg(K) - \gamma) - Z1_reach \cdot \sin(\theta L - \arg(K) - \gamma + \delta)]}{\left(|K| \cdot \frac{\sin(\theta L - \arg(K))}{\sin(\theta L - \arg(K) - \gamma)} \cdot \sin(\delta) \right)}$$

$$RP := \frac{|ZL1| \cdot [(Z1_reach + overreach) \cdot (1 - m) \sin(\theta L - \gamma) - Z1_reach \cdot \sin(\theta L - \gamma + \delta)]}{\left(\frac{\sin(\theta L)}{\sin(\theta L - \gamma)} \cdot \sin(\delta) \right)}$$

Where:

- ZL1: is the line impedance.
- Z1 reach: is zone 1 reach set in % of the line impedance (normally 80%).
- Overreach: is the maximum overreach tolerated for zone 1 (a value of 20% is normally used).
- m: is the maximum magnitude error coming from the VTs and CTs in % (2-3% is normally used).
- δ: is the maximum angle error coming from the VTs and CTs in º (3º is normally used).
- γ: is the tilting angle used by the reactance line (0º in this case).
- k=1/[1+1/3*(K0-1)], where K0 is the zero-sequence compensation factor.
- θL: is the line angle.

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The results are RG=129.58 Ω and RP=79.23 Ω. As can be seen, using the mentioned formula, both RP and RG result higher than 4 times the impedance reach. Both RG and RP are set to 3.8 times the reach to allow for power swing zones accommodation without invading load zone. The ground resistive reach is given in Ω/loop while the phase resistive reach is given in Ω/phase.

K0 factor is calculated as Z0L/Z1L, that is, 0.354/0.116 = 3.05.

As was mentioned before, the system is quite homogenous, therefore the tilting angle of the reactance line is set to 0º.

Z1 SETTINGS		
SETTING	VALUE	UNITS
Enable Neutral Zone	Yes	-
Enable Phase Zone	Yes	-
Direction	Forward	-
Ground Reach	18.75	Ω/phase
Phase Reach	18.75	Ω/phase
Ground Resistive Limit	70.35	Ω/loop
Phase Resistive Limit	70.35	Ω/phase
Ground Time	0	s
Phase Time	0	s
Positive-Sequence Angle	85	º
Zero-Sequence Angle	78	º
k0 Factor	3.05	
Tilt Time	0	s
Tilt Angle Type	Direct	
Tilt Angle	0	º
Z. Power Swing Block	Yes	
Harm. Blocking Z1	No	

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Zone 2 reach is set to 150% of the positive-sequence line impedance. The ground resistive reach is set to 3 times the impedance reach. However, the phase resistive reach cannot be set to this value as it will activate the quadrilateral characteristic during load conditions. On the other hand, some tolerance is needed to accommodate the medium and external zones for the power swing detector. A value of 2 times the impedance reach is selected.

Note that the calculation of the ground reach does not need to consider the load impedance because, if the values in the phase selector I0 and I0/I1 are properly set, the ground units will have permission to operate only during ground-fault conditions.

The time delay for both phase and ground units is set to 400 ms.

Z2 SETTINGS		
SETTING	VALUE	UNITS
Enable Neutral Zone	Yes	-
Enable Phase Zone	Yes	-
Direction	Forward	-
Ground Reach	35.2	Ω/phase
Phase Reach	35.2	Ω/phase
Ground Resistive Limit	105.55	Ω/loop
Phase Resistive Limit	70.35	Ω/phase
Ground Time	0.4	s
Phase Time	0.4	s
Positive-Sequence Angle	85	º
Zero-Sequence Angle	78	º
k0 Factor	3.05	
Tilt Time	0	s
Tilt Angle Type	Calculated	
Tilt Angle	0	º
Z. Power Swing Block	Yes	
Harm. Blocking Z1	No	

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Zone 3 reach is set to 200% of the positive-sequence line impedance. The ground resistive reach is set to 3 times the impedance reach. The phase resistive reach is set equal to the zone 2 phase resistive reach to avoid load invasion, not only for zone 3 but also for the external zone of the power swing detector.

The time delay for both phase and ground units is set to 800 ms.

Z3 SETTINGS		
SETTING	VALUE	UNITS
Enable Neutral Zone	Yes	-
Enable Phase Zone	Yes	-
Direction	Forward	-
Ground Reach	46.9	Ω/phase
Phase Reach	46.9	Ω/phase
Ground Resistive Limit	140.75	Ω/loop
Phase Resistive Limit	70.35	Ω/phase
Ground Time	0.8	s
Phase Time	0.8	s
Positive-Sequence Angle	85	º
Zero-Sequence Angle	78	º
k0 Factor	3.05	
Tilt Time	0	s
Tilt Angle Type	Calculated	
Tilt Angle	0	º
Z. Power Swing Block	Yes	
Harm. Blocking Z1	No	

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Zone 4 reach is set to 60% of the line impedance, to reach further than zone 2 from the remote end (set to 150% of the line impedance). The direction is reverse. The resistive reach is set equal to zone 2 resistive reach, ground and phase respectively.

Zone 4 is only used for the protection schemes: current reversal blocking logic and DCB scheme.

Z4 SETTINGS		
SETTING	VALUE	UNITS
Enable Neutral Zone	Yes	-
Enable Phase Zone	Yes	-
Direction	Reverse	-
Ground Reach	14.07	Ω/phase
Phase Reach	14.07	Ω/phase
Ground Resistive Limit	105.55	Ω/loop
Phase Resistive Limit	70.35	Ω/phase
Ground Time	1.5	s
Phase Time	1.5	s
Positive-Sequence Angle	85	º
Zero-Sequence Angle	78	º
k0 Factor	3.05	
Tilt Time	0	s
Tilt Angle Type	Calculated	
Tilt Angle	0	º
Z. Power Swing Block	No	
Harm. Blocking Z1	No	

Zone 5 is only enabled during power swing conditions. It will operate only for faults not involving ground that occur during power swing conditions. To cover the entire line it will have the same reach zone 3.

Zone 6, 7 and 8 are not used in this example.

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3.2 Distance Protection Schemes

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3.2.1 Protection Schemes for Distance Elements

3.2.1.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Protection Schemes for Distance Elements	PSCH2	-	85

3.2.2 Description

DLF terminal units include different protection schemes as a complement to the distance elements (zones 1 to 8). These schemes are intended to accelerate tripping for faults occurring outside Zone 1. These systems are known as **Distance Protection Schemes** and are based on the use of signals transmitted through communication channels between terminals at both line ends, so that the decision logic operates both with local and remote information. Said protection schemes are independent from **Overcurrent Protection Schemes** (Chapter 3.3), so that they may use separate communication channels.

Note: all inputs and outputs on distance protection scheme logic diagrams will be identified with the word "Distance", so as to distinguish them from inputs and outputs in overcurrent protection schemes logic, which will be identified with the word "Overcurrent".

These protection schemes can be selected in relays:

1. None	**5. Direct Transfer Trip**
2. Zone 1 Extension	**6. Permissive Overreach**
3. Permissive Underreach	**7. Directional Comparison Unblocking**
4. Directional Comparison Blocking	

Zone 1 Extension scheme only works with local information, so that a communication channel between both line ends is not required. However, it may not always accelerate the tripping in parts of the line not covered by the first zone.

Schemes 3 to 7 work with both local and remote information, so that they need a communication channel between line ends. Under the schemes 3 to 6, the signal transmitted from one equipment to another through the communication channel is deemed as a trip permissive signal, whereas the function of scheme 7 is preventing the other equipment from tripping.

But for schemes 1 to 4, all schemes use an underreach zone (set below 100% of the line), coinciding with zone 1, and an overreach zone (set above 100% of the line), which can be zone 2 or zone 3 as a function of the **Overreach Zone** setting.

DLF relay comprises **Weak Infeed Logic** and **Reverse Current Blocking Logic**, which, if enabled, could supplement those protection schemes that so require. Said logics are independent from logics associated to **Overcurrent Protection Schemes**.

Scheme 7 and weak Feed and reverse current lockout logic use a reverse looking zone, **Zone 4 or Zone 5,** as a function of the **Reverse looking Zone** setting.

The **Distance Protection Scheme** setting selects which of the seven options is active.

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3.2.3 Zone 1 Extension

Zone 1 Extension is activated when selected in the **Protection Scheme** setting. This scheme is useful in lines without any communication channel between line ends. Selecting Zone 1 Extension allows the overreach zone to trip instantaneously, which is equivalent to extending the reach of zone 1 up to the overreach zone. As this scheme is likely to produce instantaneous trips under faults external to the line, it must be supplemented with very quick reclosers for restoring the supply as soon as possible. The operation logic of said scheme is represented in the diagram of Figure 3.2.1.

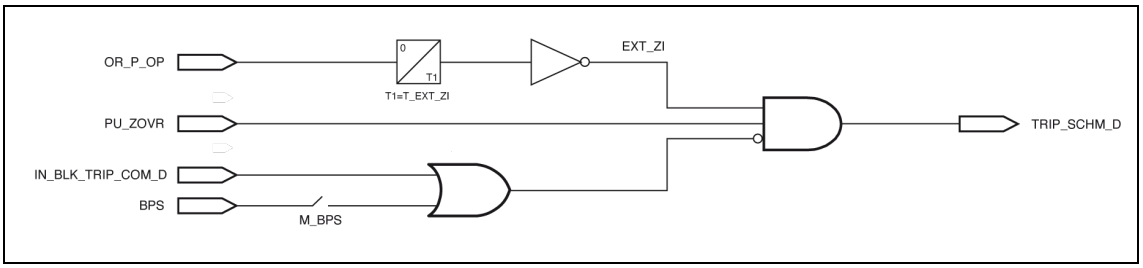


Figure 3.2.1 Zone 1 Extension Scheme Block Diagram.

Legend	
OR_P_OP: Any Pole Open.	T_EXT_ZI: Z1 Extension Blocking Time (setting).
PU_ZOVR: Overreach Zone Pickup.	
IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.	M_BPS: Power Swing Blocking Mask (setting).
BPS: Power Swing Blocking.	TRIP_SCHM_D: Distance Protection Scheme Trip.
EXT_ZI: Zone 1 Extension 1.	

After selecting this protection scheme, signal **Zone 1 Extension** (**EXT_ZI**) will be activated if the breaker has remained closed during ***Z1 Extension Blocking Time*** setting (**T_EXT_ZI**). **Zone 1 Extension** signal will activate the **Distance Channel Trip** signal provided the overreach zone is picked up. Although no communication channel between line ends is required for this scheme, the designation “channel trip” is maintained to refer to trips (instantaneous) by protection scheme.

The purpose of signal **EXT_ZI** reset after the break of any breaker pole (**OR_P_OP**) keeping it at zero for the time **T_EXT_ZI** from the moment the breaker is closed, is preventing second instantaneous trips under permanent faults external to the line. This way, after a reclosing and for the time **T_EXT_ZI** (time required to discern if two consecutive trips belong to the same fault), the equipment will operate following the Step Distance scheme.

The channel trip and activation may be blocked by digital input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**) activation or by the signal **Power Swing Blocking** (if said event is allowed to block the operation of the schemes through the corresponding bit of **Power Swing Blocking Mask**).

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3.2.4 Permissive Underreach

Permissive Underreach is activated when selected in the **Protection Scheme** setting. It functions as a complement to the Step Distance scheme.

With this scheme, if a terminal locates the fault inside Zone 1 (adjusted below 100% of the line), and the other terminal locates the fault inside overreach zone (adjusted over 100% of the line), the fault is considered internal to the transmission line; closer to the terminal that initially detects the fault.

The terminal detecting the fault inside Zone 1 will generate an instantaneous tripping signal and transmit this channel signal to the remote end to allow tripping (in case of lines with more than two terminals, the signal will be sent to all of them). The remote terminal will trip instantaneously when the channel signal is received if any overreach measuring element has picked up. In case of more than two terminals, only a permissive signal from one of them is sufficient to activate an immediate trip by the overreach zone in any of the other terminals (because of this the channel reception input should be configured as an OR of the received permissive signals).

If weak or zero infeed conditions exist at one of the line ends and the overreach zone is not activated, this end could be tripped in an instantaneous mode, by means of Weak Infeed tripping logic, provided the “strong” end has seen the fault in zone 1 and has therefore sent a permissive tripping signal towards the “weak” end. To this end, ***Distance Weak Infeed Output*** (**WI_DM**) should be set to **Echo + Trip**, even if the echo signal is not used in the Permissive Underreach scheme, it being considered useless.

If, because of weak or zero infeed conditions at one of the line ends, no end sees the fault in zone 1, it is preferable to select a Permissive Overreach scheme together with the Weak Infeed logic.

3.2.4.a Channel Activation Conditions (“Distance Channel Transmission”)

The communications channel will be activated by any of the following conditions:

1. Any of Zone 1 elements picked up.
2. Activation of the overreach zone, provided the Channel Reception input is activated.
3. The three breaker poles tripped if **Open Breaker Transmission** is set to **YES**.

3.2.4.b Tripping Conditions (“Distance Protection Scheme Trip”)

The channel trip will take place upon channel reception and the activation of the overreach zone or else signal **Distance Weak Infeed Trip** is activated, (**TRIP_WI_D**), for which **Distance Weak Infeed Output** (**WI_DM**) must be set to **Echo + Trip**.

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3.2.4.c Operation

Channel activation and trip command generation are shown in the following block diagram.

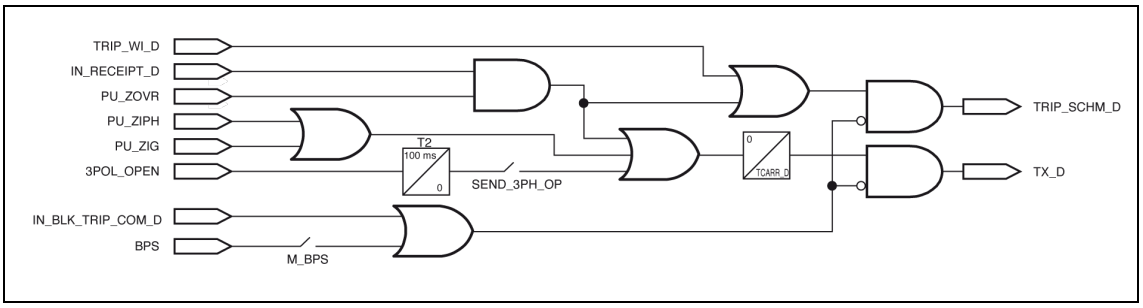


Figure 3.2.2 Permissive Underreach Scheme Block Diagram.

Legend	
TRIP_WI_D: Distance Weak Infeed Trip.	BPS: Power Swing Blocking.
IN_RECEIPT_D: Distance Channel Reception Input.	TX_D: Distance Channel Transmission.
	TRIP_SCHM_D: Distance Protection Scheme Trip.
PU_ZOVR: Overreach Zone Pickup.	
PU_ZI: Zone 1 Ground/Phase Units Pickup.	SEND_3PH_OPEN: Open Breaker Transmission (setting).
3POL_OPEN: Three Pole Open.	
IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.	TCARR_D: Distance Carrier Time (setting).
	M_BPS: Power Swing Blocking Mask (setting).

The purpose of **Distance Carrier Time** (**TCARR_D**) setting on the diagram is guaranteeing a minimum time for **Channel Activation** (**TX_D**).

Open Breaker Transmission (**SEND_3PH_OP**) setting allows activating the channel upon the opening of the three breaker poles. The purpose of **T2** time delay of 100ms is delaying carrier transmission when this is produced by breaker trip.

Channel tripping and channel activation can be disabled using the status contact input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**) activation or by the signal **Power Swing Blocking** (if said event is allowed to block the operation of the schemes through the corresponding bit of **Power Swing Blocking Mask**).

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3.2.5 Direct Transfer Trip

Direct Transfer Trip scheme is activated when selected in the **Protection Scheme** setting. It functions as a complement to the Step Distance scheme.

This scheme is similar to the **Permissive Underreach**, except that upon receiving the trip signal form the other end, an instantaneous trip is generated with no additional monitoring.

3.2.5.a Channel Activation Conditions ("Distance Channel Transmission")

The communications channel will be activated by any of the following conditions:

1. Any of Zone 1 elements picked up
2. The three breaker poles tripped if ***Open Breaker Transmission*** is set to **YES**.

3.2.5.b Tripping Conditions ("Distance Protection Scheme Trip")

Channel tripping will always take place whenever channel reception takes place.

Since this scheme produces trips without supervising any protection unit, the trips must always be three-phase. In this case, it is necessary to connect, by means of the programmable logic, the **Distance Protection Scheme Trip** output to the **Three-Phase Trip Enable** input.

3.2.5.c Operation

Channel activation and trip command generation are shown in the following block diagram.

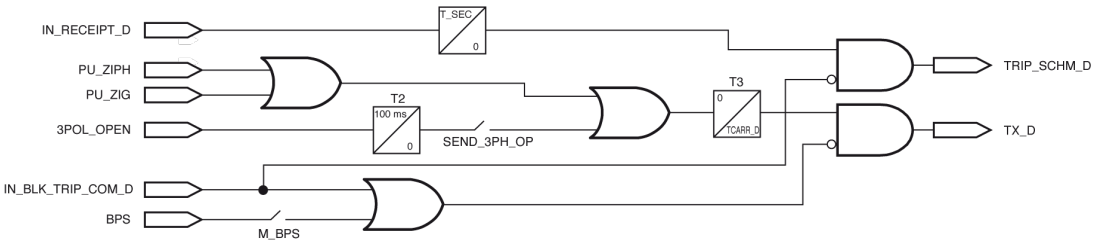


Figure 3.2.3 Direct Transfer Trip Scheme Block Diagram.

Legend	
IN_RECEIPT_D: Distance Channel Reception Input.	TRIP_SCHM_D: Distance Protection Scheme Trip.
PU_ZI x: Zone 1 Ground/Phase Units Pickup.	T_SEC: Security Time (setting)
3POL_OPEN: Three Open Pole.	SEND_3PH_OPEN: Open Breaker Transmission (setting).
IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.	TCARR_D: Distance Carrier Time (setting).
BPS: Power Swing Blocking.	M_BPS: Power Swing Blocking Mask (setting).
TX_D: Distance Channel Transmission.	

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The purpose of ***Distance Carrier Time*** (**TCARR_D**) setting on the diagram is guaranteeing a minimum **Channel Activation** (**TX_D**) time.

Open Breaker Transmission (**SEND_3PH_OP**) setting allows channel activation when the three breaker poles open. The purpose of **T2** timing of 100 ms is delaying the carrier transmission when it is caused by breaker trip.

The purpose of ***Security Time*** (**T_SEC**) setting is guaranteeing a minimum duration of the received signal, thus avoiding undue operations upon channel noise.

Channel tripping and channel activation may be blocked by digital input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**) activation. **Power Swing Blocking (BPS)** activation can disable channel activation; however, the option of channel trip blocking is not given, as no protection element activation is checked at the end receiving the transferred trip signal.

3.2.6 Permissive Overreach

Permissive Overreach is activated when selected in the **Protection Scheme** setting. It will function as a complement to the Step Distance scheme.

This scheme is based on the fact that if both terminals see the fault in the overreach zone (adjusted above 100% of the line, overreaching), the fault can be considered as internal to the line. The terminal detecting the fault inside the overreach zone sends the permissive trip signal to the other end (in case of lines with more than two terminals, the signal is sent to all of them).

At the other terminal, the reception of the permissive signal coming from the first terminal produces an instantaneous trip if any of the metering elements of the overreach-designated zone has been picked up. In case of more than two terminals, receiving permissive signals from the rest of the terminals is required to allow immediate trip activation by the overreach zone of any of them, so that the channel reception input should be setup as an AND of the signals received.

Signal **Distance Reverse Current Blocking** (**BLK_INV_A_D**), coming from **Reverse Current Blocking Logic** (for distance), blocks, provided it is activated, the input coming from the overreach zone pickup, to prevent wrong trips upon current reversal produced as a consequence of the sequential clearance of faults in a parallel line.

If weak or zero infeed conditions exist in one of the line ends, so that none of the elements associated to the overreach zone are picked up, neither end may trip under this scheme (they will trip under the Step Distance scheme). In this case, the Permissive Overreach scheme should be supplemented by the Weak Infeed logic, which allows sending a trip permissive signal to the “strong” end (as an echo of the signal sent by said end) to achieve its tripping (***Distance Weak Infeed Output*** (**WI_DM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option for tripping the “weak” end (***Distance Weak Infeed Output*** (**WI_DM**) must set to **Echo + Trip**).

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3.2.6.a Channel Activation Conditions ("Distance Channel Transmission")

In order that the communication channel activation is produced at a terminal (permissive signal transmission), any of the following conditions must be met:

1. Any of the elements associated to zone 1 or overreach zone picked up.
2. The three breaker poles tripped if ***Open Breaker Transmission*** is set to **YES**.
3. **Distance Echo** (**ECHO_D**) activated, output of Weak Infeed logic, for which ***Distance Weak Infeed Output*** (**WI_DM**) setting of said logic must be set to **Echo** or **Echo + Trip**.

3.2.6.b Tripping Conditions ("Distance Protection Scheme Trip")

Channel trip will take place upon channel reception and pickup of any of the elements associated to the Overreach Zone or if **Distance Weak Infeed Trip** (**TRIP_WI_D**) is activated, for which ***Distance Weak Infeed Output*** (**WI_DM**) of the Weak Infeed logic (for distance elements) must be set to **Echo + Trip**.

3.2.6.c Operation

Channel activation and generation of a trip command are shown in the following block diagram:

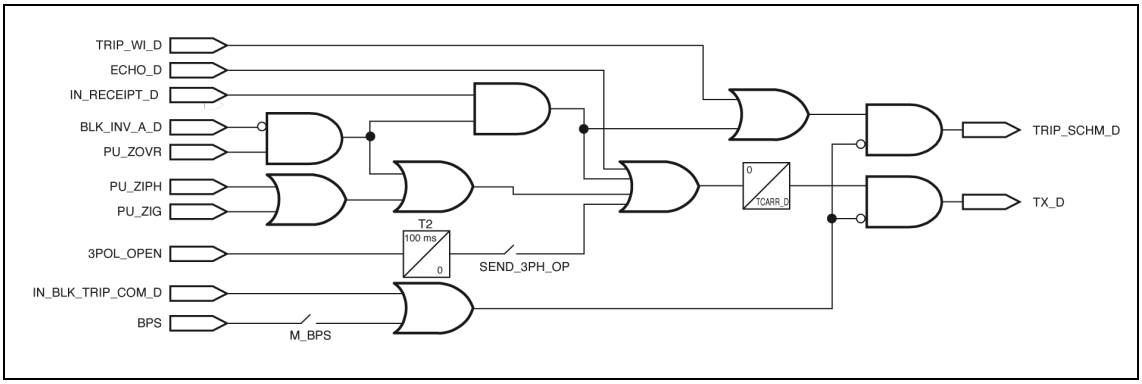


Figure 3.2.4 Permissive Overreach Scheme Block Diagram.

Legend	
TRIP_WI_D: Distance Weak Infeed Trip.	IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.
ECHO_D: Distance echo transmission.	
IN_RECEIPT_D: Distance Channel Reception Input.	BPS: Power Swing Blocking.
	TX_D: Distance Channel Transmission.
BLK_INV_A_D: Distance Reverse Current Blocking.	TRIP_SCHM_D: Distance Protection Scheme Trip.
PU_ZOVR: Overreach Zone Pickup.	SEND_3PH_OPEN: Open Breaker Transmission (setting).
PU_ZI x: Zone 1 Ground/Phase Units Pickup.	
3POL_OPEN: Three Pole Open.	TCARR_D: Distance Carrier Time (setting).
	M_BPS: Power Swing Blocking Mask (setting).

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The purpose of setting **Distance Carrier Time** (**TCARR_D**) on the diagram is guaranteeing a minimum time for **Channel Activation** (**TX_D**).

Open Breaker Transmission (**SEND_3PH_OP**) setting allows channel activation when all three breaker poles have tripped. The purpose of **T2** timing of 100 ms is to delay carrier transmission when it is produced by breaker tripping.

Channel tripping and channel activation can be disabled using the status contact input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**) activation or by the signal **Power Swing Blocking** (if said event is allowed to block the operation of the schemes through the corresponding bit of **Power Swing Blocking Mask**).

3.2.7 Directional Comparison Unblocking

Directional Comparison Unblocking is activated when selected in the **Protection Scheme** setting. It will function as a complement to the Step Distance scheme.

In permissive schemes using carrier wave channels, the trip permissive signal is frequently transmitted through the faulted phase/s, and the signal is attenuated, in a number of cases, to such a low level that the signal does not reach the other end. The end not receiving the trip permissive signal will not be able to trip following the Permissive Overreach scheme (it will trip following the Step Distance scheme). In order to avoid timed trips upon this type of situations, the Directional Comparison Unblocking scheme is used, which is an extension of the Permissive Overreach tripping scheme.

The Directional Comparison Unblocking scheme has been introduced to be used with switched frequency carrier wave equipment. When no fault is present in the line, this equipment continuously sends a signal at a “guard” frequency (guard signal) for channel supervision. Upon detecting a fault, the relay commands the carrier wave equipment to switch the guard frequency to other frequency known as “trip frequency” (trip signal). Thus, but for the time elapsed in the switching process, the teleprotection equipment will never send both signals at the same time.

Upon receipt of the trip signal and non-receipt of the guard signal at one end, said end will trip following the same criteria set up in a Permissive Overreach scheme (provided the overreach zone is picked up). On the contrary, upon non-receipt of the trip signal and non-receipt of the guard signal, the Directional Comparison Unblocking scheme will allow, during a time window, the instantaneous tripping of the overreaching zone.

Distance Reverse Current Blocking (**BLK_INV_A_D**) signal coming from the Reverse Current Blocking logic (associated to distance schemes), blocks, while activated, the input coming from the pickup of the overreaching zone, with the purpose of preventing wrong trips upon current reversals as a consequence of clearing faults in a parallel line in case of double circuits.

The same as for the Permissive Overreach scheme, if weak or zero infeed conditions exist at one of the line ends, so that no elements associated to the overreaching zone of said terminal pickup, none of the ends can trip with this scheme (it would trip following the Step Distance scheme). In this case, the Directional Comparison Unblocking scheme should be supplemented by the Weak Infeed logic, which allows the transmission of a trip permissive signal to the “strong” end (as echo of the signal transmitted by said end) in order to achieve its trip (**Distance *Weak Infeed Output*** (**WI_DM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option to trip the “weak” end (***Distance Weak Infeed Output*** (**WI_DM**) must be set to **Echo + Trip**).

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3.2.7.a Channel Activation Conditions ("Distance Channel Transmission")

For communication channel activation at a terminal (transmission of the permissive signal), any of the following conditions must be present:

1. Pickup of any of the elements associated to Zone 1 or overreach zone.
2. The three breaker poles tripped if ***Open Breaker Transmission*** is set to **YES**.
3. Activation of **Distance Echo** (**ECHO_D**) signal, Weak Infeed logic output, for which ***Distance Weak Infeed Output*** (**WI_DM**) of said logic must be set to **Echo** or **Echo + Trip**.

3.2.7.b Tripping Conditions ("Distance Protection Scheme Trip")

Tripping by channel signal reception will occur under the following conditions:

1. Channel reception and loss of guard and any of the elements associated to the overreach zone picked up.
2. Loss of guard, without channel activation, and any of the elements associated to the overreach zone picked up before **T_TRIP** times out.
3. ***Distance Weak Infeed Trip*** (**TRIP_WI_D**) activated, for which ***Distance Weak Infeed Output*** (**WI_DM**) of Weak Infeed logic (for distance elements) must be set to **Echo + trip**.

3.2.7.c Operation

Activation of a channel and generation of a trip command are shown in the following block diagram:

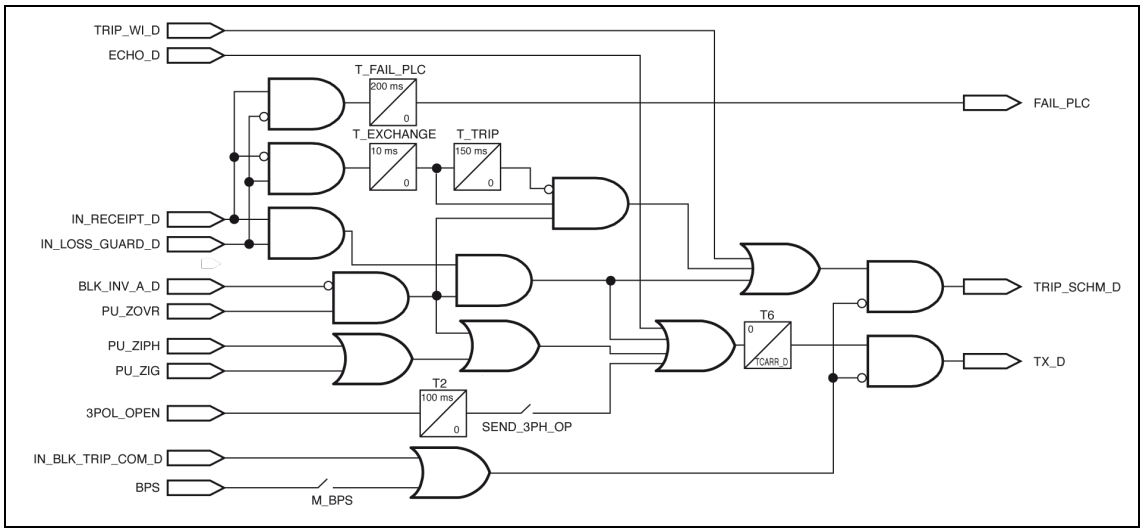


Figure 3.2.5 Directional Comparison Unblocking Scheme Block Diagram.

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Legend	
TRIP_WI_D: Distance Weak Infeed Trip.	TX_D: Distance Channel Transmission.
ECHO_D: Distance echo transmission.	FAIL_PLC: Carrier Wave Equipment Failure.
IN_RECEIPT_D: Distance Channel Reception Input.	TRIP_SCHM_D: Distance Protection Scheme Trip.
IN_LOSS_GUARD_D: Distance Guard Loss Input.	T_EXCHANGE: Switching Time.
BLK_INV_A_D: Distance Reverse Current Blocking.	T_FAIL_PLC: Carrier Wave Equipment Failure Time.
PU_ZOVR: Overreach Zone Pickup.	T_TRIP: Trip Time.
PU_ZI x: Zone 1 Ground/Phase Units Pickup.	SEND_3PH_OPEN: Open Breaker Transmission (setting).
3POL_OPEN: Three Pole Open.	
IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.	TCARR_D: Distance Carrier Time (setting).
	M_BPS: Power Swing Blocking Mask (setting).
BPS: Power Swing Blocking.	

The purpose of ***Distance Carrier Time*** (**TCARR_D**) on the diagram is guaranteeing a minimum time for **Channel Activation** (**TX_D**).

The purpose of ***Open Breaker Transmission*** (**SEND_3PH_OP**) setting is activating the channel when the three breaker poles trip. The purpose of **T2** timing of 100 ms is delaying the carrier transmission caused by breaker tripping.

The carrier wave equipment features the following output contacts: one normally closed (hereafter called **Guard**), which remains open when the guard signal is being received, and other normally open (hereafter called **Trip**) which closes upon the reception of the trip signal from the other end. The **Guard** contact must be wired to the **IN_LOSS_GUAR_D** (**Distance Guard Loss**) input, whereas the contact **Trip** will be wired to the **IN_RECEIPT_D** (**Distance Channel Reception**) input. On the other hand, the **TX_D** (**Distance Channel Transmission**) output must be wired to the wave carrier equipment input, which will give the command for frequency switching.

When both **IN_LOSS_GUAR_D** and **IN_RECEIPT_D** inputs are activated, the response is exactly equal to a Permissive Overreach scheme, an instantaneous tripping being produced provided the overreaching zone is picked up.

In case only **IN_LOSS_GUAR_D** input is activated, which might indicate a complete attenuation of the trip permissive signal from the other end, if this situation remains during the switching time **T_EXCHANGE**=10 ms (enough for the carrier wave equipment to switch from guard frequency to trip frequency), the overreaching zone will be allowed to trip instantaneously during the time **T_TRIP** =150 ms.

If only **IN_RECEIPT_D** input has been activated, after time **T_FAIL_PLC** =200 ms, the signal **FAIL_PLC** will be activated, which indicates Failure in the Carrier Wave Equipment.

Channel tripping and channel activation can be disabled using the status contact input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**) activation or by the signal **Power Swing Blocking** (**BPS**) (if said event is allowed to block the operation of the schemes through the corresponding bit of **Power Swing Blocking Mask**).

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3.2.8 Directional Comparison Blocking

Directional Comparison Blocking is activated when selected in the **Protection Scheme** setting. It will function as a complement to the Step Distance scheme.

The main difference between this scheme and the others is that the channel signal is transmitted to avoid remote tripping instead of accelerating it.

Proper operation of this scheme requires that the measuring element used to activate the channel be selected as reverse-looking. Said zone will be **Zone 4 or Zone 5,** as a function of ***Reverse Looking Zone*** setting**.** When selecting the **Directional Comparison Lockout** scheme, the zone designated as reverse looking zone will operate as reverse looking, even though the direction setting indicates otherwise.

When a terminal unit on the transmission line detects a reverse-direction fault, a channel signal will be transmitted to avoid remote-end tripping by overreach elements. This way, the trip is only produced upon non-receipt of the blocking signal from the remote end terminal of the line.

The terminal detecting the fault in the reverse direction zone sends the trip blocking signal to the other end (in case of lines with more than two terminals, the signal is sent to all of them). At the other terminal, the receipt of the blocking signal from the first terminal immediately disables the tripping of any of the metering elements of the zone designated as overreaching. In case of more than two terminals, the receipt of the blocking signal from one of the terminals is enough to block the immediate overreaching zone trip in any of the other terminals, so that the channel receipt input should be setup as one OR of the received signals.

Correct application of this scheme requires that the following conditions be satisfied:

1. The distance covered by the reverse direction zone must be greater than the distance covered by any of the overreaching zones in the rest of terminals (not in absolute value, but the measurement from the terminal considered), so as to guaranteeing the blocking of any fault within the overreaching zone and outside the line.
2. An overreaching zone trip delay time must be considered to allow the communication equipment to transmit the blocking signal from the remote to the local terminal. Said delay is given by ***Distance Delay Time*** setting.

With this scheme, if the fault current seen through one of the ends is low enough so that the reverse unit does not pickup, the rest of the terminals will be able to trip due to faults seen by the overreach unit (with the risk that those faults being outside the protected line). The same happens if the communications fail and the blocking signal can not be sent.

There exists the possibility to produce the channel activation (transmission of blocking signal) through the non-directional pickup (**Pickup Condition**, **CPU_IOC** signal) of Overcurrent Elements: Phase and Ground Instantaneous Elements nº1. This possibility is obtained by setting ***Quick Transmission*** to **YES**. The pickup condition of said Overcurrent Elements not only will activate the channel for backward looking faults but also for forward looking faults, so that the pickup of the overreaching zone and Zone 1 will be in charge of deactivating the channel. The advantage of the ***Quick Transmission*** is based on the smaller ***Delay Time*** (which can even be zero) that must be introduced into the operation of the overreaching zone, owing to an earlier blocking signal generation (the operation of a non-directional overreaching element is quicker than the operation of a distance element). This allows producing quicker trips.

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Echo and Weak Infeed trip logic is purposeless under this scheme. On the other hand, this scheme needs not be supplemented by the Reverse Current Blocking logic because this scheme can detect the current reversal thanks to the use of Zone 4 setup to reverse direction.

3.2.8.a Channel Activation Conditions ("Distance Channel Transmission")

The communications channel (trip blocking) will activate under the following condition:

1. Pickup of the reverse direction zone or the non-directional overcurrent elements, provided ***Quick Transmission*** is set to **YES**, with no activation of the overreaching zone and non-existence of any conditions for transmission disable.
2. Channel trip blocking input activated and non-existence of any conditions for transmission disable. In this case, as it is a blocking system, channel activation means trip blocking.

3.2.8.b Channel Stop Conditions ("Distance Channel Disable")

The communications channel (trip blocking) will deactivate (trip blocking deactivated) under any of the following conditions:

1. Activation of the Channel Stop status contact input.
2. Overreach element activation without channel signal reception, reverse supervision zone activation or activation of the Channel Trip Blocking input.
3. Activation of Zone 1 elements.

3.2.8.c Tripping Conditions ("Distance Protection Scheme Trip")

A trip using this protection scheme will occur provided the following conditions are satisfied at the same time:

1. Overreach elements activation.
2. No blocking signal is received through the communications channel.
3. Reverse supervision elements are not activated.

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3.2.8.d Operation

Activation of a channel and generation of a trip command are shown in the following block diagram:

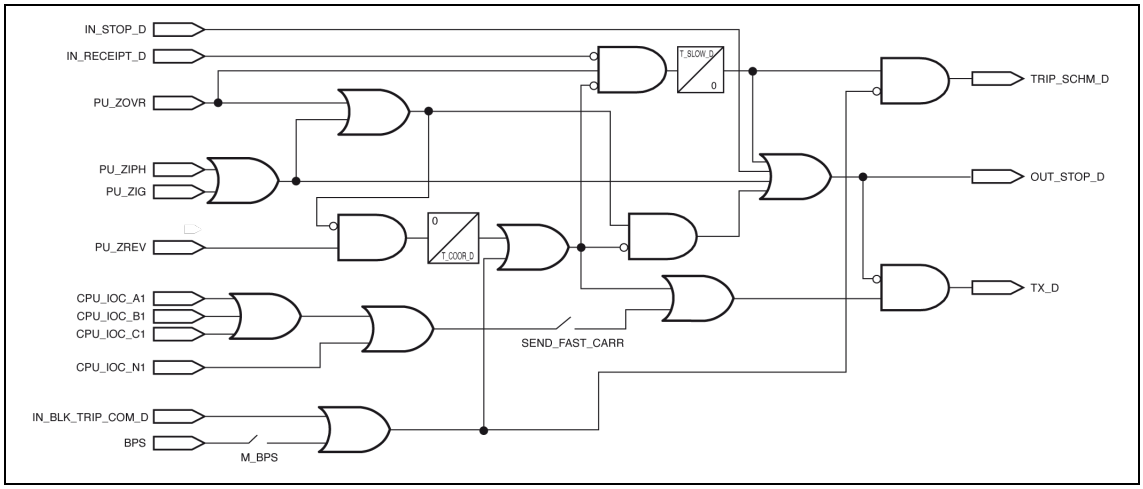


Figure 3.2.6 Directional Comparison Blocking Scheme Block Diagram.

Legend	
IN_STOP_D: Distance Channel Disable Input.	BPS: Power Swing Blocking.
IN_RECEIPT_D: Distance Channel Reception Input.	TX_D: Distance Channel Transmission.
	OUT_STOP_D: Distance Channel Disable.
PU_ZOVR: Overreach Zone Pickup.	TRIP_SCHM_D: Distance Protection Scheme Trip.
PU_ZI x: Zone 1 Ground/Phase Units Pickup.	
PU_ZREV: Reverse Looking Zone Pickup.	T_SLOW_D: Distance Delay Time (setting)
CPU_IOC_ x1: Phase/Ground X Instantaneous Element 1 Pickup Conditions.	SEND_FAST_CARR: Carrier Quick Transmission (setting).
BLK_INV_A_D: Distance Reverse Current Blocking.	T_COORD_D: Distance Coordination Time (setting)
IN_BLK_TRIP_COM_D: Distance Channel Trip Blocking Input.	M_BPS: Power Swing Blocking Mask (setting).

The purpose of ***Distance Delay Time*** (**T_SLOW_D**) setting, as previously mentioned, is to allow, for external faults, a time lapse for the receipt of the trip signal from the remote end terminal.

Distance Coordination Time (**TCOOR_D**) sets a reset time for the reverse direction zone pickup signal, so as to prevent channel disable upon current reversal in double circuits, as a consequence of sequential parallel line breaker trips on a fault in the same. It is worth mentioning that zone 1 and the instantaneous directional overcurrent element may block the trip transmission, no matter the pickup of the reverse direction zone, as said elements are only picked up upon internal line faults.

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The purpose of **DLF** channel disable output is to be wired to the teleprotection equipment **IN_STOP_D** input so as to disable the channel. However, said output also disables the channel activation output as a prevention measure, in case **IN_STOP_D** input has not been setup in the teleprotection equipment as a priority against **IN_RECEIPT_D** input, when both are active.

Channel tripping and channel activation can be disabled using the status contact input **Distance Channel Trip Blocking** (**IN_BLK_TRIP_COM_D**). It also can be disabled for power swing conditions by adjusting the ***Power Swing Blocking*** setting. Said **Distance Channel Trip Blocking** generates, at the same time, channel activation.

3.2.9 Weak Infeed Logic

The **Weak Infeed Logic**, if enable, can work in parallel with all permissive teleprotection schemes.

As mentioned before, if a Permissive Overreach scheme has been selected (or Directional Comparison Unblocking) and one of the line ends is in a weak infeed condition, so that overreaching elements are not picked up at said end, none of the line terminals can trip instantaneously. To this end, the Teleprotection scheme must be supplemented by the Weak Infeed logic, which presents two options: **Echo Transmission** and **Weak Infeed Tripping**.

3.2.9.a Echo Logic

This function is enabled by setting ***Distance Weak Infeed Output*** (**WI_DM**) to **Echo**.

The Echo function allows sending a permissive trip signal to the “strong” end (as echo of the signal transmitted by said end).

The echo signal will activate whenever a signal from the other end is received, none of the elements associated to the reverse looking zone having been picked up.

3.2.9.b Weak Infeed Tripping

This function is enabled by setting ***Distance Weak Infeed Output*** (**WI_DM**) to **Echo + Trip**.

The echo transmission allows the trip (instantaneous) of the “strong” end, but not the “weak” end trip. The Weak Infeed trip allows tripping this latter end when undervoltage conditions are detected, a trip permissive signal has been received and none of the elements associated to the reverse direction zone and the overreaching zone are picked up.

The Weak Infeed function is always associated to echo transmission.

In view of the need for one of the zones monitors in reverse direction for correct logic operation, when setting ***Distance Weak Infeed Output*** takes the value **Echo** or **Echo + Trip**, the zone designated direction reverse zone will operate as if it is set backwards, even if its setting indicates otherwise.

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3.2.9.c Operation

Figure 3.2.7 shows the logic operating diagram.

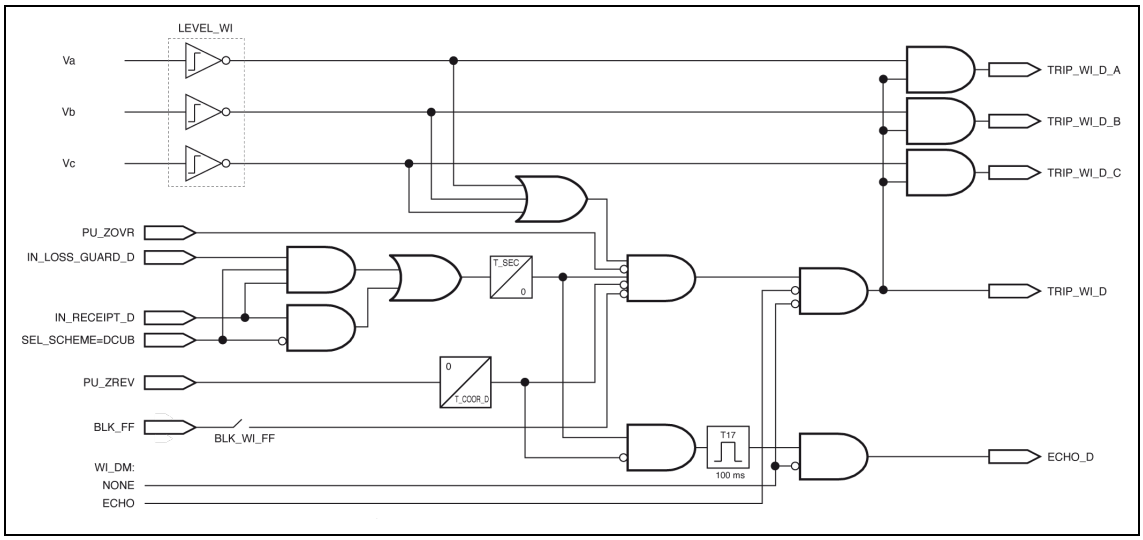


Figure 3.2.7 Weak Infeed Logic Block Diagram.

Legend	
PU_ZOVR: Overreach Zone Pickup.	TRIP_WI_D: Distance weak infeed trip.
IN_LOSS_GUARD_D: Distance Guard Loss Input.	LEVEL_WI: Weak Infeed Voltage Threshold (setting).
IN_RECEIPT_D: Distance Channel Reception Input.	BLK_WI_FF: Fuse Failure Weak Infeed Blocking (setting).
PU_ZREV: Reverse Looking Zone Pickup.	
BLK_FF: Fuse Failure Blocking.	SEL_SCHEME: Teleprotection Schemne Selection (setting).
WI_DM: Distance Weak Infeed Output.	
ECHO_D: Distance Echo Transmission.	T_SEC Security Time (setting).
TRIP_WI_D_X: Phase X Distance Weak Infeed Trip.	T_COORD_D: Distance Coordination Time (setting)

Undervoltage detectors (represented as negated overvoltage detectors) pickup and reset with only one value, equal to ***Weak Infeed Voltage Threshold*** (**LEVEL_WI**) setting.

The purpose of ***Security Time*** (**T_SEC**) setting is guaranteeing a channel receipt time to avoid echo transmission upon channel noise. On the other hand, it leaves time for the pickup of reverse direction elements (in case the fault is backward looking); although it is normal that said elements pickup before channel receipt, as upon an external fault the overreaching elements of the remote end (the ones activating the channel) will take longer to pick up than reverse direction elements of the local end.

If a **Directional Comparison Unblocking** has been selected, the **Channel Receipt** (**IN_RECEIPT_D**) must be supplemented with **Guard Loss** (**IN_LOSS_GUAR_D**) input activation.

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The setting ***Distance Coordination Time*** (**TCOOR_D**) is used to prevent weak infeed trips upon current reversal in double circuits.

The weak infeed trip can be blocked by **Fuse Failure Blocking** (**BLK_FF**) signal activation, provided ***Fuse Failure Weak Infeed Blocking*** (**BLK_WI_FF**) is set to **YES**, as the indication of undervoltage detectors is not reliable upon a fuse failure.

TRIP_WI_D_A, **TRIP_WI_D_B** and **TRIP_WI_D_C** outputs act as phase selectors (as will be seen in single-phase / three-phase trip logic) as under weak infeed conditions the phase selector may generate no outputs, the positive sequence current being very small.

3.2.10 Transient Blocking by Current Reversal Logic

In double circuits, the sequential trips of the breakers associated to one of the lines, as a consequence of the clearance of a fault in the same, can produce a current reversal in the parallel line. Said current reversal will cause the pickup of the overreaching zone hitherto deactivated at one end and the reset of said zone at the opposite end. As these events do not occur at the same time, overreaching teleprotection schemes can give way to wrong trips in the unimpaired line.

Figure 3.2.8 represents a current reversal event.

In case of a Permissive Overreaching scheme, a current reversal in line 2 takes place upon the trip of the breaker in B1, and the B2 relay overreaching zone picks up. If the trip permissive signal coming from the relay in A2 has not yet reset a channel trip will be produced in B2. In order to avoid these types of wrong trips the B2 relay overreaching zone should be temporarily blocked.

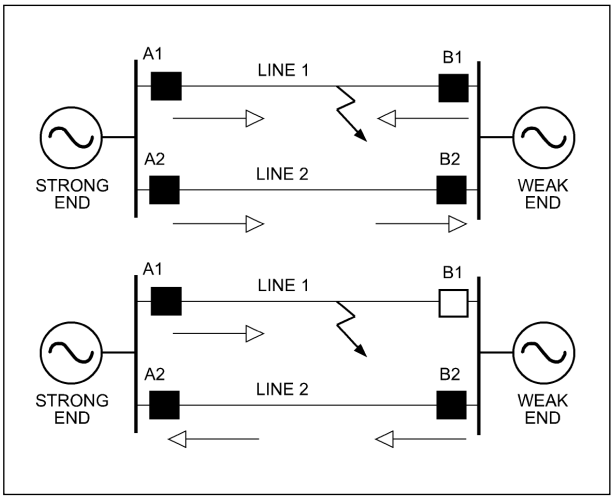


Figure 3.2.8 Current Reversal Event.

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3.2.10.a Operation

Transient current reversal lockout logic generates the signal **Distance Current Reversal Lockout** (**BLK_INV_A_D**) when the zone is activated by reverse looking (reverse looking zone) Said signal will be active during the ***Distance Coordination Time*** (**T_COOR_D**) from the reset of the reverse looking zone setting.

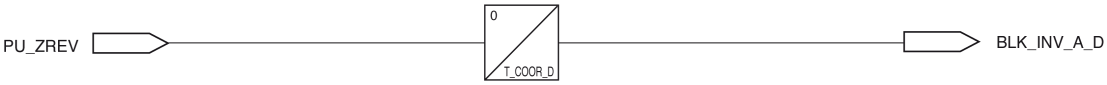


Figure 3.2.9 Block Diagram for Distance Reverse Current Blocking Logic.

Legend	
PU_ZREV: Reverse Looking Zone Pickup.	T_COORD_D: Distance Coordination Time (setting).
BLK_INV_A_D: Distance Reverse Current Blocking.	

Given the need for one of the zones supervising in reverse direction for the correct operation of this logic, enabling it will make Zone 4 or Zone 5 to operate as if it were set backward looking, even if its directional setting indicates otherwise.

3.2.11 Programmable Schemes

Apart from the available protection schemes, any other protection scheme can be setup by means of the programmable logic incorporated into the equipment. In this case, teleprotection schemes can be generated, which need the transmission of several signals between both line ends (indication of the faulted phase, single-phase and three-phase permissive signals, etc), for which a digital network may be the communication media.

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3.2.12 Setting Ranges

Protection / Protection Schemes (*)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Carrier Transmission Enable By 52 Open	Carrier Open Brkr	PSCH1.CarOpnCB	YES / NO		YES
Carrier Reception Security Time	Security Time	PSCH1.SecTmms	0 - 50 ms	1 ms	0 ms
Weak Infeed Block FF	FF WI Block		YES / NO		NO

(*) Common to distance and overcurrent schemes.

Protection / Distance Protection Schemes					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Distance Protection Scheme	Dist Protec Scheme	PSCH2.SchTyp	None. Zone 1 Extension. PUTT* DTT* POTT* DCUB* DCB*		None.
Distance Carrier Time	Dist Carrier Time	PSCH2.DurTmms	0 - 200 ms	10 ms	0 ms
Distance Coordination Time	Dist Coord Time	PSCH2.RvRsTmms	0 - 300 ms	1 ms	25 ms
Distance Time Delay DCB	Dist Delay DCB	PSCH2.CrdTmms	0 - 200 ms	10 ms	50 ms
Zone 1 Extension Block Time	Z1 Ext. Block Time		0,05-300,00 s	0,01 s	10 s
Overreaching Zone			Zone 2 / Zone 3		Zone 2
Reverse Zone			Zone 4 / Zone 5		Zone 4
Distance WI Logic Output	Dist WI Logic Output	PSCH2.WeiMod	NONE ECHO ECHO + TRIP		NONE.
Carrier Fast Transmission Enable (Blocking Schemes)	Carrier Fast Sending		YES / NO		NO
Distance Curr. Inv Block Enable	Dist Cur Inv Block	PSCH2.RvAMod	YES / NO		NO
Prot Scheme Pow. Swing Block	Prot Scheme Block		YES / NO		NO

*PUTT: Permissive Underreach Transfer Trip.
*DTT: Direct Transfer Trip.
*POTT: Permissive Overreach Transfer Trip.
*DCUB: Directional Comparison Unblocking.
*DCB: Directional Comparison Blocking.

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3.2.13 Digital Inputs to the Distance Protection Schemes Module

Table 3.2-1: Digital Inputs to the Distance Protection Schemes Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_RECEIPT_D	Logic Inputs to Protection	PSCH2.ProRx	Distance channel receipt input	I	The activation of this input means a signal receipt (trip permissive or blocking, as a function of the selected scheme) from the other end.
IN_BLK_TRIP_COM_D		PSCH2.Mod	Distance channel trip blocking input	I	The activation of this input blocks the trip of any distance protection scheme.
IN_LOSS_GUARD_D		PSCH2.LosOfGrd	Distance guard signal loss input	I	The activation of this input means that the guard signal receipt has ceased. It is used in the Directional Comparison Unblocking scheme.
IN_DISABLE_D		PSCH2.CarStop	Distance channel disable input	I	The activation of this input generates Channel Disable output. It is used in the Directional Comparison Blocking scheme.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.2.14 Auxiliary Outputs and Events of the Distance Protection Schemes Module

Table 3.2-2: Auxiliary Outputs and Events of the Distance Protection Schemes Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TX_D	Generic Outputs of Protection	PSCH2.ProTx	Distance channel transmission	I	Channel activation by the selected distance protection scheme.
ECHO_D		PSCH2.Echo	Distance echo transmission	I	Echo transmission in distance protection scheme
FAIL_PLC		PSCH2.CarWavFail	Carrier wave equipment failure	I	Carrier wave equipment failure.
BLK_INV_A_D		PSCH2.RvABlk	Distance reverse current blocking	I	Overreaching zone blocking in distance protection scheme by current reversal detection.
OUT_STOP_D		PSCH2.CarStopOut	Distance channel disable	I	Output for channel disabling used in Directional Comparison Blocking scheme.
TRIP_SCHM_D	Trip Protection Outputs	PSCH2.Op	Distance protection scheme trip	I,F	Selected distance protection scheme trip.
TRIP_WI_D		PSCH2.WeiOp	Distance weak infeed trip	I	Weak infeed condition trip in distance protection scheme.
TRIP_WI_D_A		PSCH2.WeiOp	Phase A distance weak infeed trip	I	Trip by weak infeed condition in phase (A, B, C) in distance protection scheme
TRIP_WI_D_B		PSCH2.WeiOp	Phase B distance weak infeed trip	I	
TRIP_WI_D_C		PSCH2.WeiOp	Phase C distance weak infeed trip	I	
PU_ZOVR			Overreach protection zone pickup	I	Pickup output for the overreach protection zone.
PU_ZREV			Reverse looking zone pickup	I	Reverse looking zone pickup.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.2.15 IEC61850 Logical Node

CLASS PSCH		
Data Object Name	**Common Data Class**	**Explanation**
PSCH		Distance Protection Scheme
Data Objects		
Status information		
ProTx	SPS	Teleprotection signal transmitted
ProRx	SPS	Teleprotection signal received
Str	ACD	Carrier send
Op	ACT	Operate
LosOfGrd	SPS	Loss of guard
Echo	ACT	Echo signal from weak end infeed function
WeiOp	ACT	Operate signal from weak end infeed function
RvABlk	ACT	Block signal from current reversal function
ProTx	SPS	Teleprotection signal transmitted
Settings		
SchTyp	ENG	Scheme Type
CrdTmms	ING	Co-ordination timer for blocking scheme
DurTmms	ING	Minimum duration of carrier send signal
SecTmms	ING	Pickup security timer on loss of carrier guard signal
WeiMod	ENG	Mode of weak end infeed function
RvAMod	ENG	Enable of current reversal function
RvRsTmms	ING	Delay time for coordination
SchTyp	ENG	Scheme Type
CrdTmms	ING	Co-ordination timer for blocking scheme
DurTmms	ING	Minimum duration of carrier send signal
Extended Data		
CarStop	EXT_SPC	Stop of the channel input in directional comparison block scheme
PhGndVal	EXT_ASG	Undervoltage level for weak infeed function

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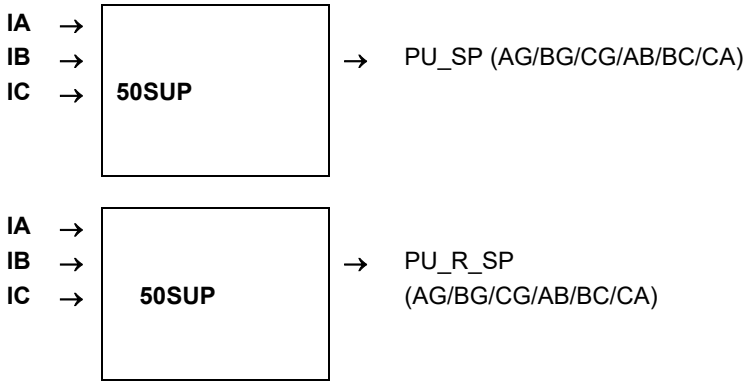
3.3 Phases Supervision for Distance Protection

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3.3.4 Setting Ranges 3.3-3
3.3.5 Analog Inputs to the Unit 3.3-4
3.3.6 Auxiliary Outputs and Events of the Distance Supervision Module 3.3-4

3.3.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Forward and Reverse Supervision Elements		-	50SUP

3.3.2 General Block



3.3.3 Operation Principles and Block Diagram

DLF relays contain overcurrent elements to supervise the operation of the distance measuring elements. These overcurrent elements are used to establish a minimum current level of operation for the distance elements. Supervision elements are divided into two groups:

- **Forward** supervision.
- **Reverse** supervision.

Each one includes supervision of phase currents (A, B, C) and line currents (AB, BC, CA).

Forward and reverse supervision elements are non-directional overcurrent elements; i.e., they do not detect fault direction, but calculate the true RMS value of the phase or line current when the preset value is exceeded. The purpose of these elements is to supervise the operation of the distance element for each zone according to the corresponding directional setting.

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The following table lists supervision elements with their operation current and pickup settings. The output signal generated is also included.

Table 3.3-1: Supervision Elements

Direction	Unit	Iop	Pickup Setting	Output	
Forward	Phase A	Ia	Single-Phase Forward	Forward AG elements supervision	(PU_SP_AG)
	Phase B	Ib		Forward BG elements supervision	(PU_SP_BG)
	Phase C	Ic		Forward CG elements supervision	(PU_SP_CG)
	Phases AB	Iab	Two Phases Forward	Forward AB elements supervision	(PU_SP_AB)
	Phases BC	Ibc		Forward BC elements supervision	(PU_SP_BC)
	Phases CA	Ica		Forward CA elements supervision	(PU_SP_CA)
Reverse	Phase A	Ia	Single-Phase Reverse	Reverse AG elements supervision	(PU_R_SP_AG)
	Phase B	Ib		Reverse BG elements supervision	(PU_R_SP_BG)
	Phase C	Ic		Reverse CG elements supervision	(PU_R_SP_CG)
	Phases AB	Iab	Two Phases Reverse	Reverse AB elements supervision	(PU_R_SP_AB)
	Phases BC	Ibc		Reverse BC elements supervision	(PU_R_SP_BC)
	Phases CA	Ica		Reverse CA elements supervision	(PU_R_SP_CA)

Where:

Ia, Ib, Ic	Phase currents
Iab, Ibc, Ica	Line currents (Ia-Ib), (Ib-Ic), (Ic-Ia)

The forward or reverse supervision element will pick up when the true RMS value of the corresponding phase or line current exceeds 105% of the pickup value, and resets below the preset value.

Single-phase forward supervision elements (outputs **PU_SP_AG**, **PU_SP_BG** and **PU_SP_CG**) also activate trip output latching, which keeps the contact closed until the measured value falls below the adjusted value (see Tripping Logic).

3.3.4 Setting Ranges

Protection / Distance Supervision					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Single-phase forward current	`Forward Sup. 1-Ph`		0.04 - 7.50	0.01 A	0.2 A
Two-phase forward current	`Forward Sup. 2-Ph`		0.04 - 7.50	0.01 A	0.2 A
Single-phase reverse current	`Reverse Sup. 1-Ph`		0.04 - 7.50	0.01 A	0.2 A
Two-phase reverse current	`Reverse Sup. 2-Ph`		0.04 - 7.50	0.01 A	0.2 A

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3.3.5 Analog Inputs to the Unit

Table 3.3-2: Analog Inputs of the Overcurrent Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC

3.3.6 Auxiliary Outputs and Events of the Distance Supervision Module

Table 3.3-3: Auxiliary Outputs and Events of the Distance Supervision Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_SP_AG			Supervision units AG forward	I	Supervision unit pickup for different types of forward and reverse faults.
PU_SP_BG			Supervision units BG forward	I	
PU_SP_CG			Supervision units CG forward	I	
PU_SP_AB			Supervision units AB forward	I	
PU_SP_BC			Supervision units BC forward	I	
PU_SP_CA			Supervision units CA forward	I	
PU_R_SP_AG			Supervision units AG reverse	I	
PU_R_SP_BG			Supervision units BG reverse	I	
PU_R_SP_CG			Supervision units CG reverse	I	
PU_R_SP_AB			Supervision units AB reverse	I	
PU_R_SP_BC			Supervision units BC reverse	I	
PU_R_SP_CA			Supervision units CA reverse	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.4 Load Encroachment

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3.4.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Load Encroachment	GENPDCF		

3.4.2 General Block



3.4.3 Operation Principles and Block Diagram

DLF terminal units incorporate Load Encroachment elements to avoid trips in high load conditions. These units delimit the load zone in the R-X plane, according to the two characteristics shown in Figure 3.4.1, such that if the impedance calculated by the distance element remains within said area its operation is blocked.

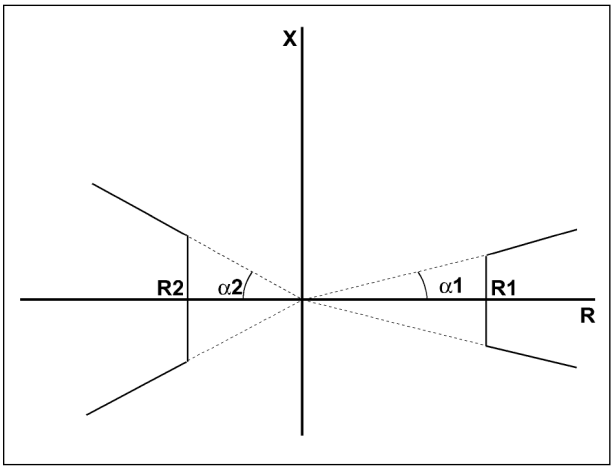


Figure 3.4.1 Characteristics of Load Encroachment Elements.

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The impedance calculated by the load encroachment element is a function of the type of fault indicated by the phase selector:

Fault type	Calculated impedance
3-Ph or AB	$Z = \frac{Vab}{Iab}$
BC	$Z = \frac{Vbc}{Ibc}$
CA	$Z = \frac{Vca}{Ica}$
AG	$Z = \frac{Va}{Ia + I0 \cdot (K0 - 1)}$
BG	$Z = \frac{Vb}{Ib + I0 \cdot (K0 - 1)}$
CG	$Z = \frac{Vc}{Ic + I0 \cdot (K0 - 1)}$

The meaning of the variables used in the table above is as follows:

Ia, Ib, Ic	Phase currents
Iab, Ibc, Ica	Phase to phase currents (Ia-Ib), (Ib-Ic), (Ic-Ia)
$I0$	Zero sequence current
Va, Vb, Vc	Phase voltages
Vab, Vbc, Vca	Phase to phase voltages (Va-Vb), (Vb-Vc), (Vc-Va)
$K0 = \frac{\lvert Z0 \rvert}{\lvert Z1 \rvert}$	Zero sequence compensation factor for zone 1

Adjusting the calculated impedance to the type of fault prevents the wrong activation of load encroachment characteristics upon fault conditions.

Load Encroachment elements present two independent characteristics, one for forward load streams and the other for backward load streams. Each of these characteristics is defined by a resistive reach setting (R) and an angle setting (α).

The operating criteria of the Load Encroachment elements is indicated in the following:

$$[\mathrm{Re}(Z1) > R1] \otimes [(360 - \alpha 1) < \mathrm{Arg}(Z1) < \alpha 1]$$
$$\oplus$$
$$[\mathrm{Re}(Z1) < -R2] \otimes [(180 - \alpha 2) < \mathrm{Arg}(Z1) < (180 + \alpha 2)]$$

The meaning of the variables used in the above equations is the following:

$R1$	Right area resistive limit
$\alpha 1$	Right area angle
$R2$	Left area resistive limit
$\alpha 2$	Left area angle

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3.4.4 Range Settings

Protection / Load Encroachment					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Load Encroach Enab	GENPDCF1.LodInSvc	YES / NO		NO
Right Zone Resistive Limit	Right Area Res Lim	GENPDCF1.RisLod1	0.1 - 500 Ω	0.01 Ω	65 Ω
Left Zone Resistive Limit	Left Area Res Lim	GENPDCF1.RisLod2	0.1 - 500 Ω	0.01 Ω	65 Ω
Right Zone Angle	Right Area Angle	GENPDCF1.AngLod1	0 - 90º	1º	20º
Left Zone Angle	Left Area Angle	GENPDCF1.AngLod2	0 - 90º	1º	20º

3.4.5 Analog Inputs to the Unit

Table 3.4-1: Analog Inputs of the Load Encroachment Module		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

3.4.6 Digital Inputs to the Load Encroachment Module

Table 3.4-2: Digital Inputs to the Load Encroachment Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_ENCR	Enabling Commands		Load encroachment elements enable input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.4.7 Auxiliary Outputs and Events of the Load Encroachment Module

Table 3.4-3: Auxiliary Outputs of the Load Encroachment Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENCR	Outputs		Activation of load encroachment elements	I	Activation output of load encroachment elements.
ENCR_ENBLD	Outputs		Load encroachment enabled	I	Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

3.4.8 IEC 61850 Logical Node

CLASS PDCF		
Data Object Name	**Common Data Class**	**Explanation**
PDCF		Distance Units Common Features
Data Objects		
Settings		
LodInSvc	SPG	Enable Load Encroach
RisLod1	ASG	Right Area Resis Limit
RisLod2	ASG	Left Area Resis Limit
AngLod1	ING	Right Area Angle
AngLod2	ING	Left Area Angle

3.4.9 Load Encroachment Elements Test

Enable the Load Encroachment element and the Distance elements. Disable the remaining elements.

Consult the following indicators during the test:

In the display on the **Information - Status - Measuring elements - Load Encroachment** screen, or on the status screen of the ***ZIVercomPlus***® (**Status - Elements - Load Encroachment**).

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Adjust the distance elements according to the settings of the tests of the distance element. Define a load encroachment area which enters up to zone 1, setting, for example, the positive and negative load limiters at 0.5 Ohms and the load angles at 45º (positive as well as negative).

A three-phase balanced voltage and current system of 65 Vac and 0º, 120º and 240º and 5 Aac and 0º, 120º and 240º, respectively will be departed from (the latter angles are inductive values). Verify that the load encroachment element is active.

The voltages of the three phases will be reduced gradually and simultaneously, until the load encroachment element is deactivated. Verify that this deactivation occurs for an impedance of 0.5 Ohms.

A three-phase balanced voltage and current system of 10 Vac and 0º, 120º and 240º and 5 Aac and 0º, 120º and 240º, respectively, will again be departed from (the latter angles are inductive values). Verify that the load encroachment element is active.

Continue to increase the angle (inductive) of the phase currents gradually and simultaneously. Verify that the load encroachment element is deactivated when the angle exceeds 45º. Carry out the same verification but with capacitive angles. The load encroachment element should also be deactivated for 45º (capacitive).

The tests for the negative area of the load encroachment element will be similar to these but with inverted currents.

Test, applying prefault-fault type faults to the relay, which when the fault point is simultaneously within a zone and within the load encroachment element, the trip (or pick up of the zone) is blocked.

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3.5 Power Swing Detector

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3.5.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Power Swing Detector			

3.5.2 Operation Principles

Power swings are disturbances basically produced by imbalances between generation and demand, which may be originated by changes in the topology of the network, load variations, failures, etc. These disturbances produce speed slip between generators, which no longer turn at the synchronism speed, but which accelerate and decelerate to adapt to the new situation, producing swings in the power transferred between different parts of the system.

During a power swing, variations are produced in the current and in the voltage, in the magnitude as well as in angle, which originates change in the impedance seen by the distance relays, which may come to see tripping conditions. Power swings may be stable (dampened until reaching a new balance situation) or unstable (balance not recovered). In case of unstable power swings, it is necessary to make separations in the system, creating islands in which there is balance between generation and demand.

In case of any type of power swing, it is necessary to block the trip of the distance units: if the swing is stable, because a trip may convert this to unstable and if the swing is unstable, because it tends to follow a strategy at the time of creating islands, opening breakers only in determined positions of the system.

DLF relays include a Power Swing Detector, in order to avoid undue tripping of the distance elements on stable power swing (power swing blocking) and allow controlled tripping on unstable power swing.

The Power Swing Detector unit bases its operation on the analysis of the transfer speed of the impedance point through the R-X diagram. In case of failure, the transfer between the situation of no failure and that of failure presents a very high transfer speed of the impedance point (since this involves an electromagnetic phenomenon) while the transfer of this same point in case of a power swing involves a much lower speed (given that this is an electromechanical phenomenon), which depends on the condition of the initial load, the out-of-square magnitude between generation and demand, generator inertia, etc.

The principle of operation of the Power Swing Detector is based on the time measurement that the viewed impedance takes to travel the strip defined between two quadrilateral zones, **External** and **Intermediate**, such that if this time is longer than a threshold (set by the ***Power Swing Detection Time*** setting), it can be considered that there is no failure but rather a power swing. Once the existence of a power swing has been detected, if the ***PS Trip Enable*** (**ENBL_TRIP_PS**) setting has been set to **YES**, it is determined if the swing is stable or unstable. For this, it is verified if the viewed impedance reaches an internal quadrilateral zone, similar to the two above. In this case, the swing is considered unstable, thus being able to generate a trip, as will be seen in the following.

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To carry out the above verifications, the **DLF** incorporates three units of phase-to-phase impedance measurement per zone. When the three poles of the breaker are closed, it is sufficient to verify one of these measuring units, for example, AB, given the symmetry of the power swing phenomenon. The opening of a pole disables the measuring units related to the open phase due to the lack of reliability of these.

Each quadrilateral zone of those mentioned above is formed of the following elements:

- Two resistive limiters.
- Two reactive limiters.

3.5.3 Resistive Limiters

The **DLF** incorporates three resistive limit units per zone (external, intermediate and internal). Each resistive limit unit is formed of a pair of limiters, left and right, with independent reach settings.

The following table shows the operation and polarization phasors of the resistive limiters, as well as the applied operating criteria.

Table 3.5-1: Resistive Limiters

Right Resistive Limiter			
Unit	**Fop**	**Fpol**	**Criteria**
AB	$Iab \cdot Rdcho - Vab$	$Iab \cdot Rdcho$	$-(180º - A\lim) \le [\arg(Fop) - \arg(Fpol)] \le A\lim$
BC	$Ibc \cdot Rdcho - Vbc$	$Ibc \cdot Rdcho$	
CA	$Ica \cdot Rdcho - Vca$	$Ica \cdot Rdcho$	
Left Resistive Limiter			
Unit	**Fop**	**Fpol**	**Criteria**
AB	$-Iab \cdot Rizdo - Vab$	$-Iab \cdot Rizdo$	$-(180º - A\lim) \le [\arg(Fop) - \arg(Fpol)] \le A\lim$
BC	$-Ibc \cdot Rizdo - Vbc$	$-Ibc \cdot Rizdo$	
CA	$-Ica \cdot Rizdo - Vca$	$-Ica \cdot Rizdo$	

Where:

Iab, Ibc, Ica	Current between phases (Ia-Ib), (Ib-Ic), (Ic-Ia)
Vab, Vbc, Vca	Voltages between phases (Va-Vb), (Vb-Vc), (Vc-Va)
$Rdcho$	Right limiter resistive reach setting (internal, intermediate and external)
$Rizdo$	Left limiter resistive reach setting (internal, intermediate and external)
$A\lim$	Resistive limiters angle setting

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Figure 3.5.1 represents the resistive limiters in a voltage plane.

To pass to an impedance plane, it is only necessary to divide this by the phase-to-phase current. The angle formed with the horizontal axis (defined by the phase-to-phase current) is given by **Alim** (**Resistive Limiter Angle**) setting. This angle should be equal to the angle of transfer impedance between the two systems which interconnect the line protected by the **DLF**, given that theoretically the path of the impedance during a power swing is perpendicular to this impedance.

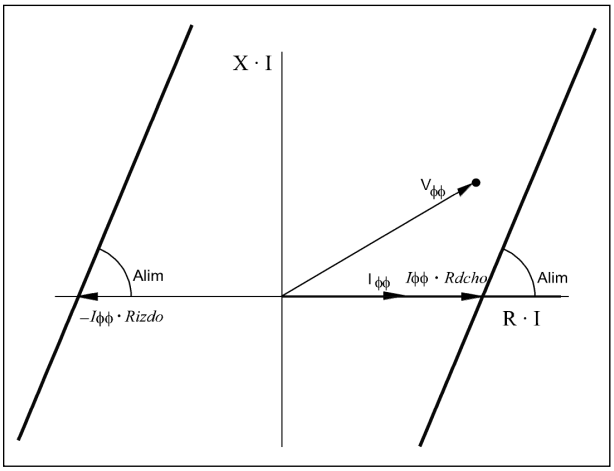


Figure 3.5.1 Diagram of Resistive Limiters of the Power Swing Detection Zones.

The transfer impedance is equal to the sum of the positive sequence impedance of a local source, line and remote source. In general, the angle of this impedance is very similar to the angle of positive sequence impedance of the line, for which it tends to be adjusted in a similar manner.

3.5.4 Reactive Limiters

The **DLF** incorporates three reactive limit units per zone (external, intermediate and internal). Each reactive limit unit is formed of a pair of limiters, upper and lower, with independent reach settings.

The following table shows the operation and polarization phasors which intervene in each of the reactance units, as well as the operating criteria applied.

Table 3.5-2: Reactive Limiters

Upper Reactive Limiter			
Unit	**Fop**	**Fpol**	**Criteria**
AB	$Iab \cdot Z\,\sup - Vab$	$Iab \cdot Z\,\sup$	$-90^{o} \le \left[\arg(Fop) - \arg(Fpol)\right] \le 90^{o}$
BC	$Ibc \cdot Z\,\sup - Vbc$	$Ibc \cdot Z\,\sup$	
CA	$Ica \cdot Z\,\sup - Vca$	$Ica \cdot Z\,\sup$	
Lower Reactive Limiter			
Unit	**Fop**	**Fpol**	**Criteria**
AB	$-Iab \cdot Z\,\inf - Vab$	$-Iab \cdot Z\,\inf$	$-90^{o} \le \left[\arg(Fop) - \arg(Fpol)\right] \le 90^{o}$
BC	$-Ibc \cdot Z\,\inf - Vbc$	$-Ibc \cdot Z\,\inf$	
CA	$-Ica \cdot Z\,\inf - Vca$	$-Ica \cdot Z\,\inf$	

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Where:

Iab, Ibc, Ica	Currents between phases (Ia-Ib), (Ib-Ic), (Ic-Ia)
Vab, Vbc, Vca	Voltages between phases (Va-Vb), (Vb-Vc), (Vc-Va)
$Z\ \mathrm{sup}$	Upper reactive limiter reach impedance setting (internal, intermediate an external)
$Z\ \mathrm{inf}$	Lower reactive limiter reach impedance setting (internal, intermediate and external)

Figure 3.5.2 represents the reactive limiters in a voltage plane. To pass to an impedance plane, it is only necessary to divide this by the phase-to-phase current. The reactive limiters are straight, perpendicular to the resistive limiters, for which the angle of **Zsup** (external, intermediate and internal) and **Zinf** (external, intermediate and internal) impedances is equal to the **Alim** (***Resistive Limiter Angle***) setting.

The external, intermediate and internal zones will be activated provided that the corresponding resistive and reactive limiters are activated simultaneously.

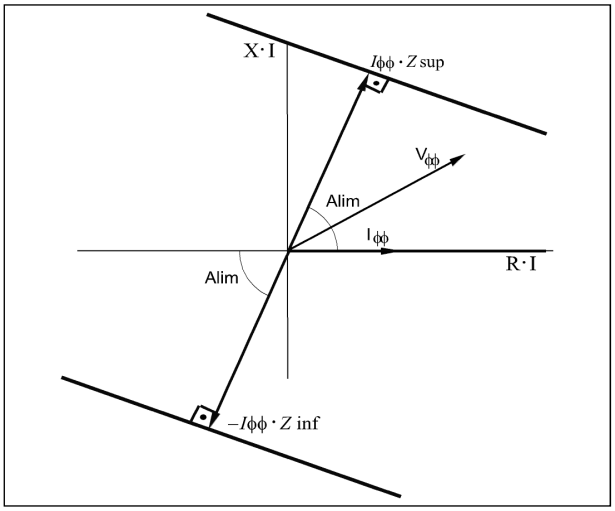


Figure 3.5.2 Diagram of Reactive Limiters of the Power Swing Detection Zones.

3.5.5 Zone Activation Logic

Figures 3.5.3, 3.5.4 and 3.5.5 show the activation logic of the external, intermediate and internal zones according to the outputs of the open-pole logic:

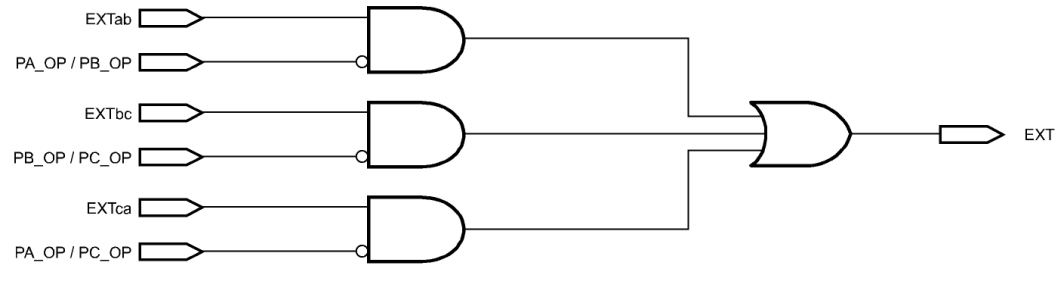


Figure 3.5.3 Activation Logic of the External Zone.

Legend	
PX_OP: Open X Pole.	EXT: External Zone Activation.

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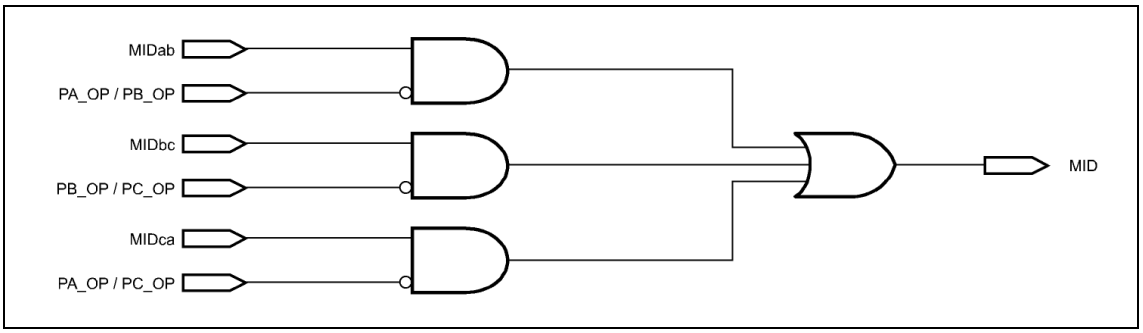


Figure 3.5.4 Activation Logic of the Intermediate Zone.

Legend	
PX_OP: Open X Pole.	MID: Intermediate Zone Activation.

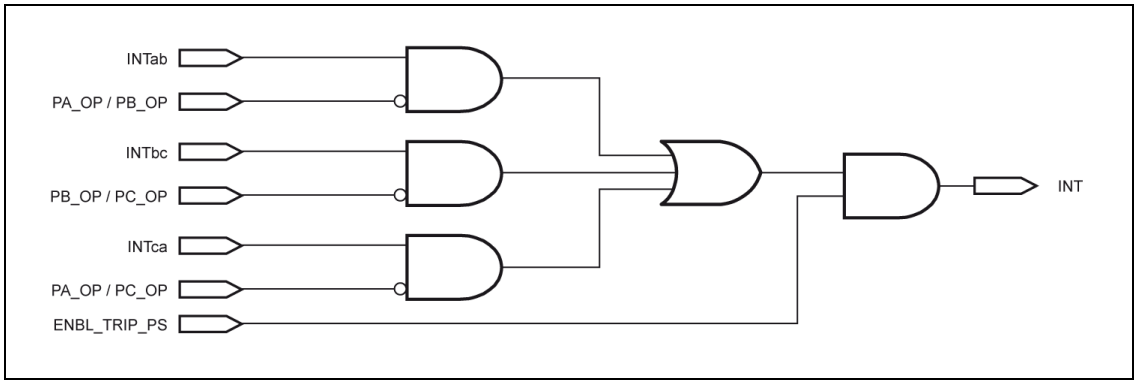


Figure 3.5.5 Activation Logic of the Internal Zone.

Legend	
PX_OP: Open X Pole.	INT: Internal Zone Activation.

The activation of the internal zone is subordinate on the ***PS Trip Enable*** (**ENBL_TRIP_PS**).

On the other hand, there is a minimum adjustable level of positive sequence current for the activation of the three zones (***I1 Supervision***).

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3.5.6 Definition of the Zones

Figure 3.5.6 represents, in an R-X plane, the three quadrilateral zones used by the Power Swing Detector together with the two distance zones with Mho characteristic.

The two types of tripping due to power swing indicated are commented on in the following point.

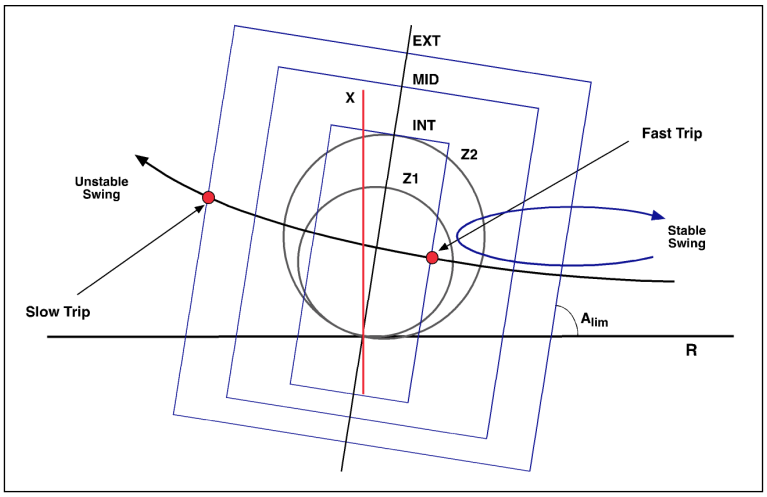


Figure 3.5.6 Power Swing Detector Zones.

The **Intermediate Zone** should be configured in order that it surrounds the most external tripping characteristic to block it before the impedance reaches it.

The **External Zone** will be configured based on the strip which defines, in respect to the intermediate zone, and the anticipated time of the impedance remaining in this strip during a power swing (***Power Swing Detection Time*** setting, commented on below). On the other hand, said zone could never be activated on load conditions, as a lockout condition could occur already on this condition, by trip delay upon later three-phase faults (see zone reset upon faults during power swing). In case of very high load conditions on the line, it will be necessary to limit the range of the external resistive limiter. This may require the intermediate resistive limiter to cut the most external tripping characteristic. In this case, a start of this characteristic would be produced if, during a power swing, the impedance reaches this without having yet reached the intermediate zone. This pickup will be reset when the ***Power Swing Detection Time*** elapses. In general, the most external tripping zone presents a longer timing than this last setting. Still, it is possible to avoid distance pickup for the most overreaching zone by conditioning this pickup to the intermediate zone pickup using the Programmable Logic (use the disable distance zones input).

In respect to the **Internal Zone**, which will only be considered when tripping due to power swing is enabled, following the meaning of the adjustments which define this is explained:

a. ***Resistive reach*** (right or left): this setting should be selected based on the maximum phase difference between the voltages of the two systems which interconnect the protected line which ensures the stability of the system. This angle will be obtained through a stability study. The right resistive reach refers to the power swings which start from a forward load situation, while the left resistive reach is for swings which originate from backward load streams.

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b. ***Impedance reach*** (higher and lower): an unstable power swing will cross the transfer impedance between two systems linked through the protected line by a point designated as the electric centre of the system. This point will be the most appropriate for making the separation between the two systems and will theoretically coincide with the intermediate point of the transfer impedance. It is usual that an **DLF** installed at one end of a line is in charge of tripping only unstable power swings viewed in a forward direction and whose electric centre is located in the line itself. This philosophy would be applied taking into consideration that the lines adjacent to the local and remote points already have protection for tripping in case of unstable power swings which pass through it. In this case, the lower reach of the internal zone could be adjusted to the minimum value and the upper reach equal to the line impedance, or a little lower, in order not to overreach power swings whose electric centre is in a remote line. In case of not having other protection which trips in case of swings with an electric centre in adjacent lines, it will be necessary to extend these impedance reaches.

3.5.7 Operation

The operation of the Power Swing Detector is shown in Figure 3.5.7:

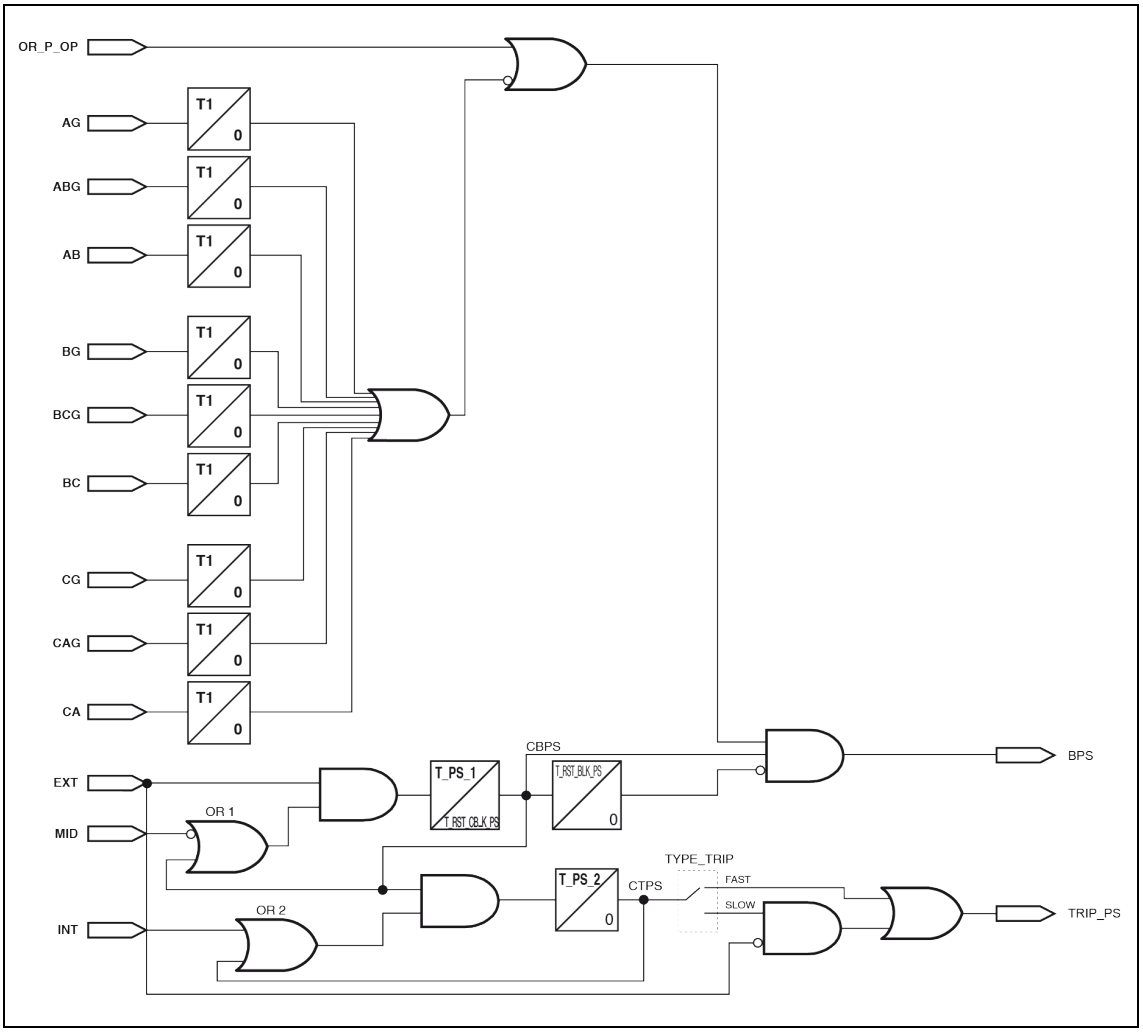


Figure 3.5.7 Block Diagram of the Power Swing Detector.

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Legend	
OR_P_OP: Any Pole Open.	T_PS_1: Power Swing Detection Time (setting).
EXT: External Zone Activation.	T_PS_2: Fast Trip Time (setting).
MID: Intermediate Zone Activation.	T_RST_BLK_PS: Power Swing Blocking Reset Time (setting).
INT: Internal Zone Activation.	
CBPS: Power Swing Blocking Condition.	T_RST_CBLK_PS: Power Swing Blocking Condition Reset Time (setting).
CTPS: Power Swing Tripping Condition.	
BPS: Power Swing Blocking.	TYPE_TRIP: Power Swing Trip Type (setting).
TRIP_PS: Power Swing Trip.	FAST: Fast Trip.
T1: Time Delay for Ground Fault Detection.	SLOW: Slow Trip.

When the impedance enters the strip between the external and intermediate zone, the **T_PS_1** (***Power Swing Detection Time***) timer starts. Once this expires, the **Power Swing Blocking Condition** signal (**CBPS**) is activated. To prevent its deactivation in case of activation of the intermediate zone, a feedback is carried out through the **OR1** port, in order that **CBPS** remains active whenever it is in the external zone. **T_PS_1** should be adjusted with a lower value than the transition through the above-mentioned strip of the fastest power swing.

The **CBPS** signal will generate the **BPS** (**Power Swing Blocking**) signal provided that:

1. None of the **AG/BG/CG/ABG/BCG/CAG/AB/BC/CA** fault signals originating from the Phase Selector are activated longer than ***Time Delay for Ground Fault Detection*** setting. These signals should never activate during a power swing, given the symmetry of this phenomenon. Its activation, consequently, permits to unblock the distance zones, blocked by the detection of a power swing, in case of unbalanced faults. Once the **BPS** signal has been activated, if the **AG/BG/CG/ABG/BCG/CAG/AB/BC/CA** signals are activated, the **BPS** signal will be deactivated after the time setting, avoiding zone 1 trips since the impedance zone was passing that zone in the moment the asymmetry was detected.
2. The **T_RST_BLK_PS** (***Power Swing Blocking Reset Time***) setting has not elapsed, which commences with the activation of the **CBPS** signal. During a power swing, the impedance of this is moving continuously, such that if it enters an external zone, it should again exit from this. The time which exists from the activation of the external zone until its deactivation depends on the speed of the power swing. If the impedance remains within the external characteristic longer than expected, it can be concluded that the power swing has developed into a failure. The **T_RST_BLK_PS** time setting should be longer than the time of duration of the slowest power swing in entering and exiting the external characteristic (on the other hand, it is necessary to add the **T_PS_1** time, which is the time it takes to activate the **CBPS** signal from the activation of the external characteristic). The objective of the **T_RST_BLK_PS** setting is to unblock the distance zones, blocked by the detection of a power swing, in case of a three-phase fault, given that the **Ground Fault** or **Two-Phase Fault** signals will not be activated. Similarly, it permits the unblocking of the distance zones in case of faults which occur from a power swing detected in an open-pole condition, since the Phase Selector's previous signals are not taken into account in this condition.

In both cases, there will be an increase in the positive sequence current, for which the failure detector will be activated, ensuring tripping.

As long as the **CBPS** signal is active, the distance units will not consider pre-fault currents or memory voltage, given that these magnitudes do not correspond to a load situation and will lack reliability.

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Once the **CBPS** signal is activated and the **Power Swing Trip**, option has been selected, the activation of the internal zone commences the counting of the **T_PS_2** (**Fast-Trip Time**) timer; if this reaches its end, the **CTPS** (**Power Swing Tripping Condition**) signal is activated. In case of **TYPE_TRIP** (**Type of Power Swing Trip**) setting is **Fast Trip**, the **CTPS** signal will directly activate **TRIP_PS** (**Power Swing Trip**). In case of selecting **Fast Trip**, the **T_PS_2** timer leaves a time margin to produce this tripping. Notwithstanding, the timer will reset when the internal zone is deactivated, for which this time cannot be longer than the time it takes the impedance to cross this zone. The **T_PS_2** time serves as additional verification that the movement of the impedance is due to a power swing.

Figure 3.5.6 shows the two possible tripping points in case of an unstable power swing.

If, on the contrary, **Slow Trip** is selected, the tripping will be produced on deactivating the external zone. In this case, the **CTPS** signal should continue active although the internal zone is deactivated, for which it is resupplied through the **OR 2**. The **CBPS** signal is kept active in case of deactivation of the external zone during reset time of the **T_PS_1**, **T_RST_BLK_PS** (***Lockout Condition Reset Time by Power Swing***), which will quantify the duration of the slow tripping due to power swing (for this reason, it is necessary to establish a minimum value of this time, if this type of tripping is selected). The slow tripping has the advantage of generating an open command of the breaker under far more favorable conditions in that referring to effort, given that the output voltages of the external zone present a difference in phase much less than at the internal zone entrance, which results in smaller currents.

The **Power Swing Blocking** (**BPS**) signal permits to block the activation of the distance zones and tripping through the distance protection scheme through the **Power Swing Blocking Mask**.

On the other hand, it is possible to block other units which may act in case of power swings, such as overcurrent units. For this, it will be necessary to "wire" the **Power Swing Blocking** (**BPS**) output to the blocking inputs of these units through the use of programmable logic incorporated in the equipment.

The Power Swing Detector is enabled only if there is an open pole, if the Phase Selector indicates three-phase fault or if Power Swing Conditions are present (CBPS signal), i.e. if a fault situation is detected before the power oscillation is detected, the power oscillation detector is not enabled.

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3.5.8 Range Settings

Protection / Power Swing Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	PS Detec Enable		YES / NO		NO
Power Swing Tripping Enable	PS Trip Enable		YES / NO		NO
Right External Resistive Limit	Right Ext Res Lim		0.1 - 500 Ω	0.01 Ω	10 Ω
Right Middle Resistive Limit	Right Med Res Lim		0.1 - 500 Ω	0.01 Ω	5 Ω
Right Internal Resistive Limit	Right Int Res Lim		0.1 - 500 Ω	0.01 Ω	1 Ω
Left External Resistive Limit	Left Ext Res Lim		0.1 - 500 Ω	0.01 Ω	10 Ω
Left Middle Resistive Limit	Left Med Res Lim		0.1 - 500 Ω	0.01 Ω	5 Ω
Left Internal Resistive Limit	Left Int Res Lim		0.1 - 500 Ω	0.01 Ω	1 Ω
Resistive Limiters Angle	Resist Limit Angle		0 - 90º	1º	75º
Upper External Reach	Forward Ext Reach		0.1 - 500 Ω	0.01 Ω	10 Ω
Upper Middle Reach	Forward Med Reach		0.1 - 500 Ω	0.01 Ω	5 Ω
Upper Internal Reach	Forward Int Reach		0.1 - 500 Ω	0.01 Ω	1 Ω
Lower External Reach	Reverse Ext Reach		0.1 - 500 Ω	0.01 Ω	10 Ω
Lower Middle Reach	Reverse Med Reach		0.1 - 500 Ω	0.01 Ω	5 Ω
Lower Internal Reach	Reverse Int Reach		0.1 - 500 Ω	0.01 Ω	1 Ω
Supervision Positive Sequence Current	I1 supervision		0.04 - 50 A	0.01 A	1 A
Power Swing Detection Time	PS Det Time		0 - 2.00s	0.002 s	0.03 s
Power Swing Blocking Reset Time	PS Bloc Reset Time		0.1 - 5 s	0.1 s	1 s
Power Swing Trip Type	PS Trip Type		Fast / Slow		Slow
Fast Trip Time Delay	Fast Trip Time		0 - 2.00s	0.002 s	0.05 s
Power Swing Condition Reset Time	PS Cond Reset Time		0.02 - 2.00s	0.002 s	0.05 s
Time Delay for Ground Fault Detection	Time for Gnd Fault		0 - 200 ms	1 ms	40 ms

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3.5.9 Digital Inputs to the Power Swing Detector Module

Table 3.5-3: Digital Inputs to the Power Swing Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_PS	Enabling Commands		Power swing detector enable input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

3.5.10 Auxiliary Outputs and Events of the Power Swing Detector Module

Table 3.5-4: Auxiliary Outputs of the Power Swing Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
EXT			External zone activation	I	Activation of the external zone.
MID			Intermediate zone activation	I	Activation of intermediate zone.
INT			Internal zone activation	I	Activation of the internal zone.
BPS			Power swing blocking	I	Power swing blocking
TRIP_PS			Power swing trip	I, F	Power swing trip
CBPS			Power swing blocking condition	I	Existence of blocking condition due to power swing
CTPS			Power swing tripping condition	I	Existence of tripping conditions due to power swing
PS_ENBLD			Power swing detector enabled	I	Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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3.5.11 Power Swing Detector Test

Enable the Power Swing Detector by adjusting and disable the other Units. During the test, consult the following indicators:

Display In the **Information** – **Status** – **Metering Units** – **Power Swing Detector** screen.
ZIVercomPlus® In the status screen (**Status** – **Elements** – **Power Swing Detector**).

3.5.11.a Activation Test of the Characteristics

Configure the unit as indicated in Table 3.5-5 (for In = 5 A):

Table 3.5-5: Test Settings for the Power Swing Detector

Trip Enable	YES
Right External Resistive Limit	8 Ω
Right Middle Resistive Limit	6 Ω
Right Internal Resistive Limit	3 Ω
Left External Resistive Limit	8 Ω
Left Middle Resistive Limit	6 Ω
Left Internal Resistive Limit	3 Ω
Resistive Limiter Angle	75º
Upper External Reach	10 Ω
Upper Middle Reach	8 Ω
Upper Internal Reach	7 Ω
Lower External Reach	10 Ω
Lower Middle Reach	8 Ω
Lower Internal Reach	7 Ω
I1 Supervision	0.2 A
Power Swing Detection Time	0.2 s
Power Swing Blocking Reset Time	5 s
Power Swing Trip Type	Fast
“Fast Trip” Time Delay	0.1 s
Power Swing Condition Reset Time	0.1 s

Although the trip is enabled, it will remain masked for this test (actuation masks of auxiliary elements in protection logic).

For this test, apply a balanced three-phase system of voltages and current of 65 Vac with inductive angles of 0º, 120º and 240º and 5 Aac and phase difference (inductive) with respect to each voltage, according to the test table.

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Gradually and simultaneously reduce the voltages of the three phases. **External Zone Activation**, **Middle Zone Activation** and **Internal Zone Activation** flags should activate within the voltage ranges indicated in Table 3.5-6.

Table 3.5-6: Pickup Ranges for the Zones				
Zone	**Activation Voltage (V)**			
	Phase I=0º	**Phase I=45º**	**Phase I=90º**	**Phase I=135º**
External	38.8 – 41.2	56 – 59.47	50.21 – 53.32	43.28 – 45.95
Middle	29.1 – 30.9	44.8 – 47.57	40.17 – 42.65	32.46 – 34.46
Internal	14.55 – 15.45	28.11 – 29.85	35.15 – 37.32	16.23 – 17.23

Zone	**Activation Voltage (V)**			
	Phase I=180º	**Phase I=225º**	**Phase I=270º**	**Phase I=315º**
External	38.8 – 41.2	56 – 59.47	50.21 – 53.32	43.28 – 45.95
Middle	29.1 – 30.9	44.8 – 47.57	40.17 – 42.65	32.46 – 34.46
Internal	14.55 – 15.45	28.11 – 29.85	35.15 – 37.32	16.23 – 17.23

The following expressions have been used to obtain the pickup values of the different characteristics:

For the right resistive limiter:

$$V = I \cdot \frac{sen(\theta) \cdot Rdcho}{sen(\theta - \alpha)}$$

For the higher reach:

$$V = I \cdot \frac{Z\,\mathrm{sup}}{\cos(\theta - \alpha)}$$

For the left resistive limiter:

$$V = I \cdot \frac{sen(\theta) \cdot Rizdo}{sen(\alpha - \theta)}$$

For the lower reach:

$$V = I \cdot \frac{Z\,\mathrm{inf}}{\cos(\theta - \alpha + 180^{\circ})}$$

Where:

$Z\,\mathrm{sup}$	Impedance reach setting for upper limit (Internal, intermediate and external)
$Z\,\mathrm{inf}$	Impedance reach setting for lower limit (Internal, intermediate and external)
$Rdcho$	Resistive reach setting of right limiter (Internal, intermediate and external)
$Rizdo$	Resistive reach setting of left limiter (Internal, intermediate and external)
θ	Limiters angle (setting)
α	Inductive angle of the current with respect to the voltage

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3.5.11.b Power Swing Blocking Test

To carry out this test we will enable the distance elements and disable the trip due to Power Swing.

We will depart from a situation of balanced voltages and currents of 65 Vac and inductive angles of 0º, 120º and 240º and 5 Aac and different phase differences (inductive), as the case may be.

In this situation and taking the values obtained in the previous test, we will cause the voltages to drop (simultaneously) up to a value between the limit voltage values of intermediate and external zone, for the intensity angle being used in each case (see values in table of the previous test).

Maintaining this situation, it will be verified that the **Power Swing Blocking** flag is activated on expiration of the power swing detection time.

Immediately after, the voltages will be reduced and the currents increased in order that the impedance enters into zone 1. It will then be verified that the power swing blocking is maintained until the expiration of the power swing blocking reset time (time which begins at the time when the external characteristic is entered).

To verify that the blocking does not act in case of three-phase faults, we will again depart from the initial situation: Balanced voltages and currents of 65 Vac and inductive angles of 0º, 120º and 240º and 5 Aac and a different phase difference (inductive) as the case may be.

In this situation, we will go directly to a situation of fault in zone 1 (this time without going through the intermediate state). It will be verified that there is a trip by zone 1 and that there is no power swing blocking.

3.5.11.c Power Swing Trip Test

To carry out this test we will disable the distance elements and enable the trip due to Power Swing.

- **Power Swing Fast Trip**

We will depart from a situation of balanced voltages and currents of 65 Vac and inductive angles of 0º, 120º and 240º and 5 Aac and a different phase difference (inductive), as the case may be.

In this situation and taking the values obtained in test 3.10.10.a, we will cause the voltages to drop (simultaneously) up to a value between the limit voltage values of the intermediate and external zones, for the intensity angle being used in each case (see values in the table of the previous test).

Maintaining this situation, it will be verified that the **Power Swing Blocking** flag is activated on expiration of the power swing detection time.

Immediately after, the voltages will be reduced to a value which makes the impedance enter the internal characteristic of the power swing. It will then be verified that a trip is produced due to power swing on expiration of the timing of the fast trip (although previously entering into a blocking situation).

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- **Power Swing Slow Trip**

To carry out this test we will adjust the ***Power Swing Trip Type*** to **Slow** and we will adjust the ***Fast Trip Time*** to 0 s.

We will start from a situation of balanced voltages and currents of 65 Vac and inductive angles of 0º, 120º and 240º and 5 Aac and angles 0º, 120º and 240º.

Being in this situation and taking the values obtained in test 3.10.10.a, we will cause the voltages to drop (simultaneously) up to a value between the limit voltage values of the intermediate and external zones (between 29.1 and 41.2 V).

Maintaining this situation, it will be verified that the **Power Swing Blocking** flag is activated on expiration of the ***Power Swing Time***. Immediately after, the voltages will be reduced to a value which makes the impedance enter the internal characteristic of the Power Swing.

Once this situation has been maintained for a period longer than **Fast Trip Time** (which in this case is set at 0 s), the currents will be inverted and the voltages increased up to a value which makes the impedance go outside the left external resistive limiter (V>41.2 V).

It will then be verified that a trip is produced due to power swing once the reset time of the power swing condition has expired (provided that the blocking has not previously dropped as a result of the expiration of the power swing blocking reset time, since if this happens there would not be any trip).

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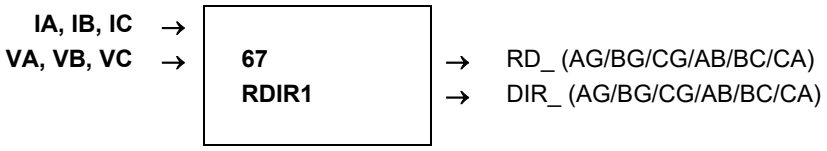
3.6 Distance Directional

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3.6.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Distance directional unit			67

3.6.2 General Block



3.6.3 Operation Principles

DLF equipment features directional elements for each type of fault. Said directional elements are polarized by the positive sequence voltage (with memory, when required) of the corresponding phase or phases, producing a behavior with the following characteristics:

- **Variable**: the use of the positive sequence voltage produces a reverse displacement of the directional element, when the fault is forward looking, proportional to the local source impedance value. The reason for said behavior is that positive sequence voltage involves the unimpaired phase or phases.
- **Dynamic**: the use of voltage memory produces a temporary reverse displacement (depending on the duration of said memory) of the directional element, when the fault is forward looking, also proportional to the local source impedance value.

Both characteristics allow the directional element to determine the correct direction under very near faults (with very low voltage) and under likely voltage reversals in lines with series compensation.

Voltage memory is used when so dictated by the memory logic (see 3.1.5).

The following table shows the operation and polarization phasors of the directional elements, as well as the applied operating criteria.

Table 3.6-1: Directional Unit

Unit	Fop	Fpol	Criteria
AG	Ia	$Va1M$	$-(90^{o}+\alpha) \le [\arg(Fop) - \arg(Fpol)] \le (90^{o}-\alpha)$
BG	Ib	$Vb1M$	
CG	Ic	$Vc1M$	
AB	Iab	$Vab1M$	
BC	Ibc	$Vbc1M$	
CA	Ica	$Vca1M$	

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Where:

Ia, Ib, Ic	Phase currents
Iab, Ibc, Ica	Line currents (Ia-Ib), (Ib-Ic), (Ic-Ia)
$Va1M, Vb1M, Vc1M$	Stored positive sequence voltages corresponding to each phase
$Vab1M, Vbc1M, Vca1M$	Stored positive sequence voltages corresponding to each pair of phases

Figures 3.6.1 and 3.6.2 show the **Directional element** for ground faults. By the effect of the polarization system used, said directional element does not go through the origin being moved down by a vector dependent of the local source impedance. This effect allows that very close forward looking faults, with very low voltage values (located very near the origin) are seen in the trip direction. The directional element will keep indicating the trip direction even for forward looking faults in lines with series compensation appearing on the third quadrant by the effect of negative capacitive reactance.

It is worth mentioning that the above effect does not imply a loss of directional capability, as for reverse direction faults, the directional element undergoes a forward displacement, following a vector proportional to the sum of line and remote source impedances. Figure 3.6.3 shows said displacement.

Figure 3.6.1 shows the directional element at moment when a forward looking fault occurs, to which, as a result of the memory, positive sequence voltage previous to the fault is applied. It is apparent that said element displacement is represented by the vector:

$$ZSL \cdot (Ieq - I\phi load)$$

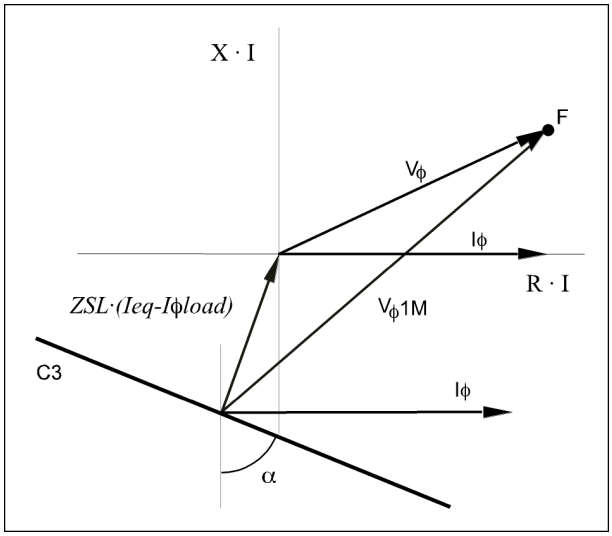


Figure 3.6.1 Directional Element Diagram for Ground Faults (I).

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Figure 3.6.2 shows the directional element after memory update under a stationary fault state. Said element undergoes a displacement given by the vector:

$$ZSL \cdot (Ieq - I1\phi)$$

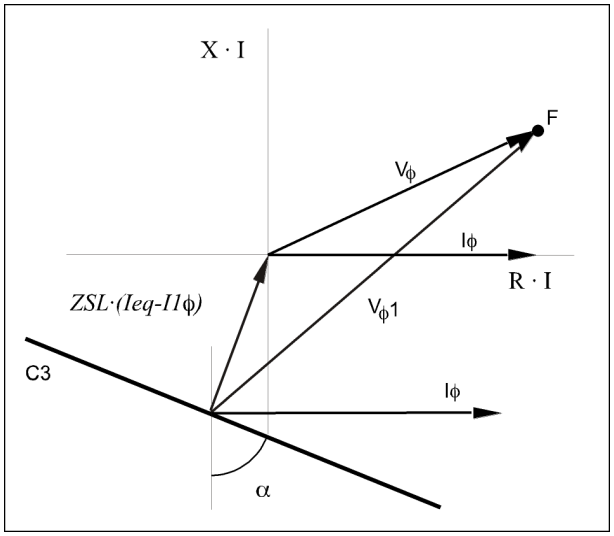


Figure 3.6.2 Directional Element Diagram for Ground Faults (II).

Figure 3.6.3 shows the directional element at the moment when a reverse looking fault occurs. As a result of the memory, the element undergoes an upward displacement given by the vector:

$$(ZL + ZSR) \cdot (Ieq - I\phi load)$$

When the memory is updated, by the effect of the positive sequence voltage, during the duration of the fault, the element will keep an upward displacement given by the vector:

$$(ZL + ZSR) \cdot (Ieq - I1\phi)$$

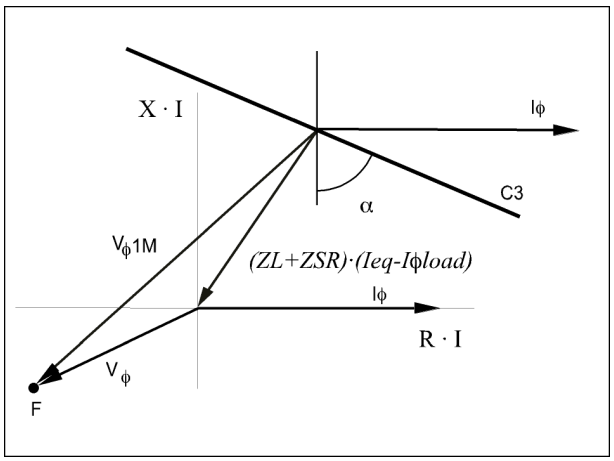


Figure 3.6.3 Directional Element Diagram for Ground Faults (III).

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Where:

ZSL	Positive sequence impedance of the local source (located behind the relay)
ZL	Positive sequence impedance of the line
ZSR	Positive sequence impedance of the remote source
Ieq	Equivalent current (common to the line, local source and remote source)*
$I\phi(Ia, Ib, Ic)$	Phase current
$I1\phi$	Fault positive sequence current
$I\phi load$	Load current, previous to the fault
$V\phi$	Phase voltage
$V\phi 1$	Positive sequence voltage

(*) Above described displacement vectors have been figured out on the bases that zero sequence compensation factors associated to the line, local source and remote source are equal.

Figures 3.6.4 and 3.6.5, shows the **Directional Element** for phase-to-phase faults. Said figures are drawn for a forward looking fault. For a reverse looking fault, the directional element would be displaced upwards, and the arrangement would be similar to figure 3.6.3, corresponding to a single-phase fault.

Figure 3.6.4 shows the directional element at the moment when the fault occurs. The displacement undergone by the element by effect of the memory is given by the vector:

$$ZSL \cdot (I\phi\phi - I\phi\phi load)$$

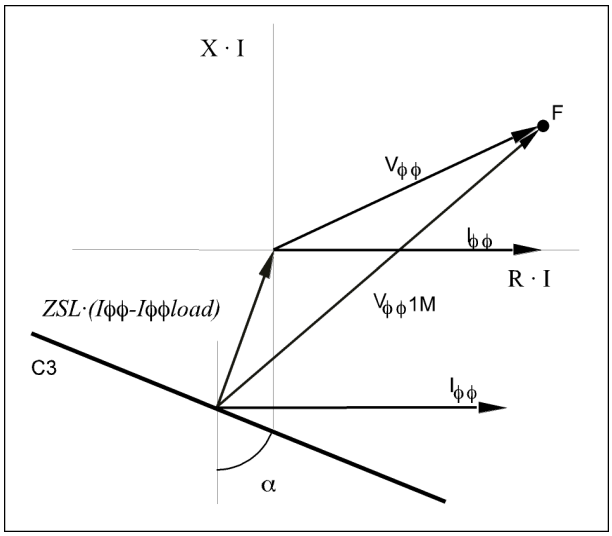


Figure 3.6.4 Directional Element Diagram for Phase-to-Phase Faults (I).

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Figure 3.6.5 shows the directional element after memory update. Under steady state fault condition, the displacement of said element is given by the vector:

$$ZSL \cdot (I\phi\phi - I\phi\phi 1)$$

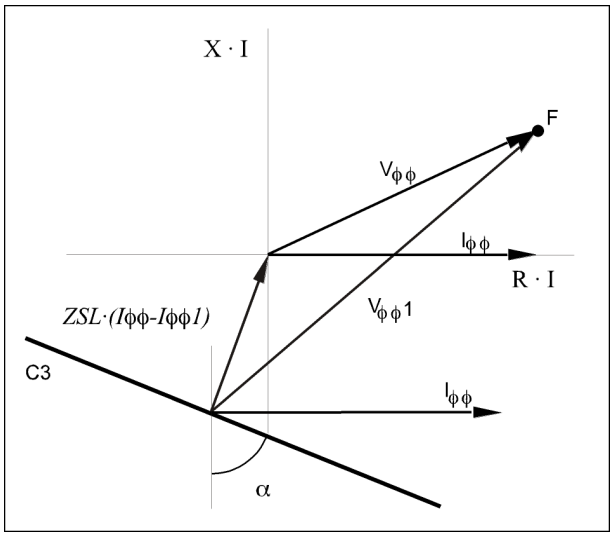


Figure 3.6.5 Directional Element Diagram for Phase-to-Phase Faults (II).

Where:

ZSL	Local source positive sequence impedance
$I\phi\phi(Iab, Ibc, Ica)$	Phase-to-phase current (fault)
$I1\phi\phi$	Positive sequence fault current (phase-to-phase)
$I\phi\phi load$	Load current (phase-to-phase), previous to fault
$V\phi\phi$	Phase-to-phase voltage
$V\phi\phi 1$	Positive sequence voltage (phase-to-phase)

3.6.4 Range Settings

Protection / Distance Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Dir Characteristic Angle	`Direc Charac Angle`		0 - 90º	1º	75º
Lack of Direction Blocking	`Lack Polariz Block`		YES / NO		YES

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3.6.5 Analog Inputs to the Unit

The operating magnitude of the Distance Directional Elements will be the fundamental current IA, IB and IC. Also, it will use the memorized phase voltages as polarization magnitude.

Table 3.6-2: Analog Inputs of the Overcurrent Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
VAB	AB Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsAB
VBC	BC Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsBC
VCA	CA Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsCA
VAC	AC Phase-to-Phase Voltage (ACB Sequence)	
VBA	BA Phase-to-Phase Voltage (ACB Sequence)	
VCB	CB Phase-to-Phase Voltage (ACB Sequence)	

3.6.6 Auxiliary Outputs and Events of the Distance Directional Module

Table 3.6-3: Auxiliary Outputs of the Distance Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
DIR_AG			AG Distance direction		
DIR_BG			BG Distance direction		
DIR_CG			CG Distance direction		
DIR_AB			AB Distance direction		
DIR_BC			BC Distance direction		
DIR_CA			CA Distance direction		
RD_AG			AG Distance reverse direction		
RD_BG			BG Distance reverse direction		
RD_CG			CG Distance reverse direction		
RD_AB			AB Distance reverse direction		
RD_BC			BC Distance reverse direction		
RD_CA			CA Distance reverse direction		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Chapter 4.

Current Protection Units

4.1 Overcurrent Elements

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Overcurrent Protection Elements		
3	Instantaneous Phase Overcurrent	**50F1 / 50F2 / 50F3**
3	Instantaneous Neutral Overcurrent	**50N1 / 50N2 / 50N3**
3	Instantaneous Ground Overcurrent	**50G1 / 50G2 / 50G3**
3	Instantaneous Negative Sequence Overcurrent	**50Q1 / 50Q2 / 50Q3**
3	Time-delayed Phase Overcurrent	**51F1 / 51F2 / 51F3**
3	Time-delayed Neutral Overcurrent	**51N1 / 51N2 / 51N3**
3	Time-delayed Ground Overcurrent	**51G1 / 51G2 / 51G3**
3	Time-delayed Negative Sequence Overcurrent	**51Q1 / 51Q2 / 51Q3**

4.1.1 Common Principles

4.1.1.a Operation and Reset

Overcurrent elements operate as a function of input current RMS value. By default, elements activate when RMS values exceed 1.05 times the pickup setting and reset at 1 times the pickup setting. Pick up level can be set from 1 to 1.10 times the pick-up setting for models with ***General / Overcurrent Pickup*** setting available.

In case of instantaneous elements, every protection element is provided with a settable output timer, which allows for optional timing of the instantaneous elements whereas in the time elements, the pickup activation enables the time function, which will perform the integration of the measured values. This integration is carried out by applying increments, as a function of the input current, to a counter whose timeout determines the time element operation.

In time elements, when inverse time curve characteristic is used, two reset systems are available: ***Instantaneous*** and ***Disk Emulation***. The ***Instantaneous*** option is adequate for applications requiring coordination with static relays, whereas the ***Disk Emulation*** option can be used in cases in which the relay must be coordinated with electromechanical protections, mainly when they are located towards the system power source.

If the ***Instantaneous*** reset system is selected, the pickup is reset when the measured value goes down to 1 time the setting value. Drop of the measured RMS value below the pickup setting value results in a quick integrator reset. For output activation, pickup must be active during the entire integration time; any integrator reset brings the integrator back to initial conditions, so that new activations start timing from zero.

If the ***Disk Emulation*** reset system is selected, the relay uses a reset process based on the decrements of a timer that starts when the current drops below 100% of the element pickup setting, using the reset curve adequate to the trip characteristic used.

The calculation of the time for a second trip, when it is generated in the disk reset timing, will be as follows:

*Second trip time = First trip time * Time between trips / Coefficient of the curve*

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The calculations of the second trip for IEC curves are added below as an example, the time between trips being 2 seconds.

Id=1 // Pu=1A // IS=2A
*Inverse --> T = 10.04 * 2.0 /9,7 = 2.070*

Id=0,9 // Pu=1A // IS=1,6A
*Very Inverse --> T = 20.31 * 2.0 /43.2 = 0.940*

Id=0,9 // Pu=1A // IS=1,6A
*Extremely Inverse --> T = 46.13 * 2.0 / 58,2 = 1.585*

4.1.1.b Trip Blocking and Time Delay Disable

Trip Blocking inputs can be programmed into time and instantaneous overcurrent elements, which disable element trip if input is activated before trip is generated. If input is activated after tripping, trip is reset. Even if the element is blocked, it remains operative such that if the relay is under trip conditions when the blocking input is deactivated, the relay will issue a trip command instantaneously.

Trip blocking inputs must be programmed before this blocking logic can be used.

Another programmable input exists that can turn a given time overcurrent element into instantaneous. Said input is called **Timer Disable** and is available for all time-delayed elements.

4.1.1.c Element Enable and Disable

Relays are provided with an enable and disable input such that, the element being enabled by protection setting, it can be disabled through the logic under given circumstances. In this way, when the enable input is deactivated, the element is not operative and the element begins to operate from zero when the enable input is activated.

4.1.1.d Harmonics Blocking

The energizing of a transformer causes transient saturation as a consequence of the DC component generated in the magnetic flux. This results in high magnetizing currents (*inrush*), which can be several times the machine rated current.

Under overexcitation conditions of the transformer, as a result of overvoltage and under frequency, important magnetizing currents can also be produced.

In order to prevent overcurrent elements from operating upon said magnetizing currents, overcurrent elements include the function **Harmonics Blocking**. In order that a distinction can be made from a fault current and an *inrush* current, both with high fundamental frequency component, the 2nd and 5th harmonic components are analyzed, such that harmonic blocking elements serve as inputs to overcurrent elements when they are so configured.

See the section corresponding to the Harmonics Blocking for more information.

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4.1.1.e Saturation Detector

The saturation of a CT causes a reduction of the magnitude of the current, obtained based on the DFT. With severe saturation, the current RMS might not exceed the set threshold. In order to avoid this situation, the magnitude of the current will be calculated based on the maximum value of the rate of change with time.

Upon activation of the Saturation Detector, overcurrent elements will use not only the RMS value of the current but also the instantaneous value so that once the Fault Detector is activated, the positive and negative maximum values will be added (sum of the positive maximum value and the negative maximum value, both in absolute values) and the total sum will be divided by 2. The value obtained from this operation is compared with the pickup setting value multiplied by $\sqrt{2}$. Since the instantaneous value used by the new overcurrent element requires two consecutive maximum values (or peak values) of opposite sign from the activation of the Fault Detector, it will operate once the two above mentioned values have been obtained, never before. This delay will always be less than one cycle, so that it is small enough to operate during CT saturation.

See the section corresponding to the Saturation Detector for more information.

4.1.1.f Time-Delayed Curves

Time characteristics can be selected among the various types of curves according to **IEC**, **IEEE** (Standard IEEE C37.112-1996) and **US** standards. Also, relays are provided with **Recloser Curves**.

IEC CURVES

Inverse curve	Inverse curve + time limit
Very inverse curve	Very inverse curve + time limit
Extremely inverse curve	Extremely inverse curve + time limit
Long time inverse curve	Long time inverse curve + time limit
Short time inverse curve	Short time inverse curve + time limit

IEEE CURVES

Moderately inverse curve	Moderately inverse curve + time limit
Very inverse curve	Very inverse curve + time limit
Extremely inverse curve	Extremely inverse curve + time limit

US CURVES

Moderately inverse curve	Moderately inverse curve + time limit
Inverse curve	Inverse curve + time limit
Very inverse curve	Very inverse curve + time limit
Extremely inverse curve	Extremely inverse curve + time limit
Short time inverse curve	Short time inverse curve + time limit

RECLOSER CURVES

Curve 105	Curve 117
Curve 113	Curve 131
Curve 107	Curve 135

The **RI Inverse Curve** may be added to the above curves, mainly used with electromechanical relays.

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Time multiplier setting is the same as for **IEC**, **IEEE**, **US**, **Recloser** and **RI Inverse** curves: range is 0.05 to 10 times. However, depending on model digits X27 and X28, effective range for **IEC** curves ranges from 0.05 to 1. For a setting higher than 1, the maximum value, equal to 1, is used. For **Recloser** curves, the range goes from 0.05 to 2, and for setting higher than 2, maximum value, equal to 2, is used. In the case of **IEEE**, **US** and **RI** curves, effective range starts in 0.1 times. If set to lower values, 0.1 is used. Despite of the setting step being 0.01, the effective step of the curve is 0.1. Any setting value not a multiple of 0.1 is symmetrically rounded: for example, a 2.37 setting is rounded up to 2.40, a 2.33 setting is rounded down to 2.3 and a 2.35 setting is applied as 2.40.

For models with digit X27/X28 equal or higher than 13, time multiplier setting is the same as for **IEC**, **IEEE**, **US**, **Recloser** and **RI Inverse** curves: range is 0.01 to 10 times.

A **User-Defined** time characteristic may be added to the above characteristics, downloading it into the relay through the communications system. For inverse-time characteristics, delay time settings are composed of two values: **Curve Type** and **Time Multiplier** (**Dial**) within the family.

Curve types with **Time Limit** are regular time delayed functions with a time threshold, so that no trip takes place before the specified time. This results in that beyond a specified time the tripping curve turns into a horizontal straight line. This operate time limit coincides with the time setting used in the ***Fixed Time*** option. Three different operating ways can result as a function of the curve selected and the ***Fixed Time*** setting.

If the ***Fixed Time*** setting is so small that the curve is not crossed, the relay will operate as if the characteristic curve were normal and not a **Time Limit** curve.

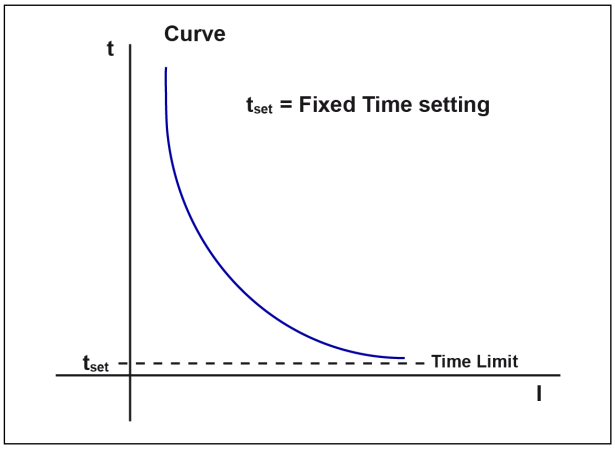


Figure 4.1.1 Diagram of a Curve with a Time Limit for a Time Overcurrent Element (Very Low Fixed Time Setting).

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Setting the relay for a usual operation, the ***Fixed Time*** setting will cross the curve such that, from a given time, the trip curve turns into a horizontal straight line, ensuring that no trip will occur for a time less than the ***Fixed Time*** setting value provided this setting value is lower than the time determined by the curve when the measured value exceeds 1.5 times the setting value.

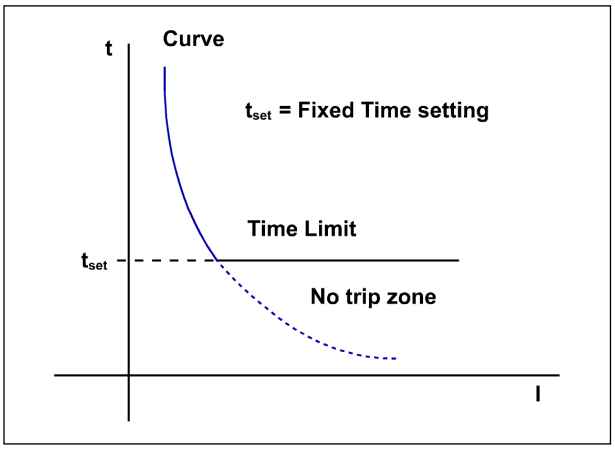


Figure 4.1.2 Time Limit Curve for a Time Overcurrent Element.

It may be that the ***Fixed Time*** setting value is excessive with reference to the curve times for the different indicators, such that the relay may never trip. If this should be the case, if curve time (for the dial setting and a current 1.5 times greater than the setting) is less than the ***Fixed Time*** setting, a time delay corresponding to 1.5 times the current is used as a limit line for element operation.

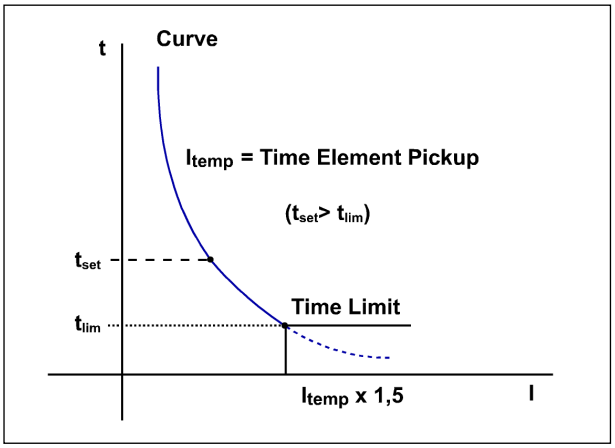


Figure 4.1.3 Diagram of a Curve with Time Limit in case of Fixed Time greater than Curve Time (in Pick-up x 1.5).

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Therefore, it could be said that whenever the ***Fixed Time*** setting value is above the time defined by the curve for a current 1.5 times the setting value, the operating time will be limited to 1.5 times, the trip curve being turned into a horizontal straight line.

Curves without **Time Limit** are not affected by the ***Fixed Time*** setting of the element, although the note below must be taken into account to consider full operating function.

Each trip curve **IEC**, **IEEE** and **US** account for a characteristic that emulates the reset time of electric magnetic relay disks for those relays provided with ***Reset Type*** setting. The equation for the reset duration is as follows:

$$t_{RESET} = index \times \left[\frac{t_r}{1 - \left(\frac{I}{I_{pickup}} \right)^2} \right]$$

where **tr** is the characteristic constant that varies as a function of the selected trip curve.

tr values are shown in the table below:

Trip Characteristic	Reset Characteristic (tr)
IEC CURVES	
Inverse curve	9.7
Very inverse curve	43.2
Extremely inverse curve	58.2
Long time inverse curve	80
Short time inverse curve	0.5
IEEE CURVES	
Moderately inverse curve	4.85
Very inverse curve	21.6
Extremely inverse curve	29.1
US CURVES	
Moderately inverse curve	1.08
Inverse curve	5.95
Very inverse curve	3.88
Extremely inverse curve	5.67
Short time inverse curve	0.323

When Inverse RI curve is selected, pick up resets instantaneously regardless the ***Reset Type*** setting.

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It should be noted that although curves are defined in the graphics for a given input of up to 20 times the tap (the tap being the time element pick up setting), they will tend to be horizontal from 32 times the tap, although, taking into account the analog input saturation, it is not always possible to guarantee this range as shown below.

Bear in mind that current channel saturation limits are 160 A for phases and ground and 3.3 A for sensitive ground. Based on these limits, the "times the tap" for which curves are effective is a function of the setting:

If $\frac{Saturation\ Limit}{Element\ Setting} > 32$,

curve operation is guaranteed for elements with said setting over the entire tap range (up to 32 times the setting).

If $\frac{Saturation\ Limit}{Element\ setting} < 32$,

curve operation is guaranteed for elements with said setting up to a number of times the tap equal to the result of dividing the saturation limit by the applicable setting. Namely, for a Sensitive Ground element set to 2A, curves will be effective up to

$$\frac{3.3}{2} = 1.55$$

times the setting.

If the current at said Sensitive Ground exceeds 3.3A, the relay measures said 3.3A and trip time corresponds to 1.55 times the tap. When a current above 20 times the setting is injected, trip time will be the same as for said 20 times.

Similarly, if a phase element is set with a value of 10A, as 32 times the setting is higher than the saturation limit (320A > 160A), the curve will be effective up to 16 times the tap:

$$\left(\frac{160}{10} = 16\right)$$

so that, for any higher value, the pickup time will be that of 16 times the tap instead of keeping different time values up to 32 times the tap.

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- **Current / Time Curve: Inverse Functions**

Figures 4.1.4, 4.1.5, 4.1.6, 4.1.7 and 4.1.8 present the inverse curves according to the IEC standards.

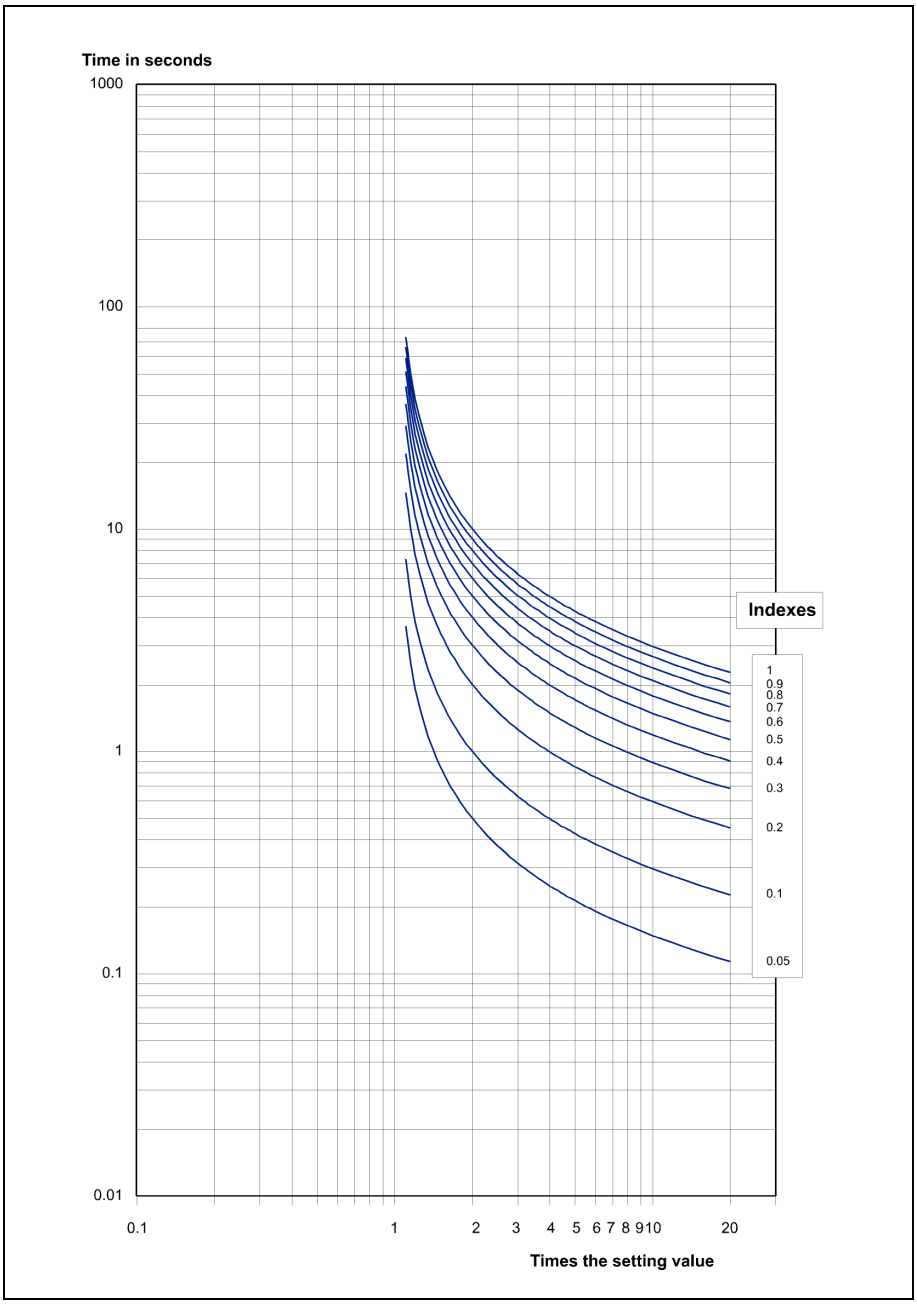


Figure 4.1.4 INVERSE Time Curve (IEC).

$t = \frac{0.14}{I_S^{0.02} - 1} \times \text{Index}$	$I_S = \frac{I_{measured}}{I_{pickup}}$

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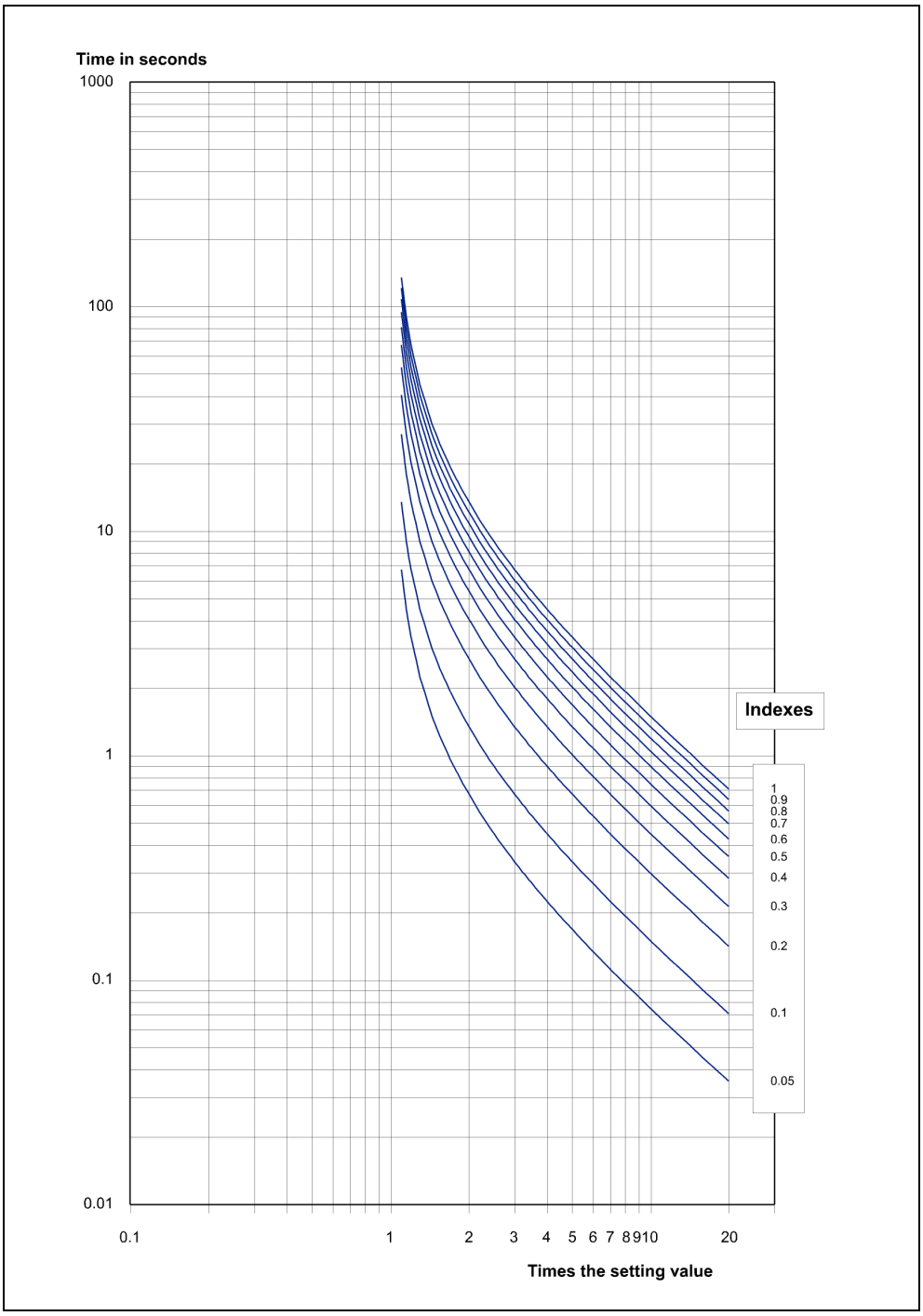


Figure 4.1.5 VERY INVERSE Time Curve (IEC).

$t = \frac{13.5}{I_S - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

M0DLFA1907I
DLF: Line Differential Protection
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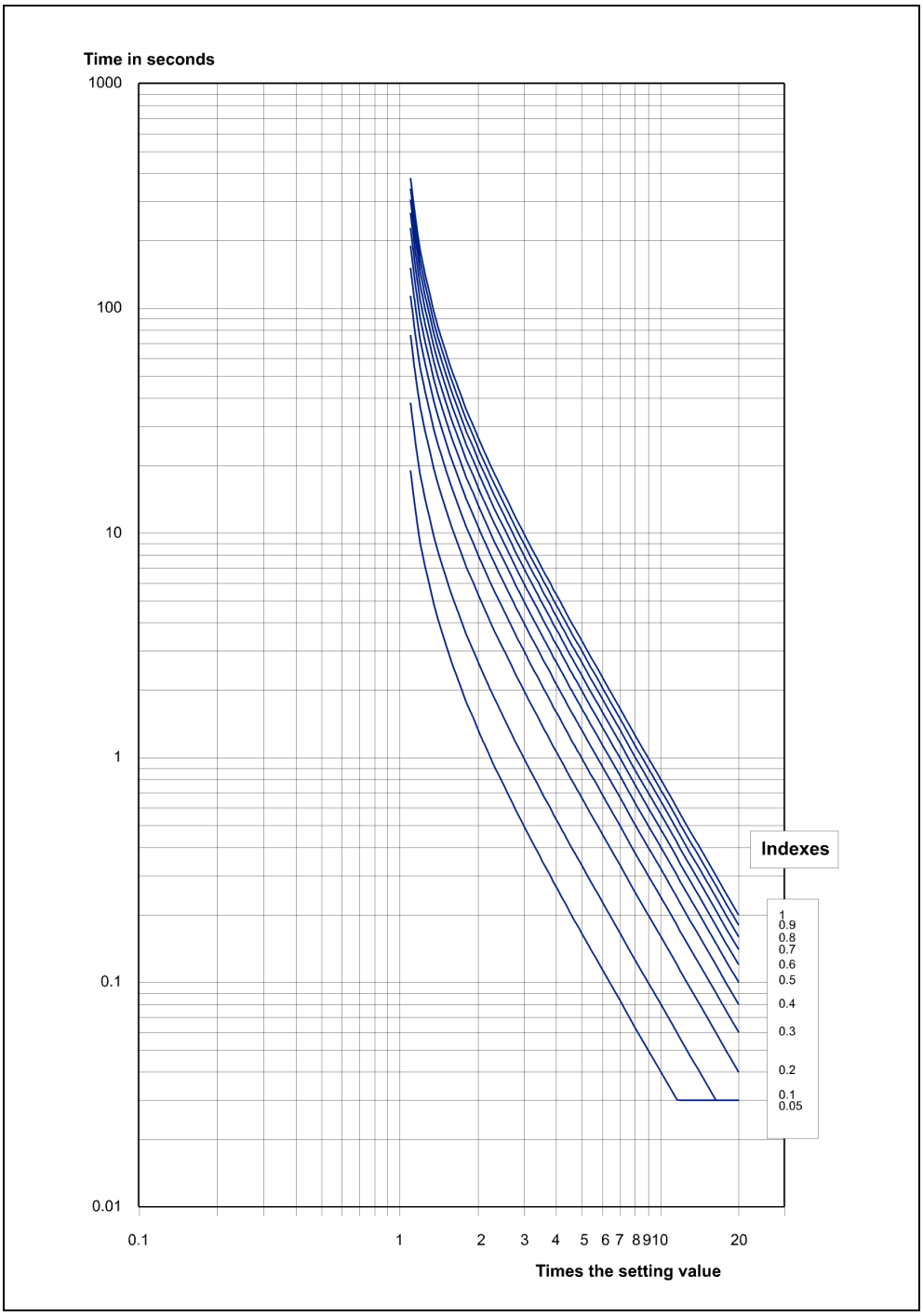


Figure 4.1.6 EXTREMELY INVERSE Time Curve (IEC).

$t = \frac{80}{I_S^2 - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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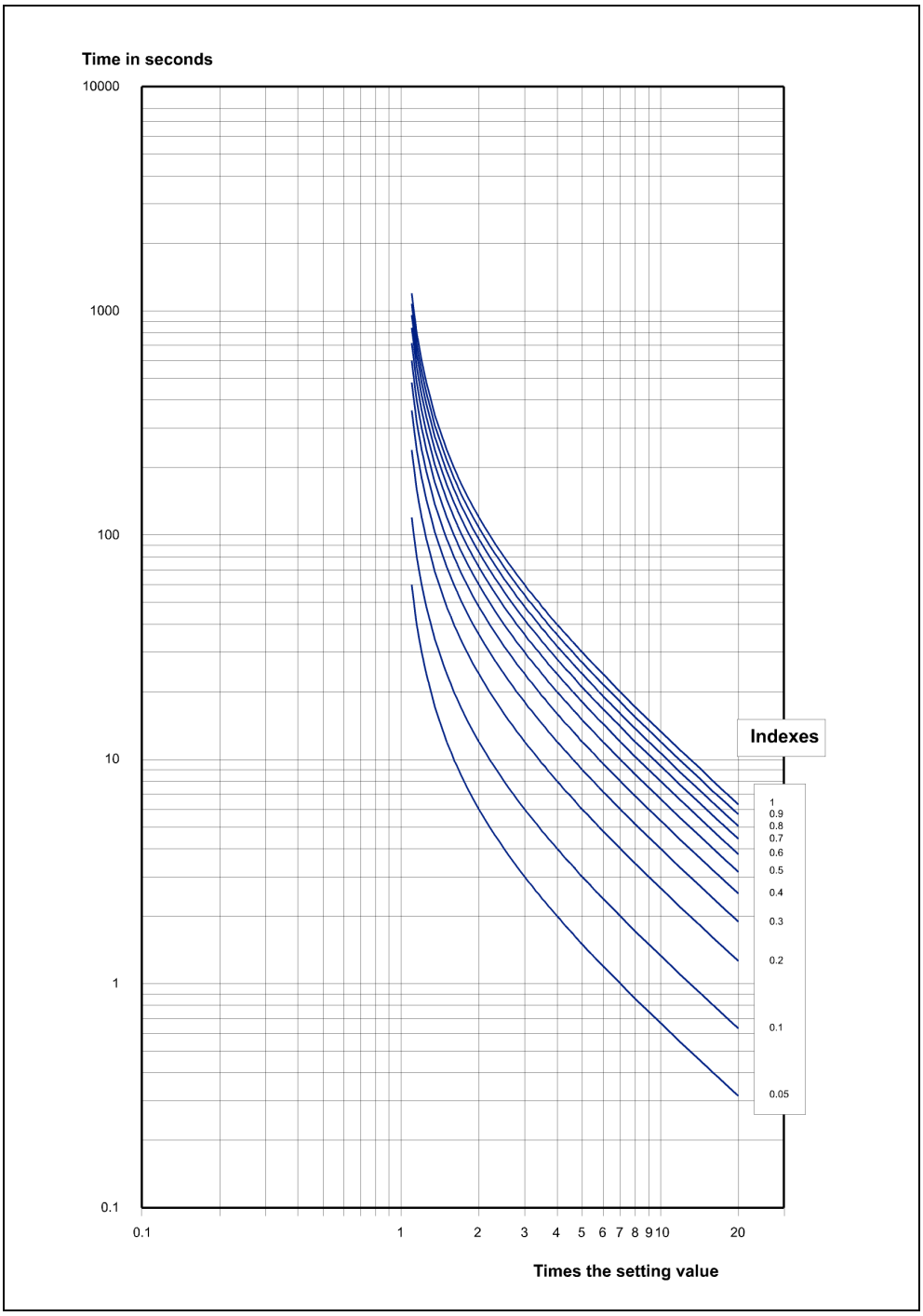


Figure 4.1.7 LONG TIME-INVERSE Curve (IEC).

$t = \frac{120}{I_S - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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DLF: Line Differential Protection
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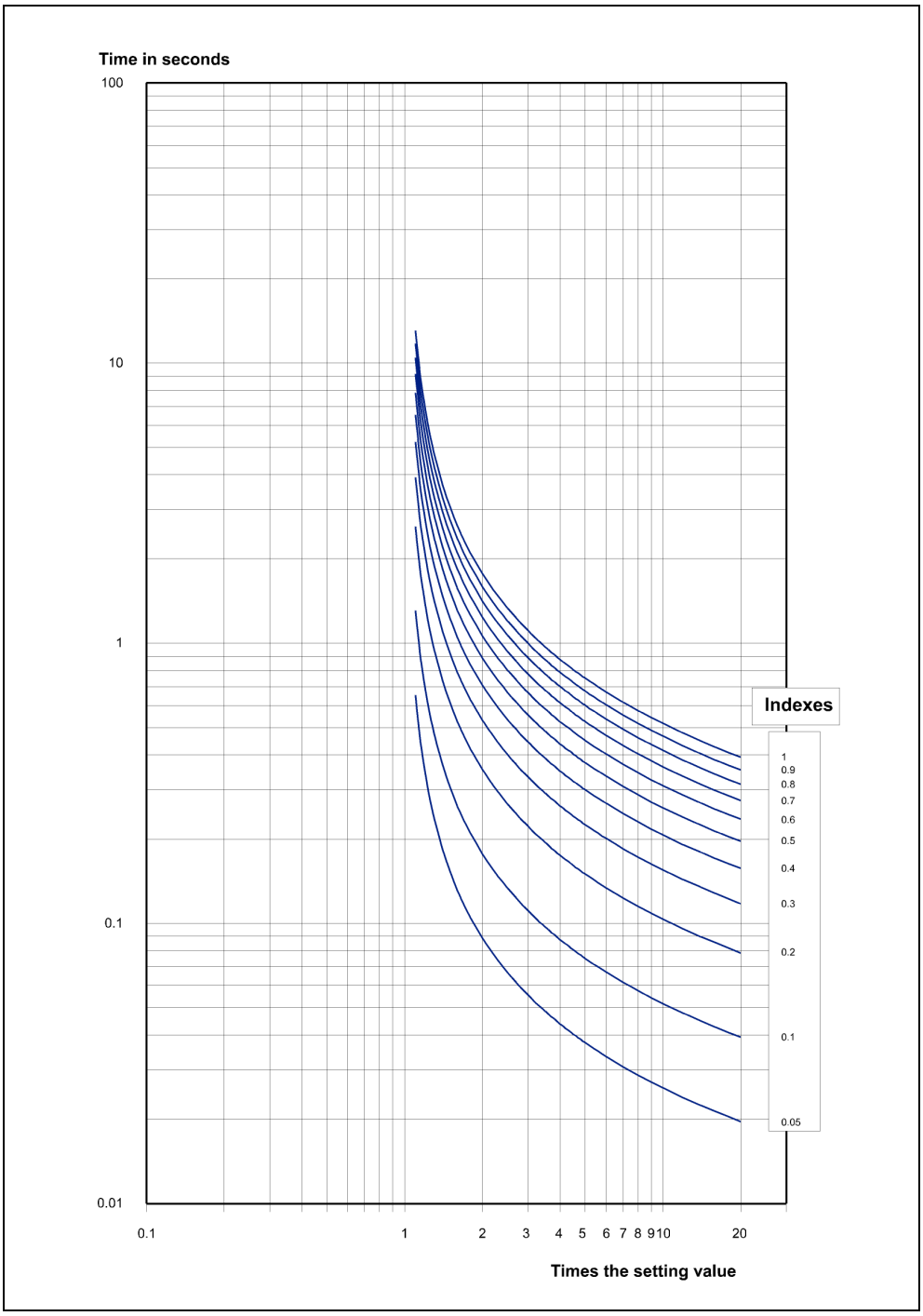


Figure 4.1.8 SHORT TIME-INVERSE Curve (IEC).

$t = \frac{0.05}{I_S^{0.04} - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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Figures 4.1.9, 4.1.10, 4.1.11, 4.1.12, 4.1.13, 4.1.14, 4.1.15 and 4.1.16 present the inverse curves according to the **IEEE** and **US** Standards.

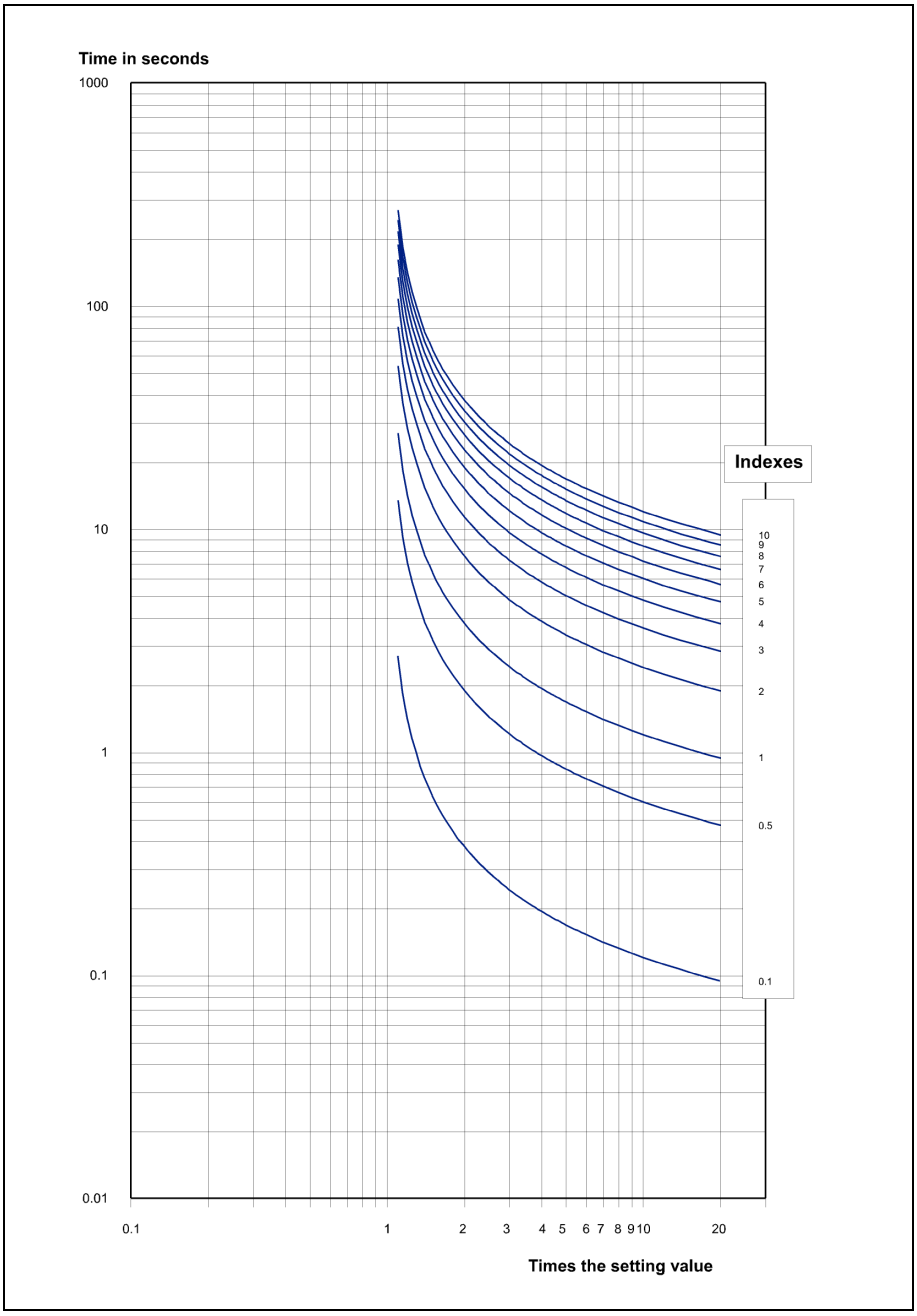


Figure 4.1.9 MODERATELY INVERSE Time Curve (IEEE).

$t = \left(0.114 + \frac{0.0515}{I_S^{0.02} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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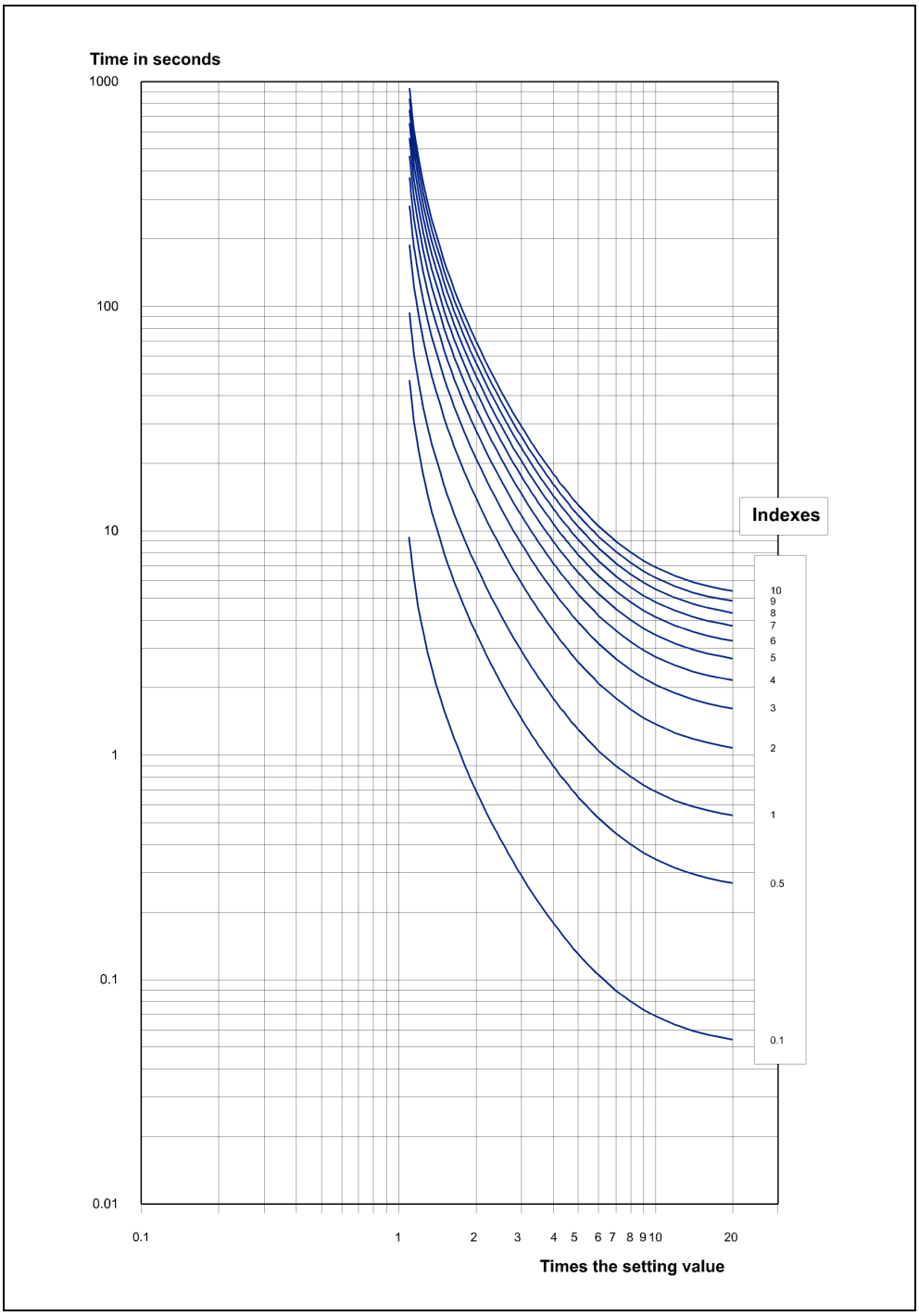


Figure 4.1.10 VERY INVERSE Time Curve (IEEE).

$t = \left(0.491 + \frac{19.61}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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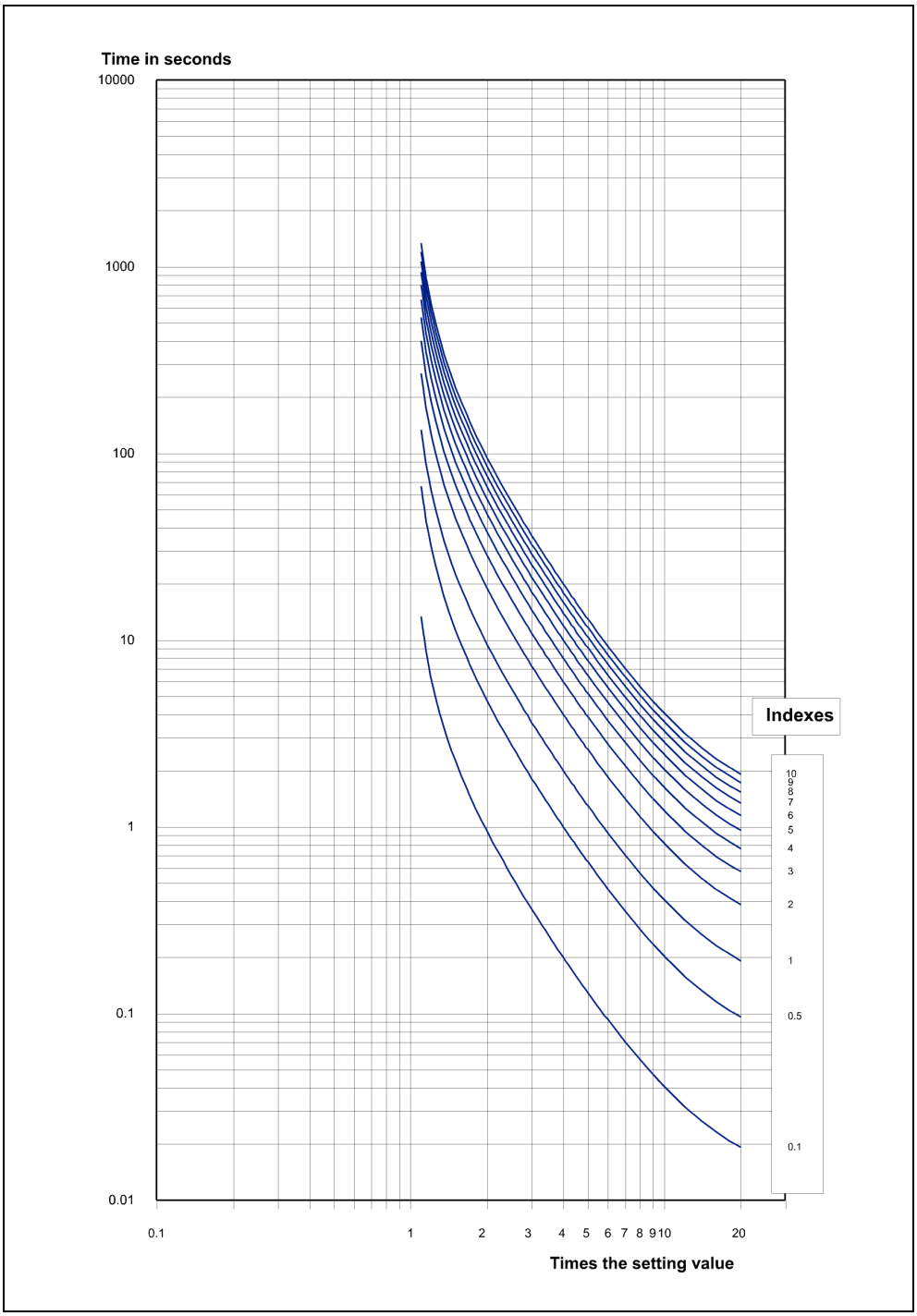


Figure 4.1.11 EXTREMELY INVERSE Time Curve (IEEE).

$t = \left(0.1217 + \frac{28.2}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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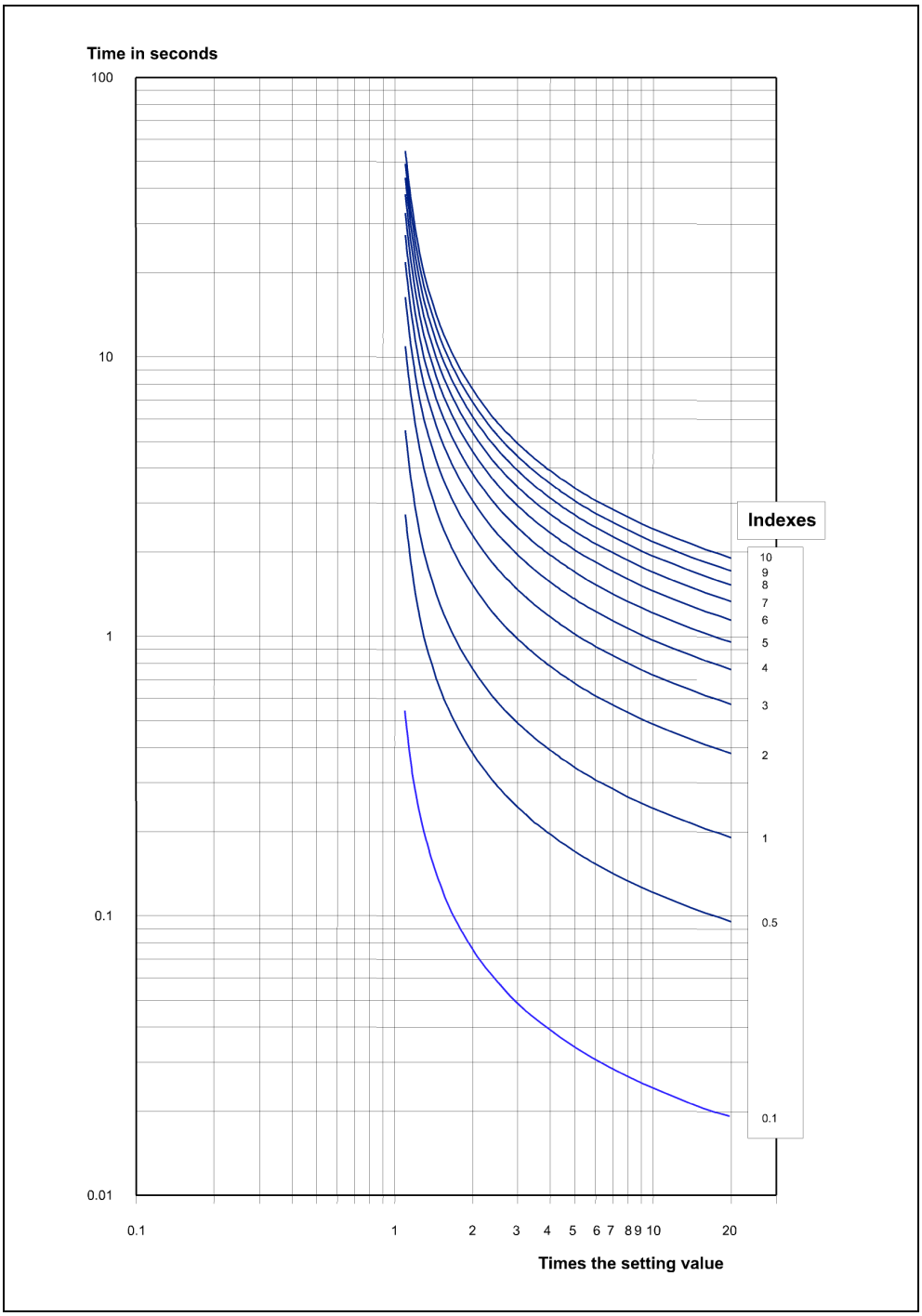


Figure 4.1.12 MODERATELY INVERSE Time Curve (U.S.)

$t = \left(0.0226 + \frac{0.0104}{I_S^{0.02} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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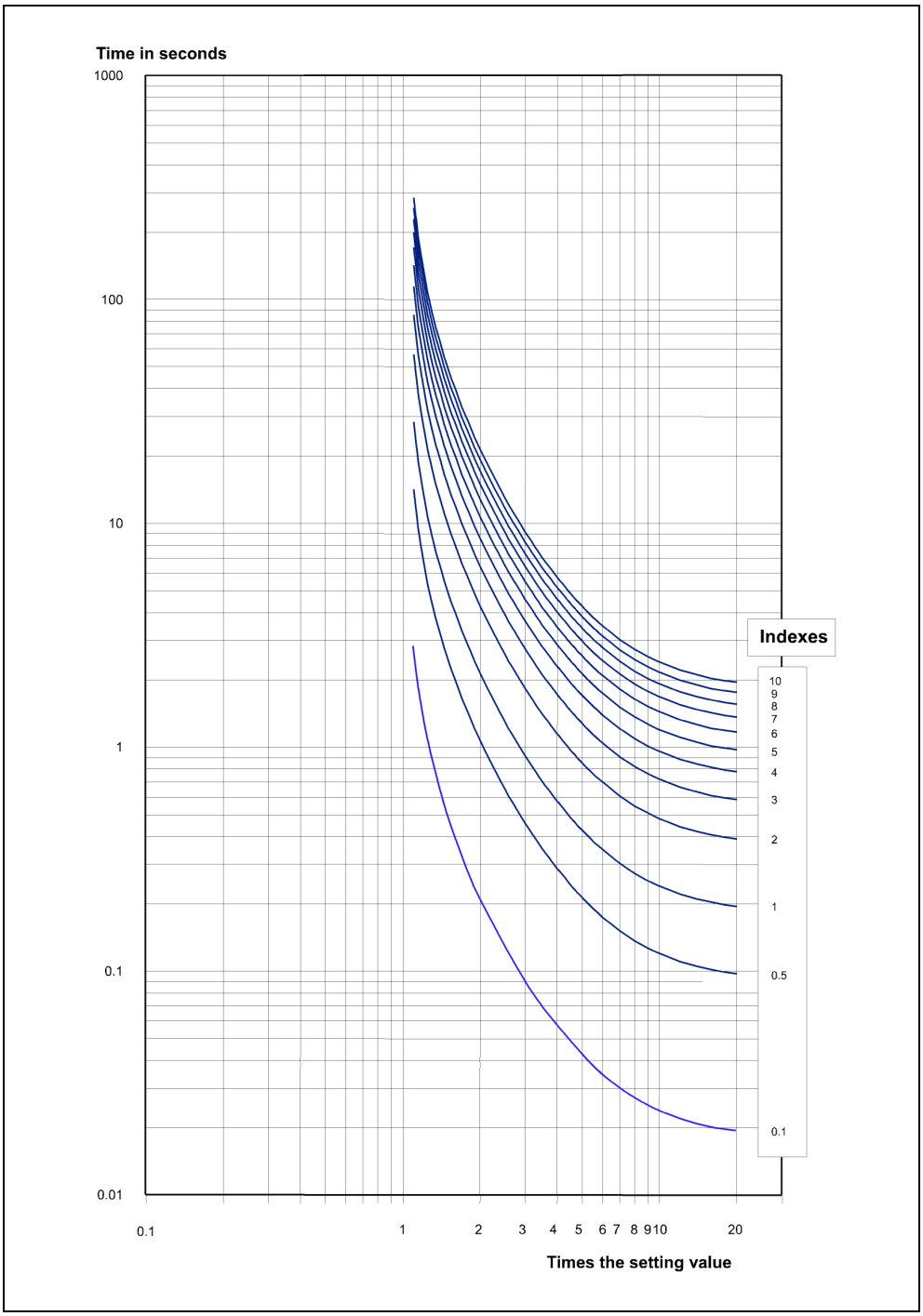


Figure 4.1.13 INVERSE Time Curve (U.S.).

$t = \left(0.180 + \frac{5.95}{I_S^2 - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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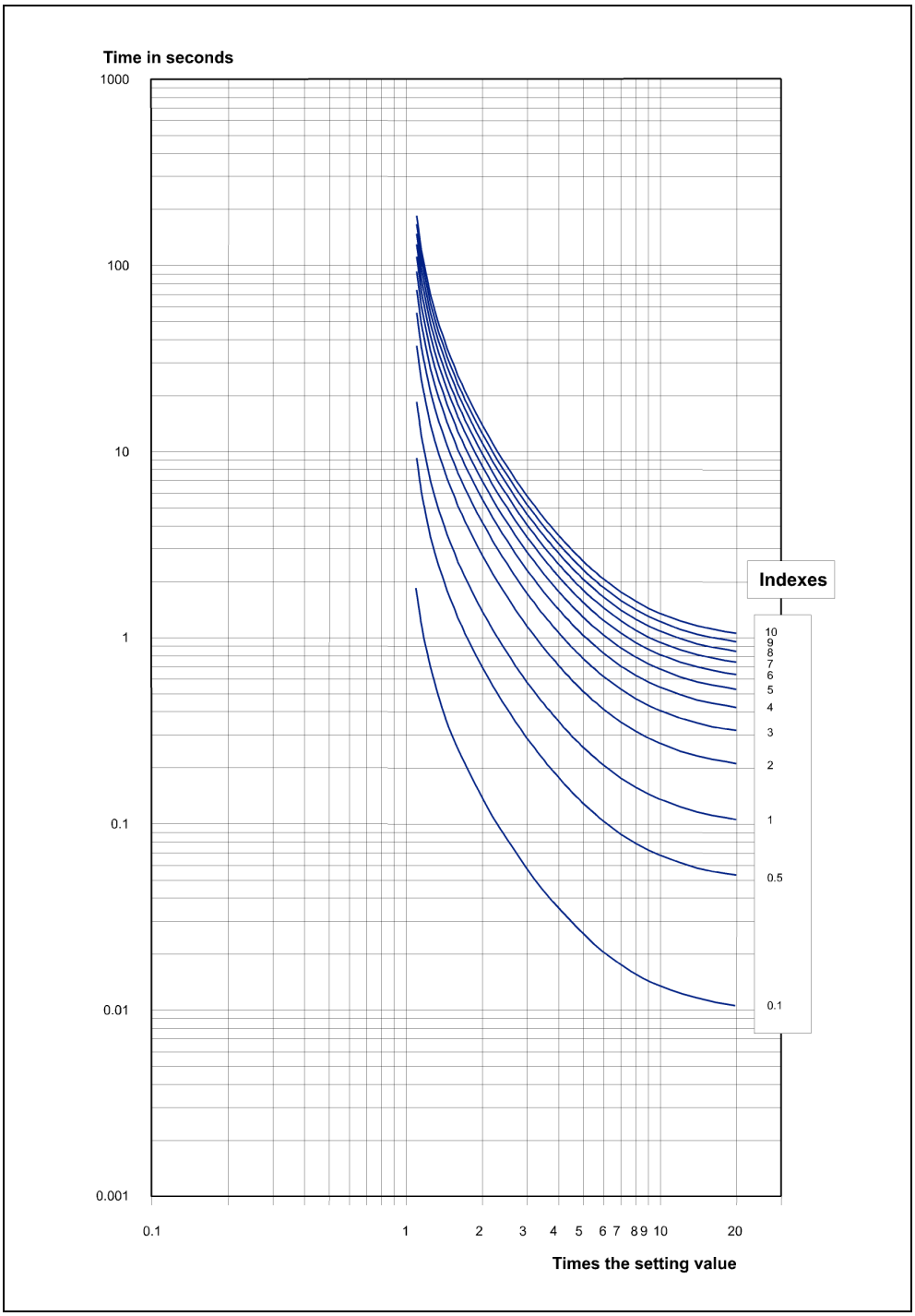


Figure 4.1.14 VERY INVERSE Time Curve (U.S.).

$t = \left(0.0963 + \frac{3.88}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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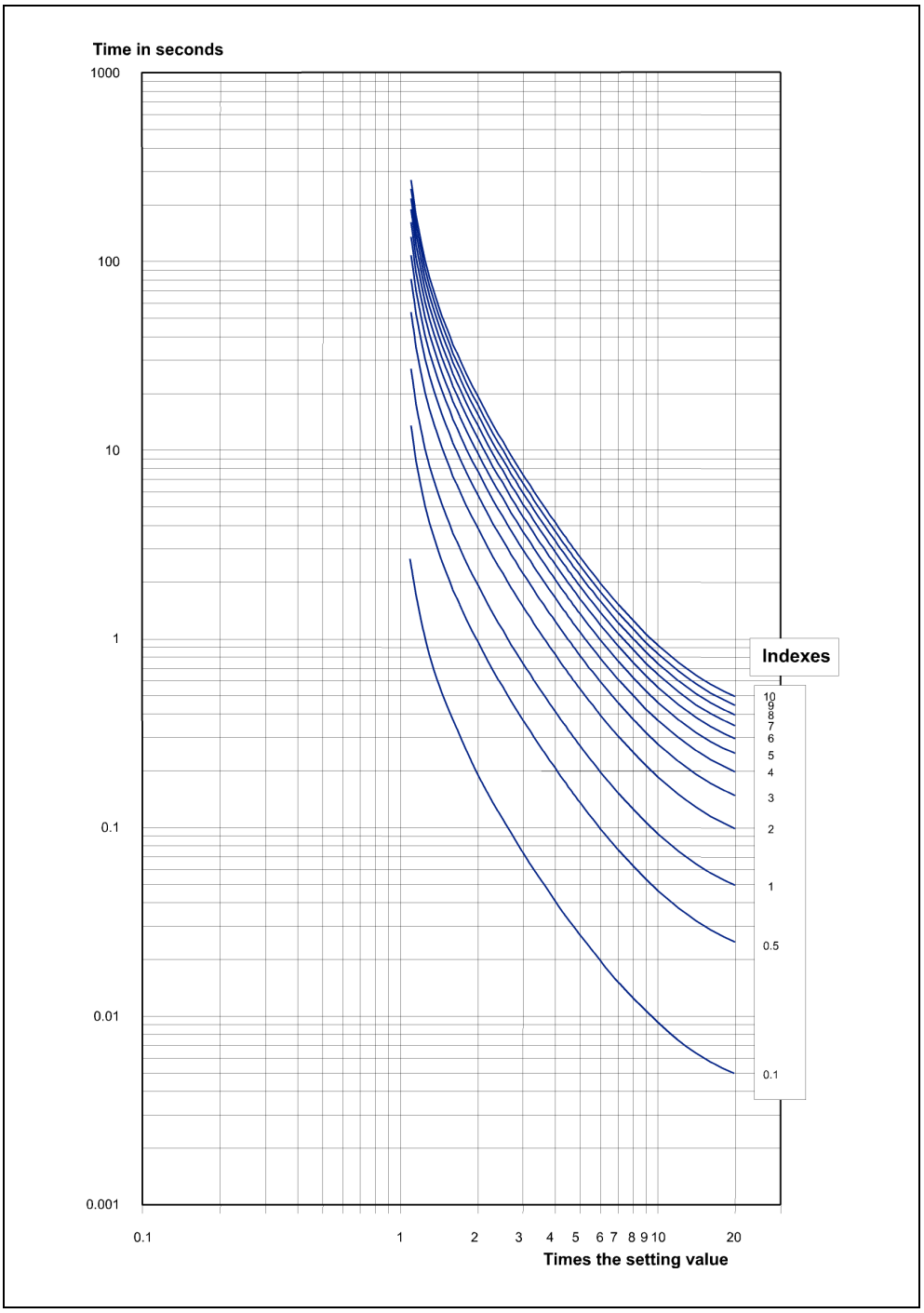


Figure 4.1.15 EXTREMELY INVERSE Time Curve (U.S.).

$t = \left(0.0352 + \frac{5.67}{I_S^2 - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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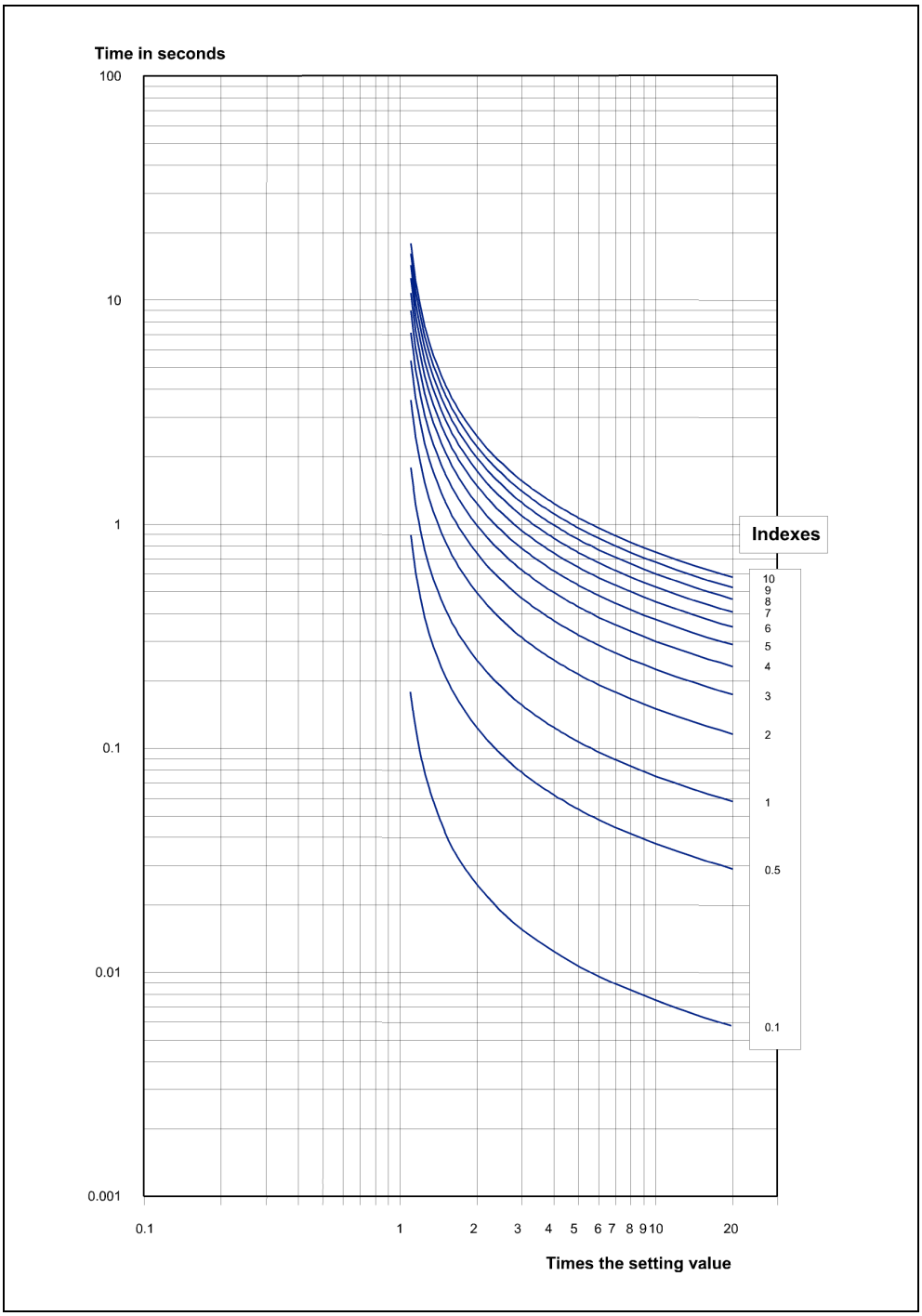


Figure 4.1.16 SHORT INVERSE Time Curve (U.S.).

$t = \left(0.00262 + \frac{0.00342}{I_S^{0.02} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

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And figure 4.1.17 presents the **RI Inverse** curve.

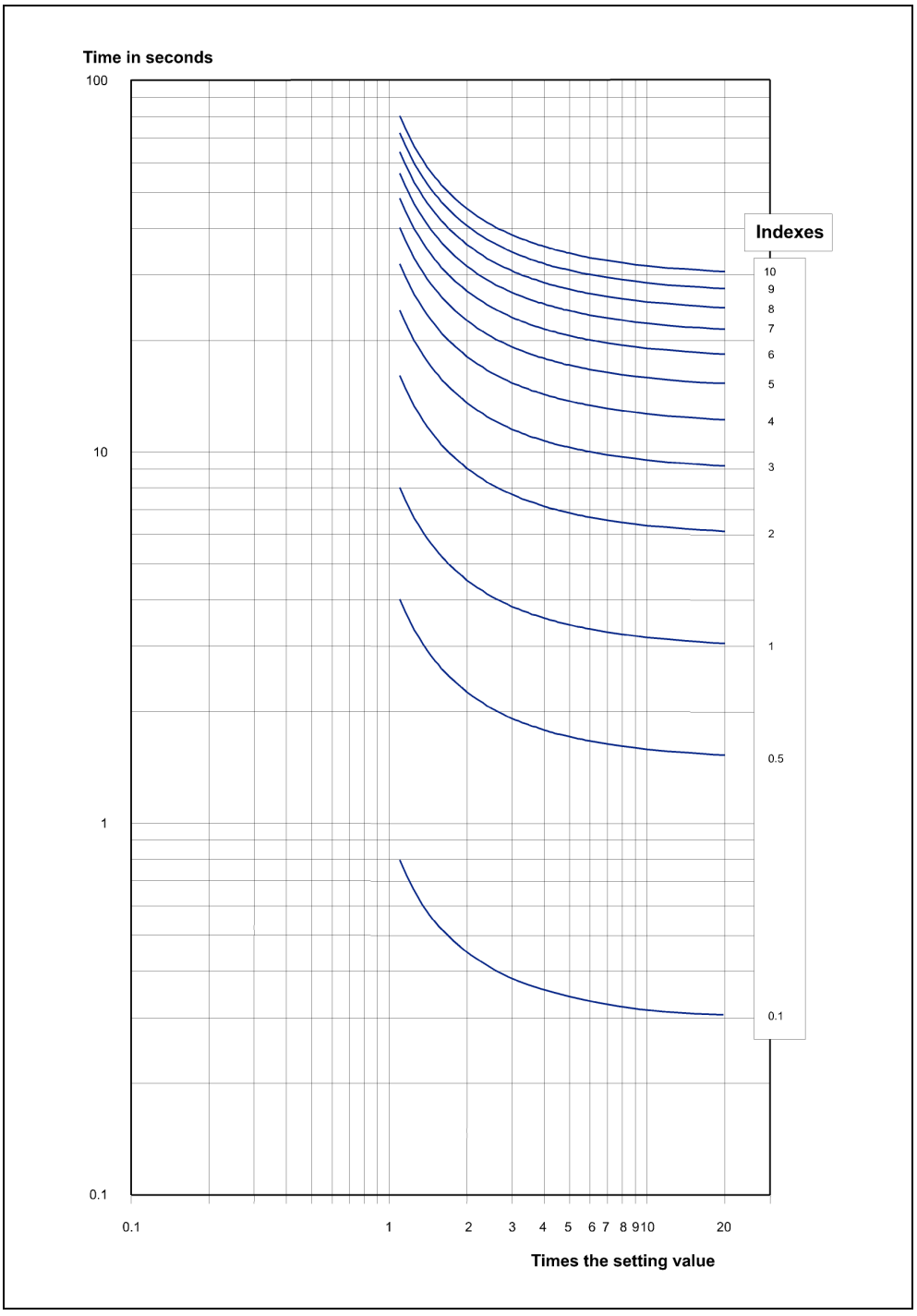


Figure 4.1.17 RI INVERSE Time Curve.

$$t = \frac{1}{0.339 - 0.236 \cdot \left(\frac{1}{I_S}\right)} \text{ x Index}$$

$$I_S = \frac{I_{measured}}{I_{pickup}}$$

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- **Recloser Curves**

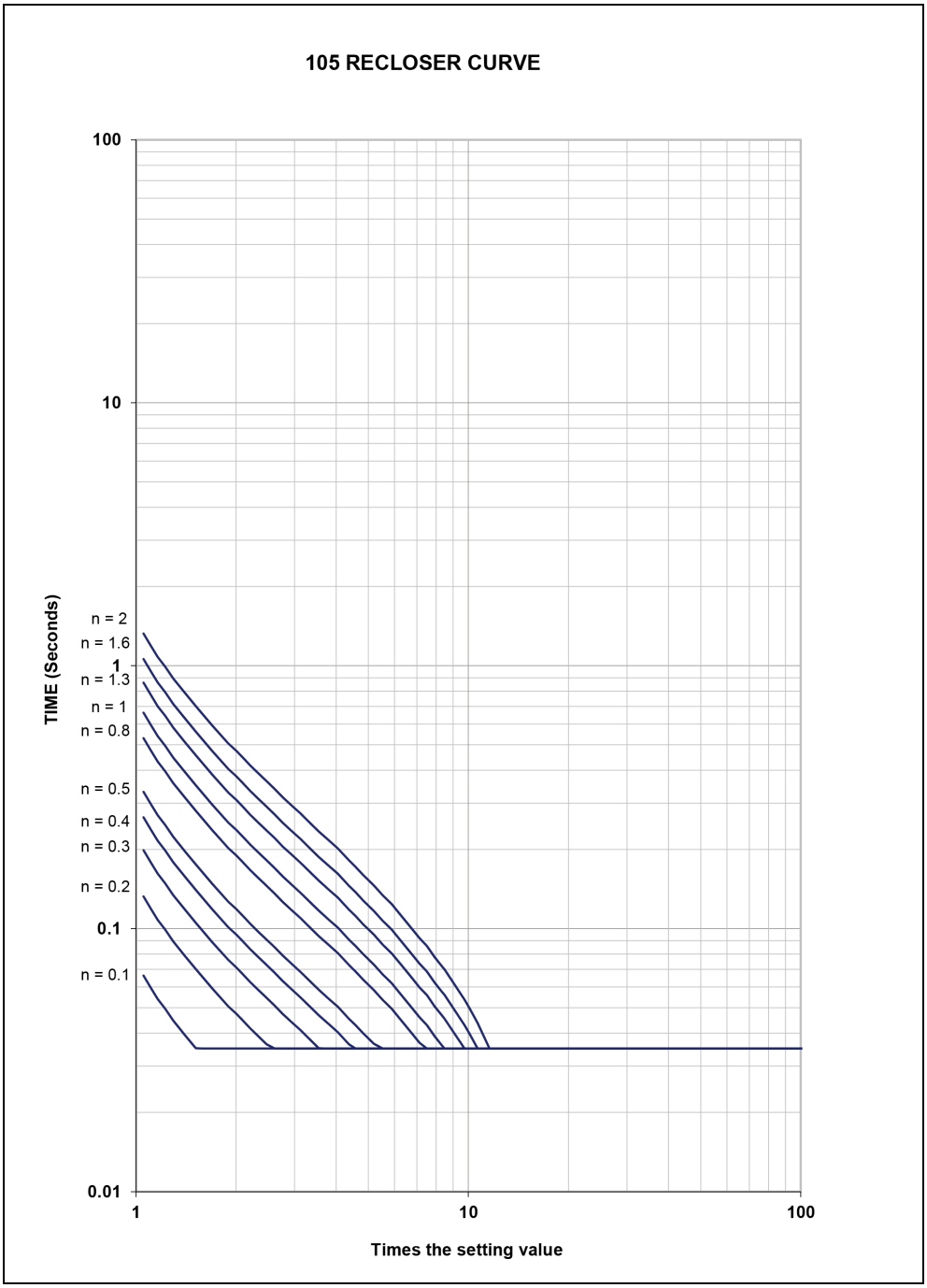


Figure 4.1.18 105 Recloser Curve.

$$t = \left(\frac{0.001015}{M^{0.00227} - 0.998848} - 0.133810 \right) \text{ x Index}$$

It being M times the element pickup setting value (multiple of the pickup).

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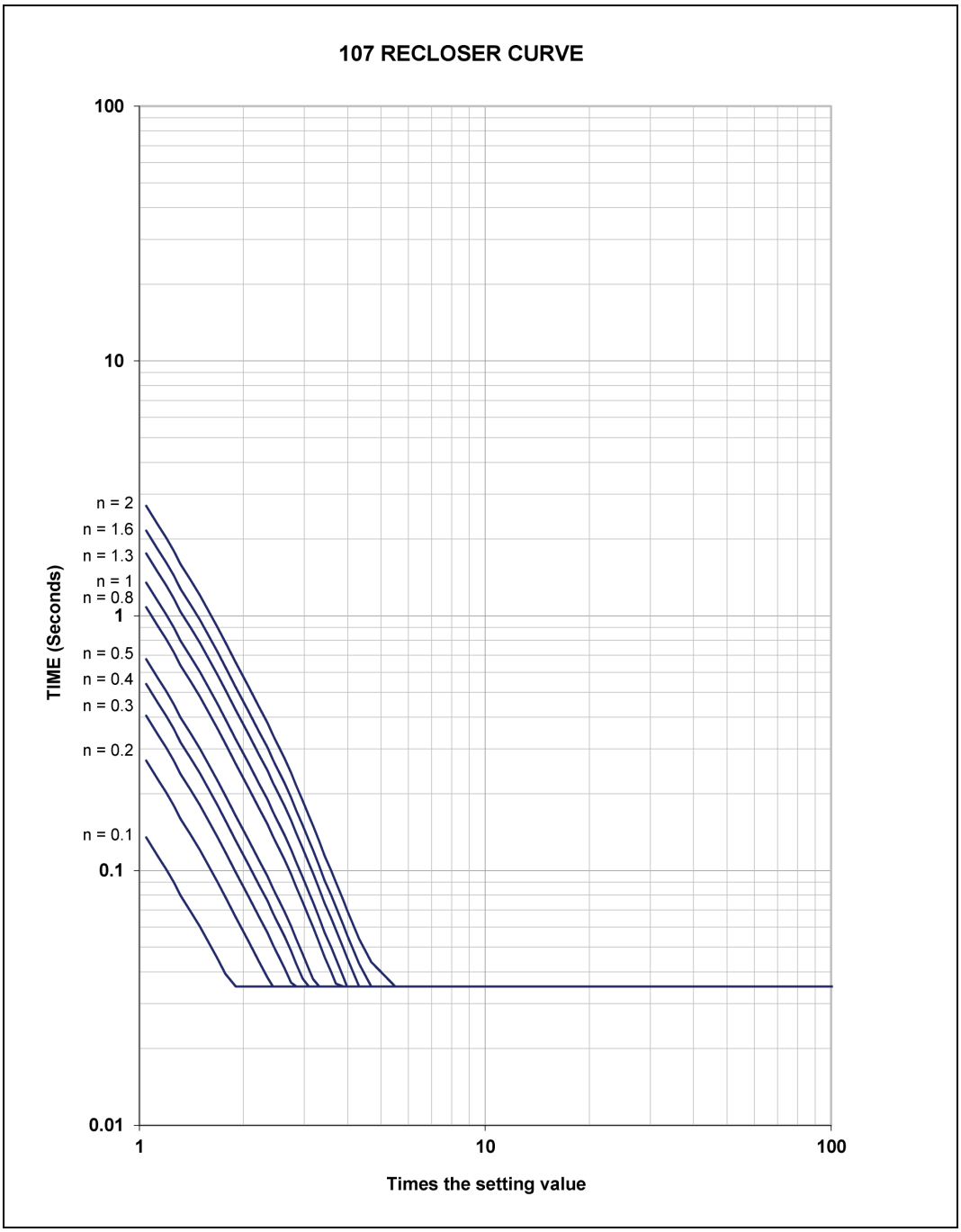


Figure 4.1.19 107 Recloser Curve.

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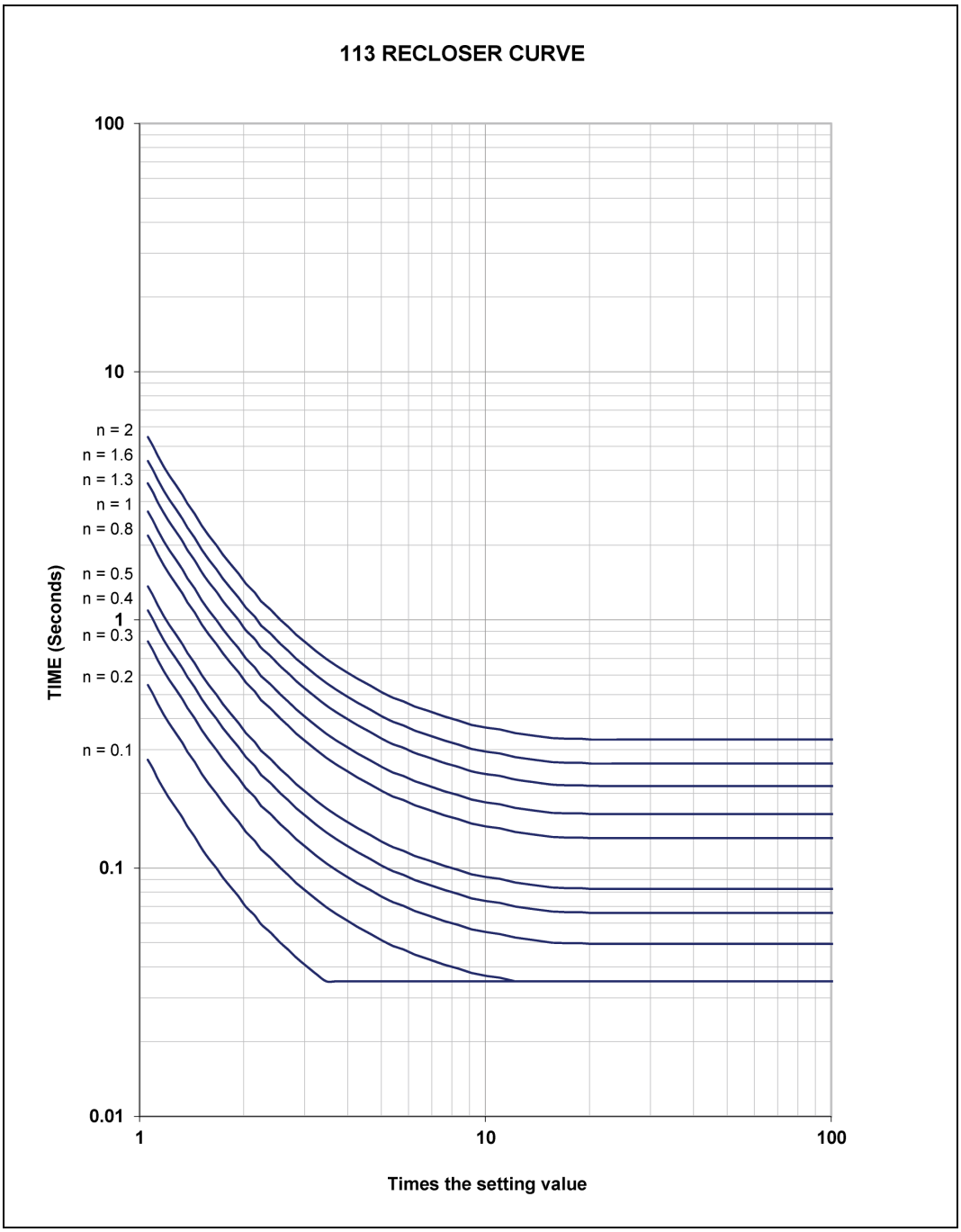


Figure 4.1.20 113 Recloser Curve.

$$t = \left(\frac{1.68546}{M^{1.78873} - 0.436523} + 0.158114 \right) \text{ x Index}$$

It being M times the element pickup setting value (multiple of the pickup).

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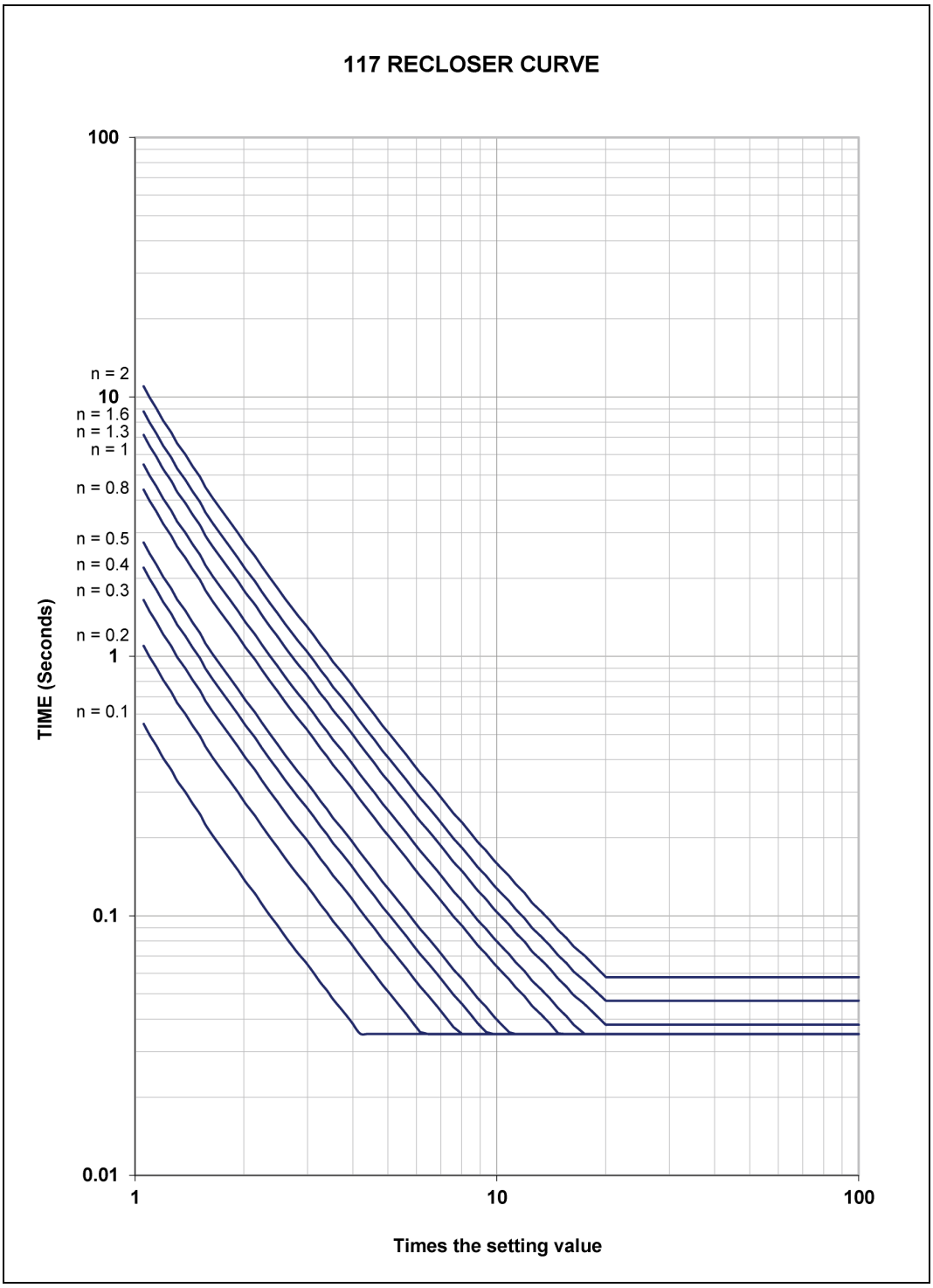


Figure 4.1.21 117 Recloser Curve.

$$t = \left(\frac{4.22886}{M^{1.78220} - 0.319885} + 0.008933 \right) \text{ x Index}$$

It being M times the element pickup setting value (multiple of the pickup).

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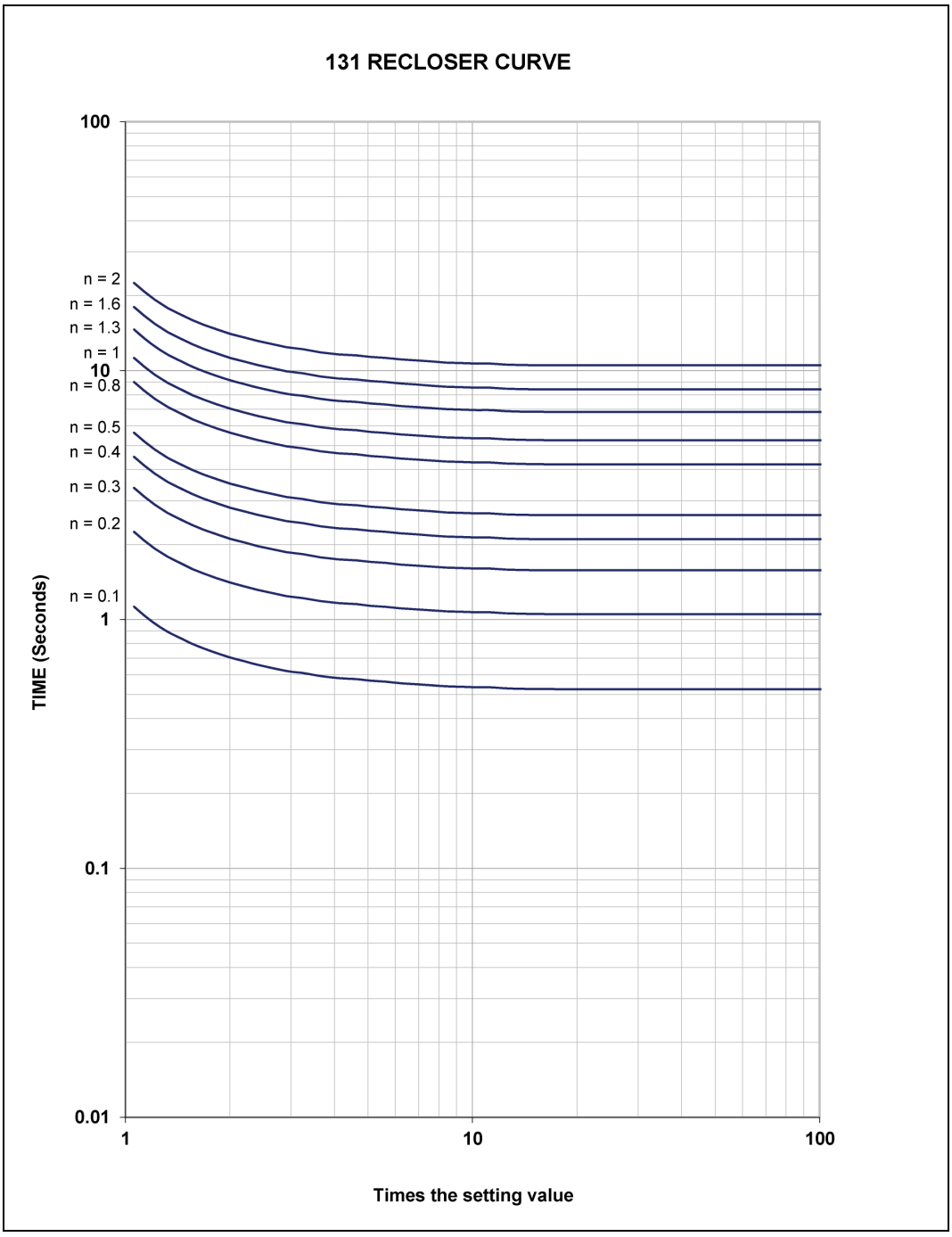


Figure 4.1.22 131 Recloser Curve.

$$t = \left(\frac{2.75978}{M^{1.03530} - 0.615248} + 5.10647 \right) \text{ x Index}$$

It being M times the element pickup setting value (multiple of the pickup).

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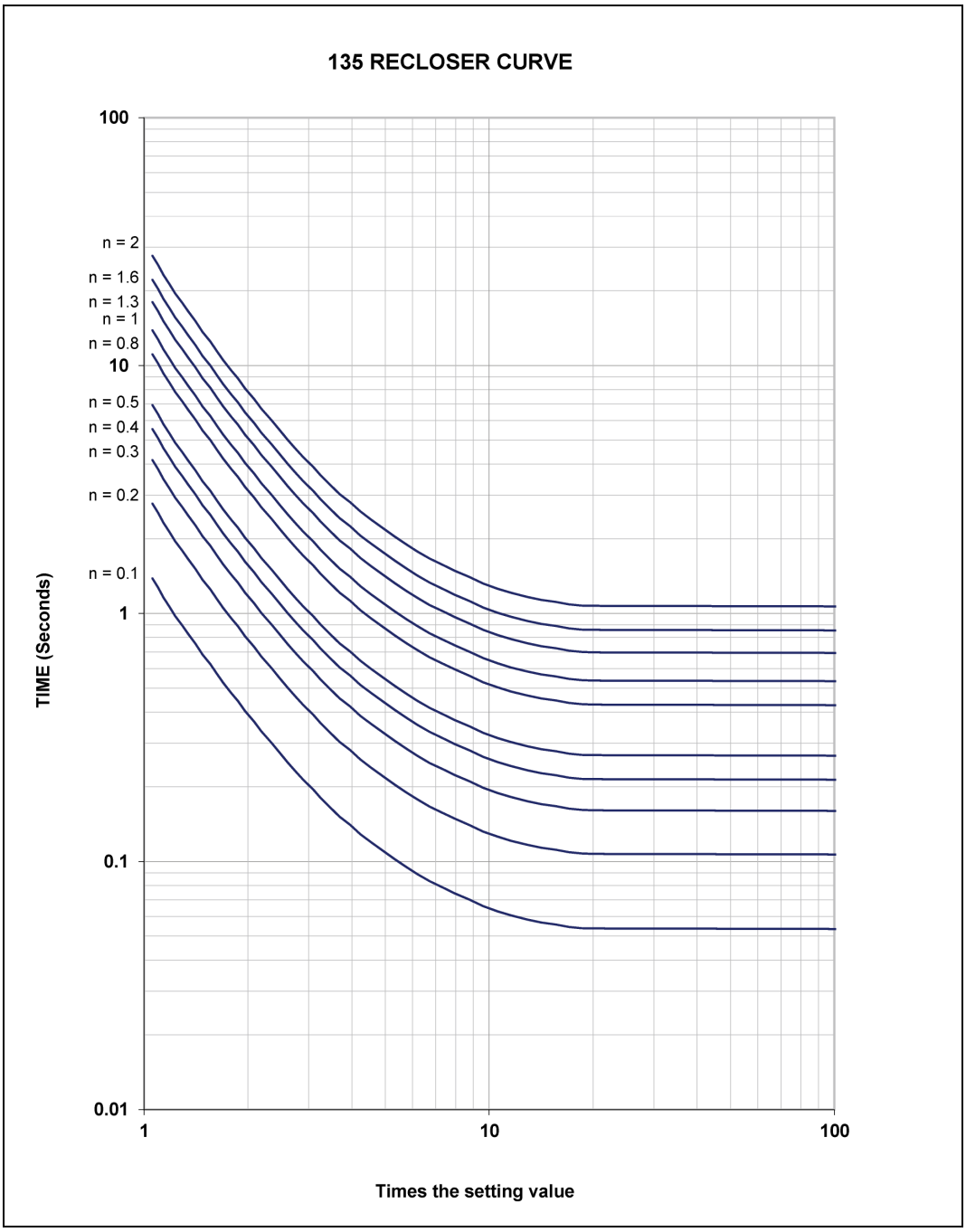


Figure 4.1.23 135 Recloser Curve.

$$t = \left[\left(\frac{11.4161}{M^{1.84911} - 0.239257} \right) + 0.488986 \right] \text{ x Index}$$

It being M times the element pickup setting value (multiple of the pickup).

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4.1.1.g Torque Control (Pickup Blocking Enable)

Torque Control setting, or ***Pickup Blocking Enable***, is associated to Directional Element, enabling or disabling the directional control (see paragraph 3.2).

Directional or non-directional control of the different phase, ground, sensitive ground and negative sequence instantaneous or time overcurrent elements can be selected through this setting, which is incorporated into the element protection group. Possible setting values are:

1. Directional control disabled.
2. Forward Direction monitoring enabled.
3. Reverse direction monitoring enabled.

Elements with ***Torque Control*** setting or ***Pickup Blocking Enable*** set to **NO** turns into non-directional.

On the other hand, Phase, Neutral and Ground Overcurrent elements are provided with ***Torque Control Type***. This allows selecting the supervising directional element. Possible values for each type of overcurrent elements are as follows:

- **Phase Overcurrent** (instantaneous and time overcurrent).
  67F (Phase Directional Element).
  67P (Positive Sequence Directional Element). Said option has been designed for series compensated lines. Positive sequence directional element polarization (positive sequence voltage memory) allows generating correct directional decisions on voltage reversal.
  67PQ (Negative Sequence Directional Element during non three-phase faults and positive sequence directional element in three-phase faults). The benefit of this option vs. the **67P** option is that for non three-phase faults, the directional element operates correctly even with no voltage memory (close-on-to-fault conditions) or when, even with adequate prefault voltage, current reversals are generated. This last situation will be given, for a forward fault, with the VT on capacitor bank busbar side, when line capacitive reactance is higher than the inductive reactance of the local source. In that case, the use of voltage memory does not solve the directionality problem, as the faulted circuit impedance, measured from the local source will be capacitive. With the VT on capacitor bank busbar side, the negative sequence directional element will operate correctly even with the ***Negative Sequence Voltage Compensation Factor*** set to zero (see paragraph 2.2.6.a).
- **Neutral and Ground Overcurrent** (instantaneous and time overcurrent).
  67N (Neutral Directional Overcurrent).
  67G (Ground Directional Element).
  67Q (Negative Sequence Directional Element). Option **67Q** may be interesting compared with option **67N** or **67G** when very low V0 levels are expected, lower than the minimum threshold to polarize the ground directional element. This condition may be present in systems with very high zero sequence sources (low local source zero sequence impedance).
- **Negative Sequence Overcurrent** (instantaneous and time-overcurrent). They are not provided with this setting as they are only monitored by Negative Sequence Directional element (**67Q**).

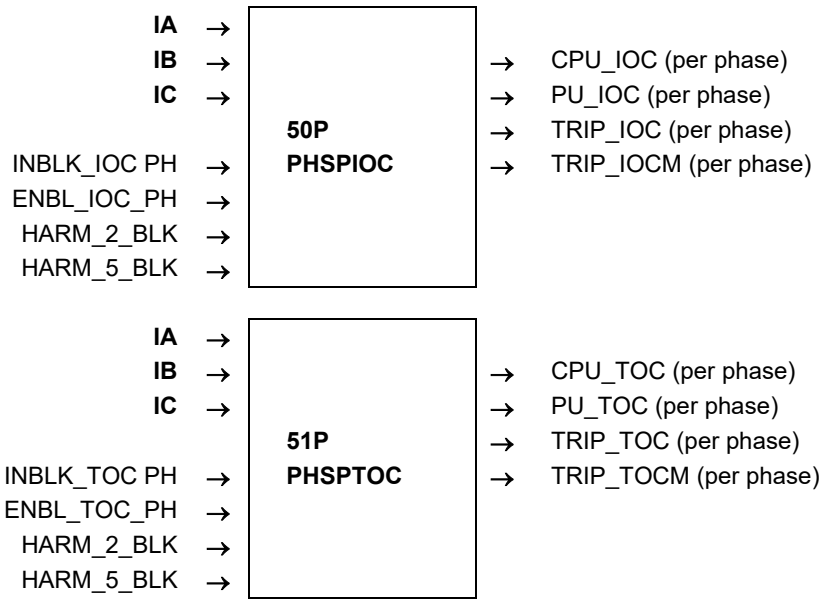
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4.1.2 Phase Overcurrent Elements

4.1.2.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Instantaneous Phase Overcurrent Element 1	PHSPIOC1	3I>>	50P1
Instantaneous Phase Overcurrent Element 2	PHSPIOC2	3I>>	50P2
Instantaneous Phase Overcurrent Element 3	PHSPIOC3	3I>>	50P3
Time-Delayed Phase Overcurrent Element 1	PHSPTOC1	3I>	51P1
Time-Delayed Phase Overcurrent Element 2	PHSPTOC2	3I>	51P2
Time-Delayed Phase Overcurrent Element 3	PHSPTOC3	3I>	51P3

4.1.2.b General Block



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4.1.2.c Operation Principles and Block Diagram

The phase element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The current value of any phase exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section.

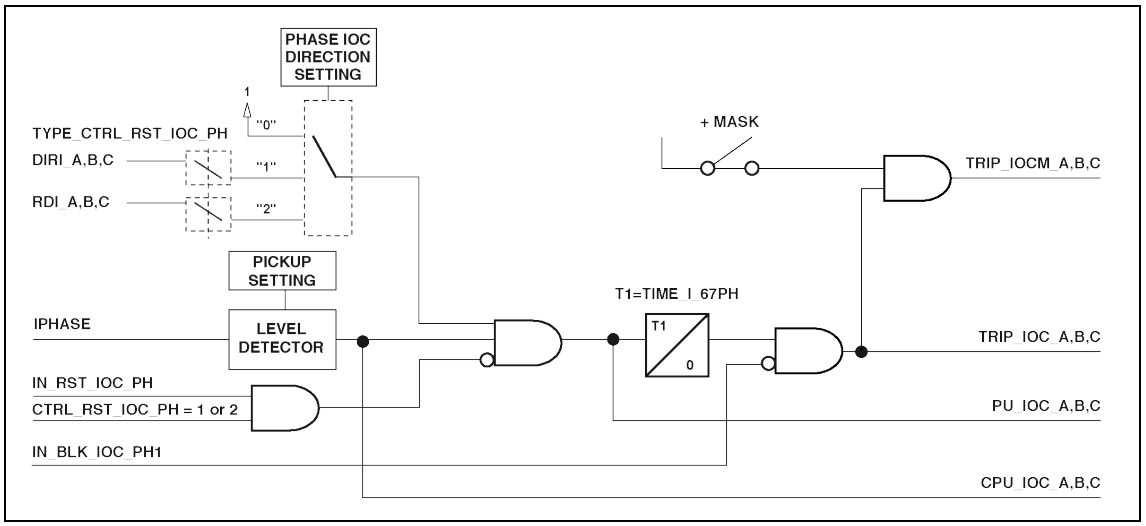


Figure 4.1.24 Block Diagram of a Phase Instantaneous Overcurrent Element.

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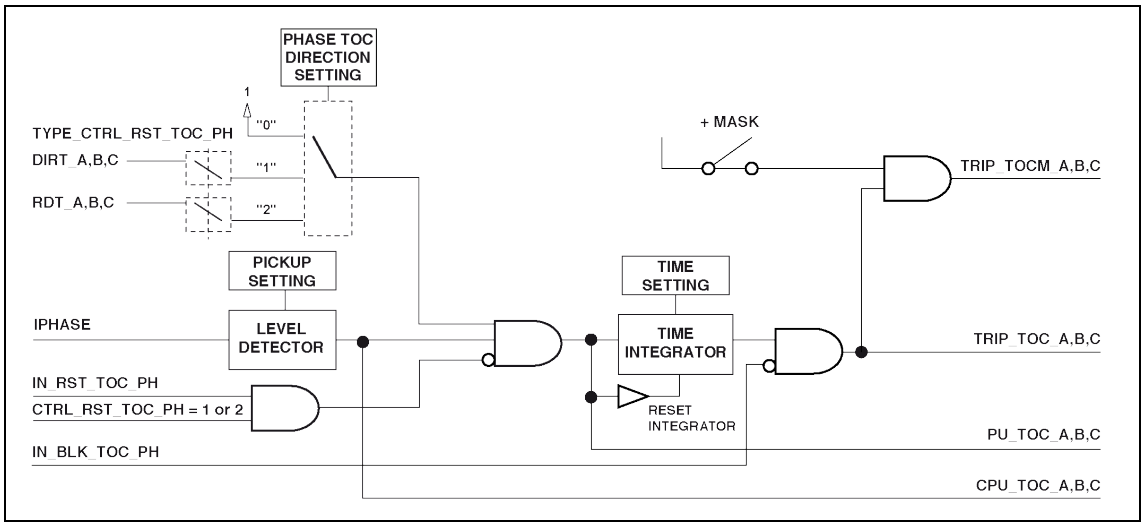


Figure 4.1.25 Block Diagram of a Phase Time-Delayed Overcurrent Element.

4.1.2.d Application

The phase overcurrent element is in charge of detecting fault currents flowing between two or more phases in three phase power systems. The fault current can flow between the conductors or between the conductors and ground, therefore, phase to phase, phase to ground and three phase faults can be detected, phase to phase faults being typically more severe.

An example of a fault detected by the phase overcurrent element could be the contact between two or more conductors due to a branch falling on a line.

The time set overcurrent element is of common use as backup for transformer differential and distance protections, although it is also used as main element in medium voltage lines and specific applications to detect close onto fault or in ring systems, among many others.

In parallel transformers and busbar coupling systems, the instantaneous overcurrent elements will be applied first with directionality in order to prevent the opening leaving the busbar without power supply upon faults in one of the transformers, the use of non directional elements with higher time delay being possible as backup.

In ring systems, as for airports or underground secondary substations, the current can flow in any direction so that directional elements are used to detect faults between bays.

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4.1.2.e Example of Settings Calculation

For pickup current and trip time setting calculation of the instantaneous overcurrent element, the standard short circuit calculation principles should be taken into account. The example below shows a typical calculation.

Starting values:

- CT: 1500/5.
- Load current: 1470 A.
- Lowest protection downstream: 400 A.

Relay settings must take into account both the load current and the reset current, such that it operates only upon real faults. As the element picks up at 1.05 times the pickup setting, this being exactly the minimum fault current value, the element will be set directly with this value, referred to the secondary, as both the protection element and the settings are referred to the secondary. Therefore, the pickup setting value must a minimum of 4.9 A.

When the relay is to be coordinated with other protections, their trip times must match as much as possible, setting a proper definite time for each case.

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4.1.2.f Setting Ranges

Protection / Overcurrent / Instantaneous / Phase Instantaneous (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase IOC Enable	Phase IOC Enable	PHSPIOC.LNInSvc	YES / NO		NO
Phase IOC Pickup	Phase IOC Pickup	PHSPIOC.StrVal	(0.01-30) In	0.01 A	5.00 A
Phase IOC Delay	Phase IOC Delay	PHSPIOC.OpDlTmms	0-300 s	0.01 s	0 s
Phase IOC Direction	PhaseIOC Direction	PHSPIOC.DirMod	None Direction Reverse		None
Phase IOC Direct Unit	Phase IOC Dir Unt	PHSPIOC.DirUnit	67F 67P-67Q 67P		67F
Phase IOC Harm Blocking	Ph IOC Harm Blk	PHSPIOC.HBlkEna	YES / NO		NO

Protection / Overcurrent / Time Overcurrent / Phase Time Overcurrent (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase TOC Enable	Phase TOC Enable	PHSPTOC.LNInSvc	YES / NO		NO
Phase TOC Pickup	Phase TOC Pickup	PHSPTOC.StrVal	(0.01-30) In	0.01 A	5.00 A
Phase TOC Curve	Phase TOC Curve	PHSPTOC.TmACrv	See list of curves		Fixed Time
Phase TOC Dial	Phase TOC Dial	PHSPTOC.TmMult	0.05-10 (inv)	0.01	1
			0.05-1 (IEC)	0.01	1
			0.1-10 (IEEE/US/RI)	0.01	1
Phase TOC Definite Time	Phase TOC Delay	PHSPTOC.OpDlTmms	0.05-300 s	0.01 s	0.05 s
Phase TOC Direction	Ph TOC Direction	PHSPTOC.DirMod	None Direction Reverse		None
Phase TOC Direct Unit	Phase TOC Dir Unt	PHSPTOC.DirUnit	67F 67P-67Q 67P		67F
Reset Type	Reset Type	PHSPTOC.TypRs	Instantaneous. Induction Disk Emulation.		Instant.
Phase TOC Harm Blocking	Ph TOC Harm Blk	PHSPTOC.HBlkEna	YES / NO		NO

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4.1.2.g Analog Inputs to the Unit

The operating magnitude of phase overcurrent elements will be the fundamental current IA, IB and IC. However, the relay will take into account the presence of harmonics when harmonic blocking is enabled, the relay being blocked when harmonic percentage exceeds the setting value. When the Saturation Detector is activated, the relay will also work with instantaneous currents, as explained in detail in **Common Principles** section.

Table 4.1-1: Analog Inputs of the Overcurrent Modules

Name	Description	IEC 61850
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC

4.1.2.h Digital Inputs to the Phase Overcurrent Unit

Table 4.1-2: Digital Inputs to the Phase Overcurrent Modules

Name	Group	IEC 61850	Description	Vis.	Function
IN_BLK_IOC_PH1	Logic Inputs to Protection	PHSPIOC1.Mod	Block Phase Instantaneous Unit 1	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_IOC_PH2		PHSPIOC2.Mod	Block Phase Instantaneous Unit 2	I	
IN_BLK_IOC_PH3		PHSPIOC3.Mod	Block Phase Instantaneous Unit 3	I	
IN_BLK_TOC_PH1		PHSPTOC1.Mod	Block Phase Time Overcurrent Unit 1	I	
IN_BLK_TOC_PH2		PHSPTOC2.Mod	Block Phase Time Overcurrent Unit 2	I	
IN_BLK_TOC_PH3		PHSPTOC3.Mod	Block Phase Time Overcurrent Unit 3	I	
IN_RST_IOC_PH1		PHSPIOC1.DirInh	Disable Torque Control Phase Instantaneous Unit 1	I	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_IOC_PH2		PHSPIOC2.DirInh	Disable Torque Control Phase Instantaneous Unit 2	I	
IN_RST_IOC_PH3		PHSPIOC3.DirInh	Disable Torque Control Phase Instantaneous Unit 3	I	
IN_RST_TOC_PH1		PHSPTOC1.DirInh	Disable Torque Control Time Overcurrent Unit 1	I	
IN_RST_TOC_PH2		PHSPTOC2.DirInh	Disable Torque Control Time Overcurrent Unit 2	I	
IN_RST_TOC_PH3		PHSPTOC3.DirInh	Disable Torque Control Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-2: Digital Inputs to the Phase Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_IOC_PH1	Enabling Commands	PHSPIOC1.Mod	Enable Phase Instantaneous Unit 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ENBL_IOC_PH2		PHSPIOC2.Mod	Enable Phase Instantaneous Unit 2	I	
ENBL_IOC_PH3		PHSPIOC3.Mod	Enable Phase Instantaneous Unit 3	I	
ENBL_TOC_PH1		PHSPTOC1.Mod	Enable Phase Time Overcurrent Unit 1	I	
ENBL_TOC_PH2		PHSPTOC2.Mod	Enable Phase Time Overcurrent Unit 2	I	
ENBL_TOC_PH3		PHSPTOC3.Mod	Enable Phase Time Overcurrent Unit 3	I	
IN_BPT_PH1	Logic Inputs to Protection	PHSPTOC1.OpDIInh	Phase Time Overcurrent Unit 1 Time Disable	I	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_PH2		PHSPTOC2.OpDIInh	Phase Time Overcurrent Unit 2 Time Disable	I	
IN_BPT_PH3		PHSPTOC3.OpDIInh	Phase Time Overcurrent Unit 3 Time Disable	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.2.i Auxiliary Outputs and Events of the Phase Overcurrent Modules

Table 4.1-3: Auxiliary Outputs and Events of the Phase Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IOC_A1	Pickup Protection Outputs	PHSPIOC1.Str	Phase A Instantaneous Unit 1 Pick Up	I,F	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_B1		PHSPIOC1.Str	Phase B Instantaneous Unit 1 Pick Up	I,F	
PU_IOC_C1		PHSPIOC1.Str	Phase C Instantaneous Unit 1 Pick Up	I,F	
PU_IOC_A2		PHSPIOC2.Str	Phase A Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_B2		PHSPIOC2.Str	Phase B Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_C2		PHSPIOC2.Str	Phase C Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_A3		PHSPIOC3.Str	Phase A Instantaneous Unit 3 Pick Up	I,F	
PU_IOC_B3		PHSPIOC3.Str	Phase B Instantaneous Unit 3 Pick Up	I,F	
PU_IOC_C3		PHSPIOC3.Str	Phase C Instantaneous Unit 3 Pick Up	I,F	
PU_TOC_A1		PHSPTOC1.Str	Phase A Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_B1		PHSPTOC1.Str	Phase B Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_C1		PHSPTOC1.Str	Phase C Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_A2		PHSPTOC2.Str	Phase A Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_B2		PHSPTOC2.Str	Phase B Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_C2		PHSPTOC2.Str	Phase C Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_A3		PHSPTOC3.Str	Phase A Time Overcurrent Unit 3 Pick Up	I,F	
PU_TOC_B3		PHSPTOC3.Str	Phase B Time Overcurrent Unit 3 Pick Up	I,F	
PU_TOC_C3		PHSPTOC3.Str	Phase C Time Overcurrent Unit 3 Pick Up	I,F	
PU_IOC		PTRC1.Str	Instantaneous Pick Up (does not generate an event)		Pickup of the grouped current elements (50, 50N, 50G, 50Q, 50GS)
PU_TOC		PTRC1.Str	Time Overc Pick Up (does not generate an event)		Pickup of the grouped current elements (51, 51N, 51G, 51Q, 51GS)

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-3: Auxiliary Outputs and Events of the Phase Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
CPU_IOC_A1	Pickup Protection Outputs	PHSPIOC1.Str	Phase A Instantaneous Unit 1 Pick Up Condition	I	Pickup of the current elements, unaffected by the torque control.
CPU_IOC_B1		PHSPIOC1.Str	Phase B Instantaneous Unit 1 Pick Up Condition	I	
CPU_IOC_C1		PHSPIOC1.Str	Phase C Instantaneous Unit 1 Pick Up Condition	I	
CPU_IOC_A2		PHSPIOC2.Str	Phase A Instantaneous Unit 2 Pick Up Condition	I	
CPU_IOC_B2		PHSPIOC2.Str	Phase B Instantaneous Unit 2 Pick Up Condition	I	
CPU_IOC_C2		PHSPIOC2.Str	Phase C Instantaneous Unit 2 Pick Up Condition	I	
CPU_IOC_A3		PHSPIOC3.Str	Phase A Instantaneous Unit 3 Pick Up Condition	I	
CPU_IOC_B3		PHSPIOC3.Str	Phase B Instantaneous Unit 3 Pick Up Condition	I	
CPU_IOC_C3		PHSPIOC3.Str	Phase C Instantaneous Unit 3 Pick Up Condition	I	
CPU_TOC_A1		PHSPTOC1.Str	Phase A Time Overcurrent Unit 1 Pick Up Condition	I	
CPU_TOC_B1		PHSPTOC1.Str	Phase B Time Overcurrent Unit 1 Pick Up Condition	I	
CPU_TOC_C1		PHSPTOC1.Str	Phase C Time Overcurrent Unit 1 Pick Up Condition	I	
CPU_TOC_A2		PHSPTOC2.Str	Phase A Time Overcurrent Unit 2 Pick Up Condition	I	
CPU_TOC_B2		PHSPTOC2.Str	Phase B Time Overcurrent Unit 2 Pick Up Condition	I	
CPU_TOC_C2		PHSPTOC2.Str	Phase C Time Overcurrent Unit 2 Pick Up Condition	I	
CPU_TOC_A3		PHSPTOC3.Str	Phase A Time Overcurrent Unit 3 Pick Up Condition	I	
CPU_TOC_B3		PHSPTOC3.Str	Phase B Time Overcurrent Unit 3 Pick Up Condition	I	
CPU_TOC_C3		PHSPTOC3.Str	Phase C Time Overcurrent Unit 3 Pick Up Condition	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-3: Auxiliary Outputs and Events of the Phase Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_IOC_A1	Trip Protection Outputs	PHSPIOC1.Op	Phase A Instantaneous Unit 1 Trip	I,F	Trip of the current elements.
TRIP_IOC_B1		PHSPIOC1.Op	Phase B Instantaneous Unit 1 Trip	I,F	
TRIP_IOC_C1		PHSPIOC1.Op	Phase C Instantaneous Unit 1 Trip	I,F	
TRIP_IOC_A2		PHSPIOC2.Op	Phase A Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_B2		PHSPIOC2.Op	Phase B Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_C2		PHSPIOC2.Op	Phase C Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_A3		PHSPIOC3.Op	Phase A Instantaneous Unit 3 Trip	I,F	
TRIP_IOC_B3		PHSPIOC3.Op	Phase B Instantaneous Unit 3 Trip	I,F	
TRIP_IOC_C3		PHSPIOC3.Op	Phase C Instantaneous Unit 3 Trip	I,F	
TRIP_TOC_A1		PHSPTOC1.Op	Phase A Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_B1		PHSPTOC1.Op	Phase B Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_C1		PHSPTOC1.Op	Phase C Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_A2		PHSPTOC2.Op	Phase A Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_B2		PHSPTOC2.Op	Phase B Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_C2		PHSPTOC2.Op	Phase C Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_A3		PHSPTOC3.Op	Phase A Time Overcurrent Unit 3 Trip	I,F	
TRIP_TOC_B3		PHSPTOC3.Op	Phase B Time Overcurrent Unit 3 Trip	I,F	
TRIP_TOC_C3		PHSPTOC3.Op	Phase C Time Overcurrent Unit 3 Trip	I,F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-3: Auxiliary Outputs and Events of the Phase Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_IOC_A1M	Masked Trips		Phase A Instantaneous Unit 1 Masked Trip		Trip of the current elements.
TRIP_IOC_B1M			Phase B Instantaneous Unit 1 Masked Trip		
TRIP_IOC_C1M			Phase C Instantaneous Unit 1 Masked Trip		
TRIP_IOC_A2M			Phase A Instantaneous Unit 2 Masked Trip		
TRIP_IOC_B2M			Phase B Instantaneous Unit 2 Masked Trip		
TRIP_IOC_C2M			Phase C Instantaneous Unit 2 Masked Trip		
TRIP_IOC_A3M			Phase A Instantaneous Unit 3 Masked Trip		
TRIP_IOC_B3M			Phase B Instantaneous Unit 3 Masked Trip		
TRIP_IOC_C3M			Phase C Instantaneous Unit 3 Masked Trip		
TRIP_TOC_A1M			Phase A Time Overcurrent Unit 1 Masked Trip		
TRIP_TOC_B1M			Phase B Time Overcurrent Unit 1 Masked Trip		
TRIP_TOC_C1M			Phase C Time Overcurrent Unit 1 Masked Trip		
TRIP_TOC_A2M			Phase A Time Overcurrent Unit 2 Masked Trip		
TRIP_TIOC_B2M			Phase B Time Overcurrent Unit 2 Masked Trip		
TRIP_TOC_C2M			Phase C Time Overcurrent Unit 2 Masked Trip		
TRIP_TOC_A3M			Phase A Time Overcurrent Unit 3 Masked Trip		
TRIP_TOC_B3M			Phase B Time Overcurrent Unit 3 Masked Trip		
TRIP_TOC_C3M			Phase C Time Overcurrent Unit 3 Masked Trip		
TRIP_IOC	Trip Protection Outputs	PTRC1.Op	Instantaneous trip (does not generate an event)		Trip of the grouped current elements. (50, 50N, 50G, 50Q).
TRIP_TOC		PTRC1.Op	Time Overc Trip (does not generate an event)		Trip of the grouped current elements. (51, 51N, 51G, 51Q).

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.2.j IEC 61850 Logical Nodes

CLASS IRLPHSPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

CLASS IRLPHSPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
TypRs	ING	Type of Reset Curve
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

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4.1.2.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time. This test should be carried out with the relay directionality disabled, not to depend on the voltages (***Pickup Blocking Enable*** or ***Torque Control*** set to **NO**). Otherwise, voltages must be injected, in order for the elements to be in the trip enable zone. In case of using a time element, the reset will be instantaneous.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end. It may also be verified by checking the trip flags in **Information** - **Status** - **Elements** menu or the events generated by the IED. Likewise, it may also be checked that the trip flag in said menu activates when element trips as well as the trip indication in the HMI.

Table 4.1-4: Pickup and Reset of the Overcurrent Instantaneous Elements				
Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

- **Operating Times**

For testing, at least one relay output must be configured with the trip signals of the element under test. The output configuration will be carried out with the ***ZIV e-NET tool***® changing the protection settings of the output to be used as shown in the Inputs, Outputs and LEDs Configuration section.

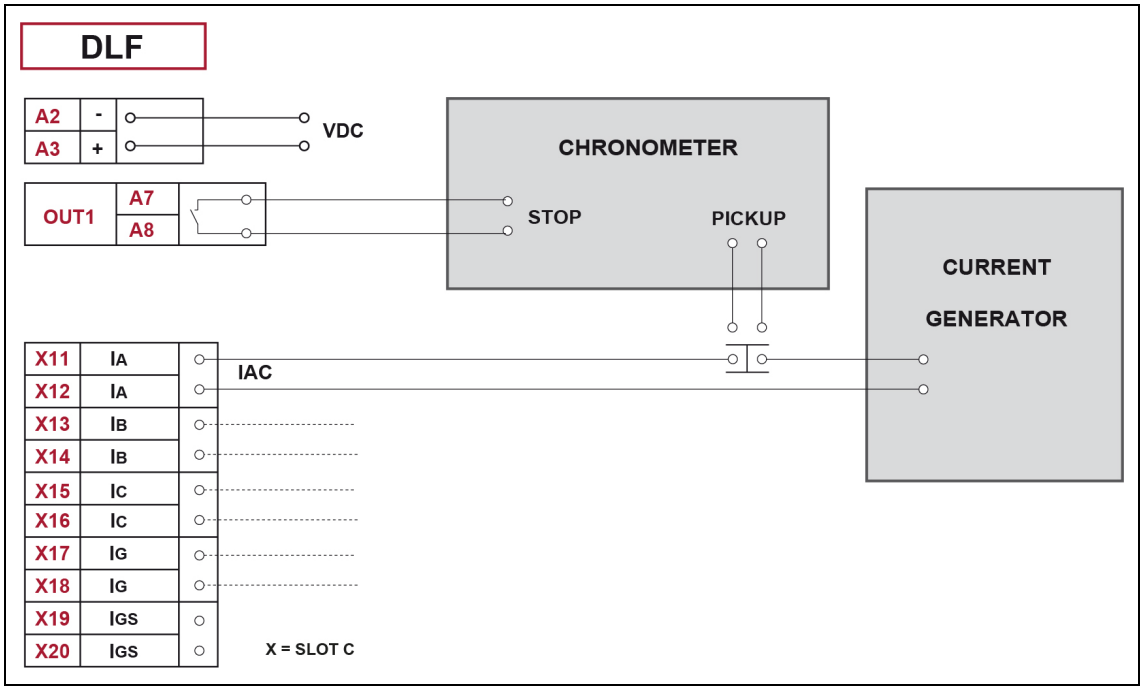


Figure 4.1.26 Operating Time Test Setup.

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- **Definite or Instantaneous Time**

A current equal to 1.5 times the selected pickup setting value will be applied. Operating time should be ±30ms (for 50Hz) or 25ms (for 60Hz) of the selected time delay setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 30 ms (for 50Hz) or between 15 and 25 ms (for 60Hz). The reset time will be equal to 1.5 cycles (30ms for 50Hz and 25ms for 60Hz) after stopping the injection.

- **Inverse Time**

For a given curve, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

Operating times can be checked for curves shown in paragraph 4.1.1.f according to IEC and IEEE/ANSI standards. RI Inverse Curve characteristic is added to these curves, mainly used in combination with electromechanical relays.

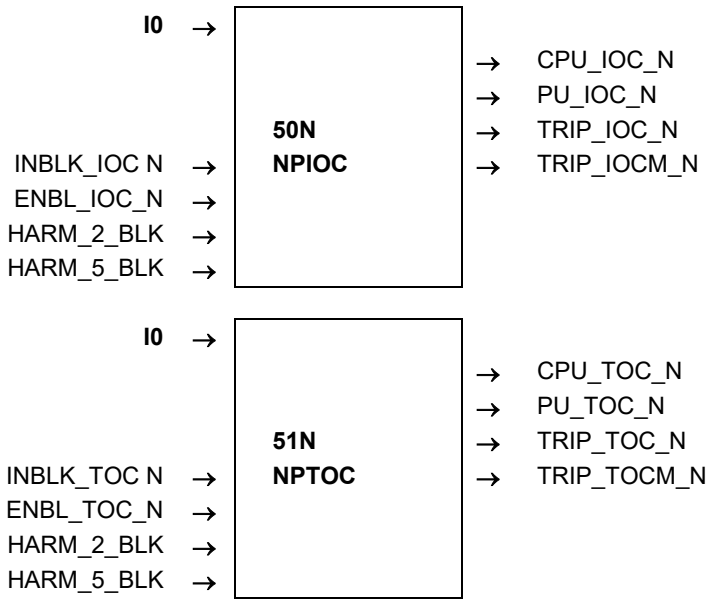
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4.1.3 Neutral Overcurrent Elements

4.1.3.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Neutral Instantaneous Overcurrent Unit 1	NPIOC1	3Io>>	50N1
Neutral Instantaneous Overcurrent Unit 2	NPIOC2	3Io>>	50N2
Neutral Instantaneous Overcurrent Unit 3	NPIOC3	3Io>>	50N3
Neutral Time-Delayed Overcurrent Unit 1	NPTOC1	3Io>	51N1
Neutral Time-Delayed Overcurrent Unit 2	NPTOC2	3Io>	51N2
Neutral Time-Delayed Overcurrent Unit 3	NPTOC3	3Io>	51N3

4.1.3.b General Block



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4.1.3.c Operation Principles and Block Diagram

The neutral element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The current value of neutral exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section.

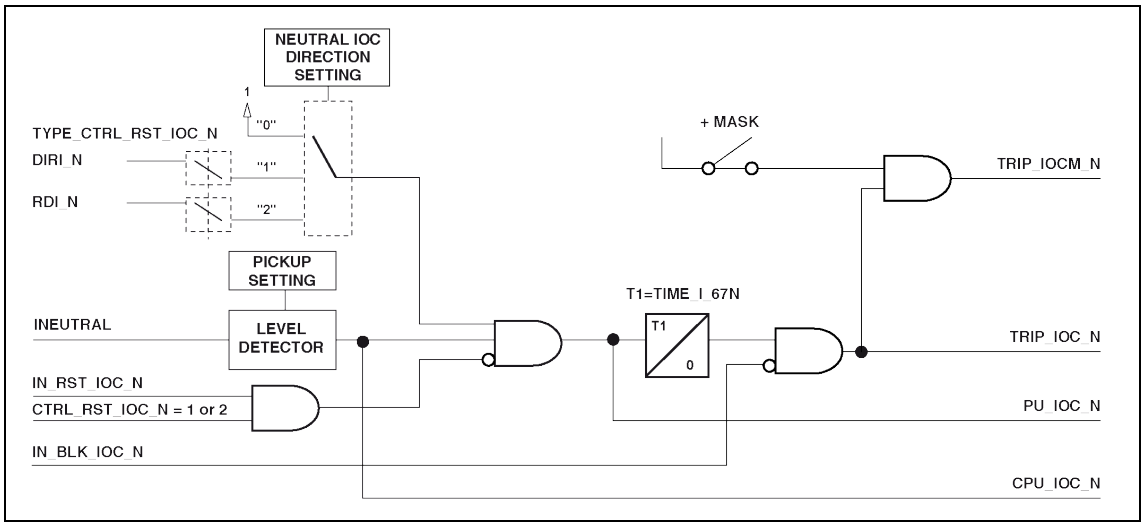


Figure 4.1.27 Block Diagram of a Neutral Instantaneous Overcurrent Element.

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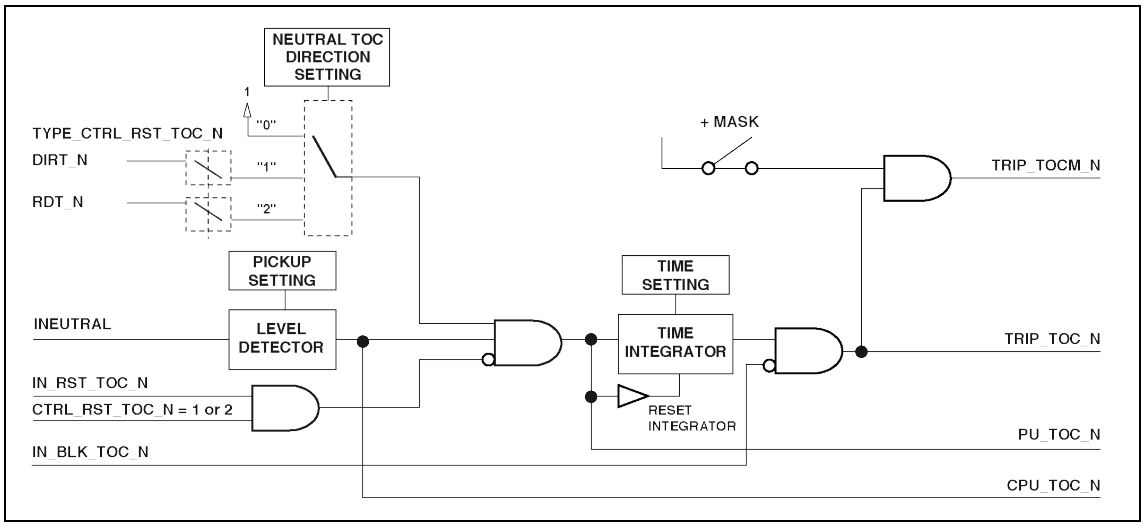


Figure 4.1.28 Block Diagram of a Neutral Time-Delayed Overcurrent Element.

4.1.3.d Application

Fault currents flowing to ground are detected by the neutral overcurrent element.

The neutral overcurrent element detects ground faults through the current calculated from the sum of phase currents, namely, it does not use a magnitude directly read by a measurement transformer as is the case for ground elements.

4.1.3.e Examples of Settings Calculation

For a totally balanced system, the residual current detected by the relay in the faulted bay equals the coil current minus the sum of the load currents flowing from the rest of the system. Also, the addition of the two sound phase load currents in each bay provides a total load current of a magnitude three times the phase stationary value. Therefore, for a totally balanced system, the detected unbalanced current equals three times the phase load current of the faulty circuit. In this way, a typical setting can be about 30% of this value, namely, equal to the phase load current of the faulty circuit. In practice, exact settings may be at the site, where system failures can be applied and adequate settings based on actual results can be adopted.

In most cases, the system will not be totally balanced and, thus, a small stable fault current flow is permitted. Therefore, the residual current observed by the IED at the faulty bay can be slightly higher, which implies that its settings must be based on actual current levels where possible.

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4.1.3.f Setting Ranges

Protection / Overcurrent / Instantaneous / Neutral Instantaneous (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Gnd IOC Enable	Neut IOC Enable	NPIOC.LNInSvc	YES / NO		NO
Gnd IOC Pickup	Neut IOC Pickup	NPIOC.StrVal	(0.01-30) In	0.01 A	5.00 A
GND IOC Delay	Neut IOC Delay	NPIOC.OpDlTmms	0-300 s	0.01 s	0 s
Neutr IOC Direction	Neut IOC Direction	PHSPIOC.DirMod	None Direction Reverse		None
Neutr IOC Direct Unit	Neut IOC Dir Unt	PHSPIOC.DirUnit	67N 67Q 67G		67N
Neutr IOC Harm Blocking	N IOC Harm Blk	PHSPIOC.HBlkEna	YES / NO		NO

Protection / Overcurrent / Time Overcurrent / Neutral Time Overcurrent (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Ground TOC Enable	Neut TOC Enable	NPTOC.LNInSvc	YES / NO		NO
Ground TOC Pickup	Neut TOC Pickup	NPTOC.StrVal	(0,01 - 30) In	0.01 A	5.00 A
Ground TOC Curve	Neut TOC Curve	NPTOC.TmACrv	See list of curves		Definite Time
Ground TOC Dial	Neut TOC Dial	NPTOC.TmMult	0.05-10 (inv)	0.01	1
			0.05-1 (IEC)	0.01	1
			0.1-10 (IEEE/US/RI)	0.01	1
Ground TOC Definite Time	Neut TOC Delay	NPTOC.OpDlTmms	0,05 - 300 s	0.01 s	0.05 s
Neutr TOC Direction	Neut TOC Direction	NPTOC.DirMod	None Direction Reverse		None
Neutral TOC Direct Unit	Neut TOC Dir Unt	NPTOC.DirUnit	67N 67Q 67G		67N
Reset Type	Reset Type	NPTOC.TypRs	Instantaneous. Induction Disk Emulation.		Instant.
Neutral TOC Harm Blocking	N TOC Harm Blk	NPTOC.HBlkEna	YES / NO		NO

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4.1.3.g Analog Inputs to the Unit

The operating magnitude of phase overcurrent elements will be the fundamental current IA, IB and IC. However, the relay will take into account the presence of harmonics when harmonic blocking is enabled, the relay being blocked when harmonic percentage exceeds the setting value.

Table 4.1-5:Analog Inputs to the Overcurrent Module		
Name	**Description**	**IEC 61850**
IN	Neutral calculated current	MMXU1.A.res

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

4.1.3.h Digital Inputs to the Neutral Overcurrent Element

Table 4.1-6: Digital Inputs to the Neutral Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_IOC_N1	Logic Inputs to Protection	NPIOC1.Mod	Block Neutr Instantaneous Unit 1	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_IOC_N2		NPIOC2.Mod	Block Neutr Instantaneous Unit 2	I	
IN_BLK_IOC_N3		NPIOC3.Mod	Block Neutr Instantaneous Unit 3	I	
IN_BLK_TOC_N1		NPTOC1.Mod	Block Neutr Time Overcurrent Unit 1	I	
IN_BLK_TOC_N2		NPTOC2.Mod	Block Neutr Time Overcurrent Unit 2	I	
IN_BLK_TOC_N3		NPTOC3.Mod	Block Neutr Time Overcurrent Unit 3	I	
IN_RST_IOC_N1	Logic Inputs to Protection	NPIOC1.DirInh	Disable Torque Control Neutr Instantaneous Unit 1	I	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_IOC_N2		NPIOC2.DirInh	Disable Torque Control Neutr Instantaneous Unit 2	I	
IN_RST_IOC_N3		NPIOC3.DirInh	Disable Torque Control Neutr Instantaneous Unit 3	I	
IN_RST_TOC_N1		NPTOC1.DirInh	Disable Torque Control Neutr Time Overcurrent Unit 1	I	
IN_RST_TOC_N2		NPTOC2.DirInh	Disable Torque Control Neutr Time Overcurrent Unit 2	I	
IN_RST_TOC_N3		NPTOC3.DirInh	Disable Torque Control Neutr Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-6: Digital Inputs to the Neutral Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BPT_N1	Logic Inputs to Protection	NPTOC1.OpDlInh	Neutr Time Overcurrent Unit 1 Time Disable	I	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_N2		NPTOC2.OpDlInh	Neutr Time Overcurrent Unit 2 Time Disable	I	
IN_BPT_N3		NPTOC3.OpDlInh	Neutr Time Overcurrent Unit 3 Time Disable	I	
ENBL_IOC_N1	Enabling Commands	NPIOC1.Mod	Enable Neutr Instantaneous Unit 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_IOC_N2		NPIOC2.Mod	Enable Neutr Instantaneous Unit 2	I	
ENBL_IOC_N3		NPIOC3.Mod	Enable Neutr Instantaneous Unit 3	I	
ENBL_TOC_N1		NPTOC1.Mod	Enable Ground Time Overcurrent Unit 1	I	
ENBL_TOC_N2		NPTOC2.Mod	Enable Ground Time Overcurrent Unit 2	I	
ENBL_TOC_N3		NPTOC3.Mod	Enable Ground Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.3.i Auxiliary Outputs and Events of the Neutral Overcurrent Modules

Table 4.1-7: Auxiliary Outputs of the Neutral Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IOC_N1	Pickup Protection Outputs	NPIOC1.Str	Neutr Instantaneous Unit 1 Pick Up	I,F	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_N2		NPIOC2.Str	Neutr Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_N3		NPIOC3.Str	Neutr Instantaneous Unit 3 Pick Up	I,F	
PU_TOC_N1		NPTOC1.Str	Neutr Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_N2		NPTOC2.Str	Neutr Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_N3		NPTOC3.Str	Neutr Time Overcurrent Unit 3 Pick Up	I,F	
PU_IOC		PTRC1.Str	Instantaneous Pick up (does not generate an event)		Pickup of the grouped current elements. (50, 50N, 50G, 50Q)
PU_TOC		PTRC1.Str	Time Overc Pick Up (does not generate an event)		Pickup of the grouped current elements. (51, 51N, 51G, 51Q)
CPU_IOC_N1		NPIOC1.Str	Neutr Instantaneous Unit 1 Pick Up Condition		Pickup of the current elements, unaffected by the torque control.
CPU_IOC_N2		NPIOC2.Str	Neutr Instantaneous Unit 2 Pick Up Condition		
CPU_IOC_N3		NPIOC3.Str	Neutr Instantaneous Unit 3 Pick Up Condition		
CPU_TOC_N1		NPTOC1.Str	Neutr Time Overcurrent Unit 1 Pick Up Condition		
CPU_TOC_N2		NPTOC2.Str	Neutr Time Overcurrent Unit 2 Pick Up Condition		
CPU_TOC_N3		NPTOC3.Str	Neutr Time Overcurrent Unit 3 Pick Up Condition		
TRIP_IOC_N1	Trip Protection Outputs	NPIOC1.Op	Neutr Instantaneous Unit 1 Trip	I,F	Trip of the current elements.
TRIP_IOC_N2		NPIOC2.Op	Neutr Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_N3		NPIOC3.Op	Neutr Instantaneous Unit 3 Trip	I,F	
TRIP_TOC_N1		NPTOC1.Op	Neutr Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_N2		NPTOC2.Op	Neutr Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_N3		NPTOC3.Op	Neutr Time Overcurrent Unit 3 Trip	I,F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-7: Auxiliary Outputs of the Neutral Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_IOC	Trip Protection Outputs	PTRC1.Op	Instantaneous Trip (does not generate an event)		Trip of the grouped current elements. (50, 50N, 50G, 50Q)
TRIP_TOC		PTRC1.Op	Time Overc Trip (does not generate an event)		Trip of the grouped current elements. (51, 51N, 51G, 51Q)
TRIP_IOC_N1M	Masked Trips		Neutr Instantaneous Unit 1 Masked Trip		Trip of the elements affected by their corresponding trip mask.
TRIP_IOC_N2M			Neutr Instantaneous Unit 2 Masked Trip		
TRIP_IOC_N3M			Neutr Instantaneous Unit 3 Masked Trip		
TRIP_TOC_N1M			Neutr Time Overcurrent Unit 1 Masked Trip		
TRIP_TOC_N2M			Neutr Time Overcurrent Unit 2 Masked Trip		
TRIP_TOC_N3M			Neutr Time Overcurrent Unit 3 Masked Trip		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.3.j IEC 61850 Logical Nodes

CLASS IRLNPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

CLASS IRLNPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
TypRs	ING	Type of Reset Curve
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

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4.1.3.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time. This test should be carried out with the relay directionality disabled, not to depend on the voltages (***Pickup Blocking Enable*** or ***Torque Control*** set to **NO**). Otherwise, voltages must be injected, in order for the elements to be in the trip enable zone.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end. It may also be verified by checking the trip flags in **Information** - **Status** - **Elements** menu or the events generated by the IED. Likewise, it may also be checked that the trip flag in said menu activates when element trips as well as the trip indication in the HMI.

Table 4.1-8: Pickup and Reset of the Overcurrent Instantaneous Elements				
Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

- **Operating Times**

For testing, at least one relay output must be configured with the trip signals of the element under test. The output configuration will be carried out with the ***ZIV e-NET tool***® changing the protection settings of the output to be used as shown in the Inputs, Outputs and LEDs Configuration section.

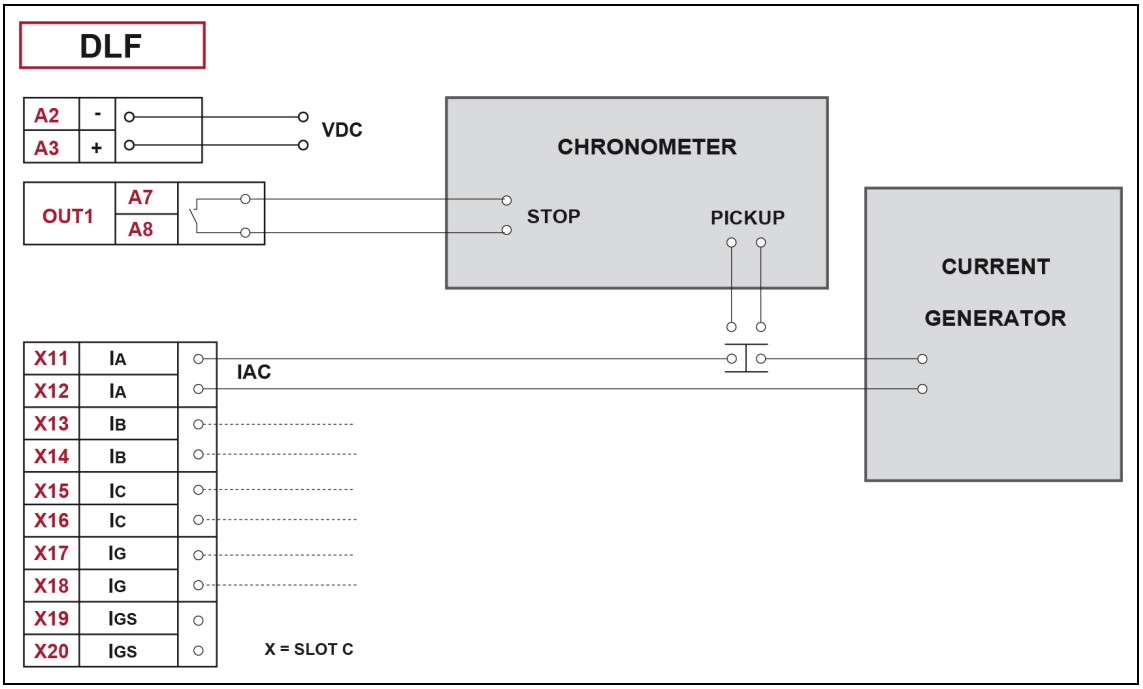


Figure 4.1.29 Operating Time Test Setup.

- **Definite or Instantaneous Time**

A current equal to 1.5 times the selected pickup setting value will be applied. Operating time should be ±30ms (for 50Hz) or 25ms (for 60Hz) of the selected time delay setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 30 ms (for 50Hz) or between 15 and 25 ms (for 60Hz). The reset time will be equal to 1.5 cycles (30ms for 50Hz and 25ms for 60Hz) after stopping the injection.

- **Inverse Time**

For a given curve, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

Operating times can be checked for curves shown in paragraph 4.1.1.f according to IEC and IEEE/ANSI standards. RI Inverse Curve characteristic is added to these curves, mainly used in combination with electromechanical relays.

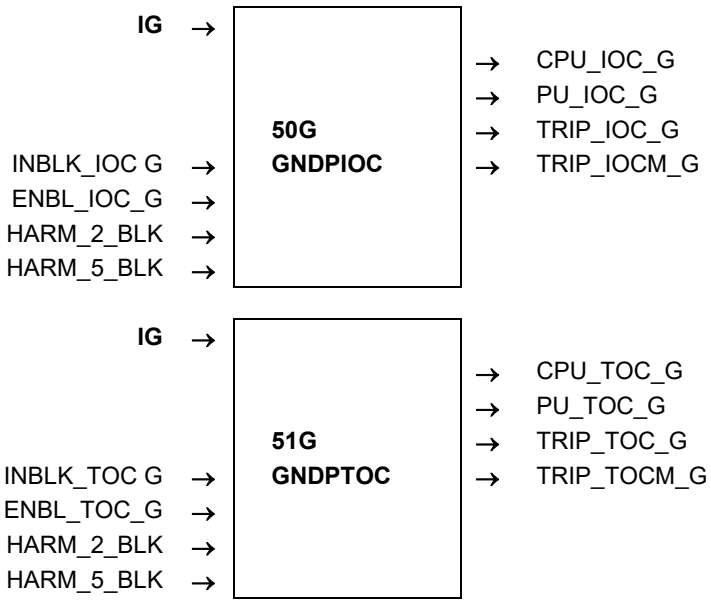
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4.1.4 Ground Overcurrent Elements

4.1.4.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Instantaneous Ground Overcurrent Unit 1	GNDPIOC1	3Io>>	50G1
Instantaneous Ground Overcurrent Unit 2	GNDPIOC2	3Io>>	50G2
Instantaneous Ground Overcurrent Unit 3	GNDPIOC3	3Io>>	50G3
Time-Delayed Ground Overcurrent Unit 1	GNDPTOC1	3Io>	51G1
Time-Delayed Ground Overcurrent Unit 2	GNDPTOC2	3Io>	51G2
Time-Delayed Ground Overcurrent Unit 3	GNDPTOC3	3Io>	51G3

4.1.4.b General Block



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4.1.4.c Operation Principles and Block Diagram

The ground instantaneous element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The ground current value exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section**.**

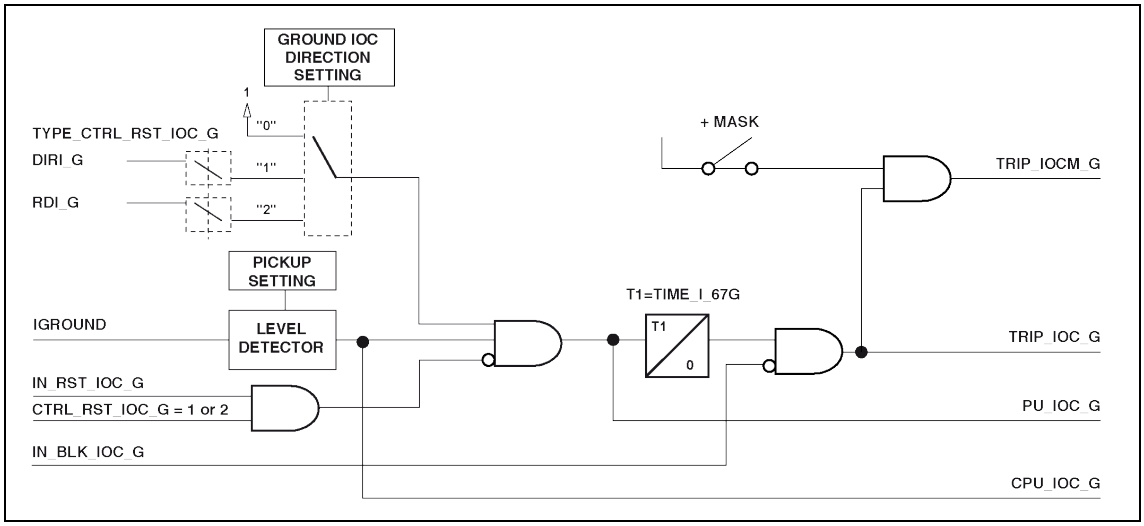


Figure 4.1.30 Block Diagram of a Ground Instantaneous Overcurrent Element.

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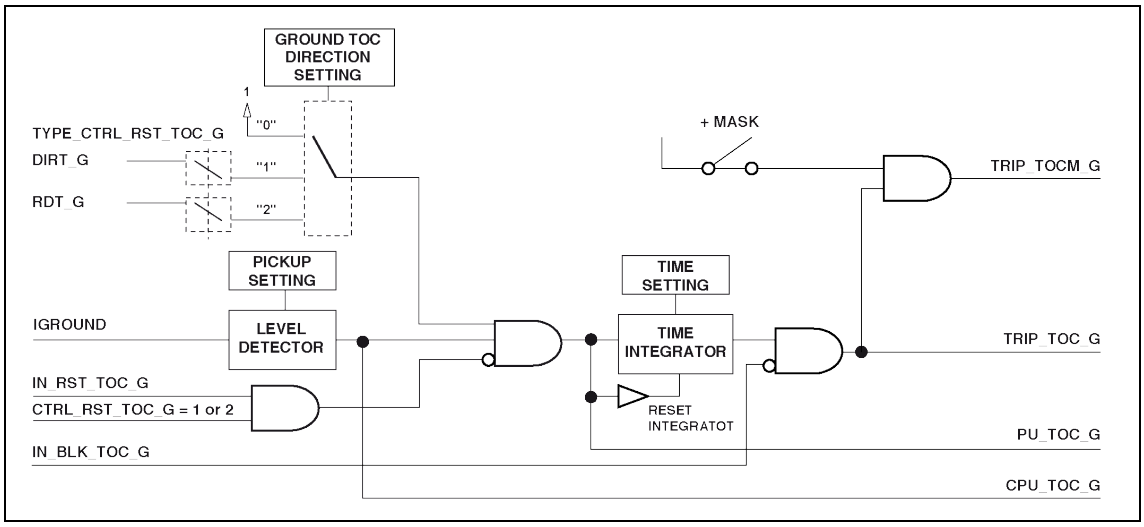


Figure 4.1.31 Block Diagram of a Ground Time-Delayed Overcurrent Element.

4.1.4.d Application

Fault currents flowing to ground are detected by the ground overcurrent element.

The ground overcurrent element detects ground faults by means of the measured current of the ground channel IG, namely, using a directly read magnitude of a current transformer and not through a measurement calculated from the phase currents as is the case of the neutral units

4.1.4.e Examples of Settings Calculation

For a totally balanced system, the residual current detected by the relay in the faulted bay equals the coil current minus the sum of the load currents flowing from the rest of the system. Also, the addition of the two sound phase load currents in each bay provides a total load current of a magnitude three times the phase stationary value. Therefore, for a totally balanced system, the detected unbalanced current equals three times the phase load current of the faulty circuit. In this way, a typical setting can be about 30% of this value, namely, equal to the phase load current of the faulty circuit. In practice, exact settings may be at the site, where system faults can be applied and adequate settings based on actual results can be adopted.

In most cases, the system will not be totally balanced and, thus, a small stable fault current flow is permitted. Therefore, the residual current observed by the IED at the faulty bay can be slightly higher, which implies that its settings must be based on actual current levels where possible.

4.1.4.f Setting Ranges

Protection / Overcurrent / Instantaneous / Ground Instantaneous (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Gnd IOC Enable	Gnd IOC Enable	GNDPIOC.LNInSvc	YES / NO		NO
Gnd IOC Pickup	Gnd IOC Pickup	GNDPIOC.StrVal	(0.01-30) In	0.01 A	5.00 A
Gnd IOC Delay	Gnd IOC Delay	GNDPIOC.OpDlTmms	0-300 s	0.01 s	0 s
Gnd IOC Direction	Gnd IOC Direction	GNDPIOC.DirMod	None Direction Reverse		None
Ground IOC Direct Unit	Gnd IOC Dir Unt	GNDPIOC.DirUnit	67G 67Q 67N		67G
Neutral IOC Harm Blocking	Gnd IOC Harm Blk	GNDPIOC.HBlkEna	YES / NO		NO

Protection / Overcurrent / Time Overcurrent / Ground Time Overcurrent (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Ground TOC Enable	Ground TOC Enable	GNDPTOC.LNInSvc	YES / NO		NO
Ground TOC Pickup	Ground TOC Pickup	GNDPTOC.StrVal	(0.01 - 30) In	0.01 A	5.00 A
Ground TOC Curve	Ground TOC Curve	GNDPTOC.TmACrv	See list of curves		Definite Time
Ground TOC Dial	Ground TOC Dial	GNDPTOC.TmMult	0.05-10 (inv)	0.01	1
			0.05-1 (IEC)	0.01	1
			0.1-10 (IEEE/US/RI)	0.01	1
Ground TOC Delay	Ground TOC Delay	GNDPTOC.OpDlTmms	0.05-300 s	0.01 s	0.05 s
Gnd TOC Direction	Gnd TOC Direction	GNDPTOC.DirMod	None Direction Reverse		None
Gnd TOC Direct Unit	Gnd TOC Dir Unt	GNDPTOC.DirUnit	67G 67Q 67N		67G
Reset Type	Reset Type	GNDPTOC.TypRs	Instantaneous. Induction Disk Emulation.		Instant.
Ground TOC Harm Blocking	Gnd TOC Harm Blk	GNDPTOC.HBlkEna	YES / NO		NO

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4.1.4.g Analog Inputs to the Unit

The operating magnitude of ground overcurrent elements will be the measured magnitude of the input channel IG. However, the relay will take into account the presence of harmonics when harmonic blocking is enabled, the relay being blocked when harmonic percentage exceeds the setting value.

Table 4.1-9:Analog Inputs to the Overcurrent Module		
Name	**Description**	**IEC 61850**
IG	Ground Current	MMXU1.A.neut

4.1.4.h Digital Inputs to the Ground Overcurrent Element

Table 4.1-10: Digital Inputs to the Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_IOC_G1	Logic Inputs to Protection	GNDPIOC1.Mod	Block Ground Instantaneous Unit 1	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_IOC_G2		GNDPIOC2.Mod	Block Ground Instantaneous Unit 2	I	
IN_BLK_IOC_G3		GNDPIOC3.Mod	Block Ground Instantaneous Unit 3	I	
IN_BLK_TOC_G1		GNDPTOC1.Mod	Block Ground Time Overcurrent Unit 1	I	
IN_BLK_TOC_G2		GNDPTOC2.Mod	Block Ground Time Overcurrent Unit 2	I	
IN_BLK_TOC_G3		GNDPTOC3.Mod	Block Ground Time Overcurrent Unit 3	I	
IN_RST_IOC_G1	Logic Inputs to Protection	GNDPIOC1.DirInh	Disable Torque Control Ground Instantaneous Unit 1	I	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_IOC_G2		GNDPIOC2.DirInh	Disable Torque Control Ground Instantaneous Unit 2	I	
IN_RST_IOC_G3		GNDPIOC3.DirInh	Disable Torque Control Ground Instantaneous Unit 3	I	
IN_RST_TOC_G1		GNDPTOC1.DirInh	Disable Torque Control Ground Time Overcurrent Unit 1	I	
IN_RST_TOC_G2		GNDPTOC2.DirInh	Disable Torque Control Ground Time Overcurrent Unit 2	I	
IN_RST_TOC_G3		GNDPTOC3.DirInh	Disable Torque Control Ground Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-10: Digital Inputs to the Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BPT_G1	Logic Inputs to Protection	GNDPTOC1.OpDIInh	Ground Time Overcurrent Unit 1 Time Disable	I	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_G2		GNDPTOC2.OpDIInh	Ground Time Overcurrent Unit 2 Time Disable	I	
IN_BPT_G3		GNDPTOC3.OpDIInh	Ground Time Overcurrent Unit 3 Time Disable	I	
ENBL_IOC_G1	Enabling Commands	GNDPIOC1.Mod	Enable Ground Instantaneous Unit 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_IOC_G2		GNDPIOC2.Mod	Enable Ground Instantaneous Unit 2	I	
ENBL_IOC_G3		GNDPIOC3.Mod	Enable Ground Instantaneous Unit 3	I	
ENBL_TOC_G1		GNDPTOC1.Mod	Enable Ground Time Overcurrent Unit 1	I	
ENBL_TOC_G2		GNDPTOC2.Mod	Enable Ground Time Overcurrent Unit 2	I	
ENBL_TOC_G3		GNDPTOC3.Mod	Enable Ground Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.1.4.i Auxiliary Outputs and Events of the Ground Overcurrent Modules

Table 4.1-11:Auxiliary Outputs of the Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IOC_G1	Pickup Protection Outputs	GNDPIOC1.Str	Ground Instantaneous Unit 1 Pick Up	I,F	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_G2		GNDPIOC2.Str	Ground Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_G3		GNDPIOC3.Str	Ground Instantaneous Unit 3 Pick Up	I,F	
PU_TOC_G1		GNDPTOC1.Str	Ground Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_G2		GNDPTOC2.Str	Ground Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_G3		GNDPTOC3.Str	Ground Time Overcurrent Unit 3 Pick Up	I,F	
PU_IOC		PTRC1.Str	Instantaneous Pick Up (does not generate an event)		Pickup of the grouped current elements. (50, 50N, 50G, 50Q).
PU_TOC		PTRC1.Str	Time Overc Pick Up (does not generate an event)		Pickup of the grouped current elements. (51, 51N, 51G, 51Q).

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-11: Auxiliary Outputs of the Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
CPU_IOC_G1	Pickup Protection Outputs	GNDPIOC1.Str	Ground Instantaneous Unit 1 Pick Up Condition	I	Pickup of the current elements, unaffected by the torque control.
CPU_IOC_G2		GNDPIOC2.Str	Ground Instantaneous Unit 2 Pick Up Condition	I	
CPU_IOC_G3		GNDPIOC3.Str	Ground Instantaneous Unit 3 Pick Up Condition	I	
CPU_TOC_G1		GNDPTOC1.Str	Ground Time Overcurrent Unit 1 Pick Up Condition	I	
CPU_TOC_G2		GNDPTOC2.Str	Ground Time Overcurrent Unit 2 Pick Up Condition	I	
CPU_TOC_G3		GNDPTOC3.Str	Ground Time Overcurrent Unit 3 Pick Up Condition	I	
TRIP_IOC_G1	Trip Protection Outputs	GNDPIOC1.Op	Ground Instantaneous Unit 1 Trip	I,F	Trip of the current elements.
TRIP_IOC_G2		GNDPIOC2.Op	Ground Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_G3		GNDPIOC3.Op	Ground Instantaneous Unit 3 Trip	I,F	
TRIP_TOC_G1		GNDPTOC1.Op	Ground Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_G2		GNDPTOC2.Op	Ground Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_G3		GNDPTOC3.Op	Ground Time Overcurrent Unit 3 Trip	I,F	
TRIP_IOC		PTRC1.Op	Instantaneous Trip (does not generate an event)		Trip of the grouped current elements. (50, 50N, 50G, 50Q).
TRIP_TOC		PTRC1.Op	Time Overc Trip (does not generate an event)		Trip of the grouped current elements. (51, 51N, 51G, 51Q).
TRIP_IOC_G1M	Masked Trips		Ground Instantaneous Unit 1 Masked Trip		Trip of the elements affected by their corresponding trip mask.
TRIP_IOC_G2M			Ground Instantaneous Unit 2 Masked Trip		
TRIP_IOC_G3M			Ground Instantaneous Unit 3 Masked Trip		
TRIP_TOC_G1M			Ground Time Overcurrent Masked Unit 1 Trip		
TRIP_TOC_G2M			Ground Time Overcurrent Masked Unit 2 Trip		
TRIP_TOC_G3M			Ground Time Overcurrent Masked Unit 3 Trip		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.4.j IEC 61850 Logical Nodes

CLASS IRLGNDPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

CLASS IRLGNDPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
TypRs	ING	Type of Reset Curve
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirUnit	EXT_ING_ENUM	Type of torque control
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

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4.1.4.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time. This test should be carried out with the relay directionality disabled, not to depend on the voltages (***Pickup Blocking Enable*** or ***Torque Control*** set to **NO**). Otherwise, voltages must be injected, in order for the elements to be in the trip enable zone.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end. It may also be verified by checking the trip flags in **Information** - **Status** - **Elements** menu or the events generated by the IED. Likewise, it may also be checked that the trip flag in said menu activates when element trips as well as the trip indication in the HMI.

Table 4.1-12: Pickup and Reset of the Overcurrent Instantaneous Elements				
Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

- **Operating Times**

For testing, at least one relay output must be configured with the trip signals of the element under test. The output configuration will be carried out with the ***ZIV e-NET tool***® changing the protection settings of the output to be used as shown in the Inputs, Outputs and LEDs Configuration section.

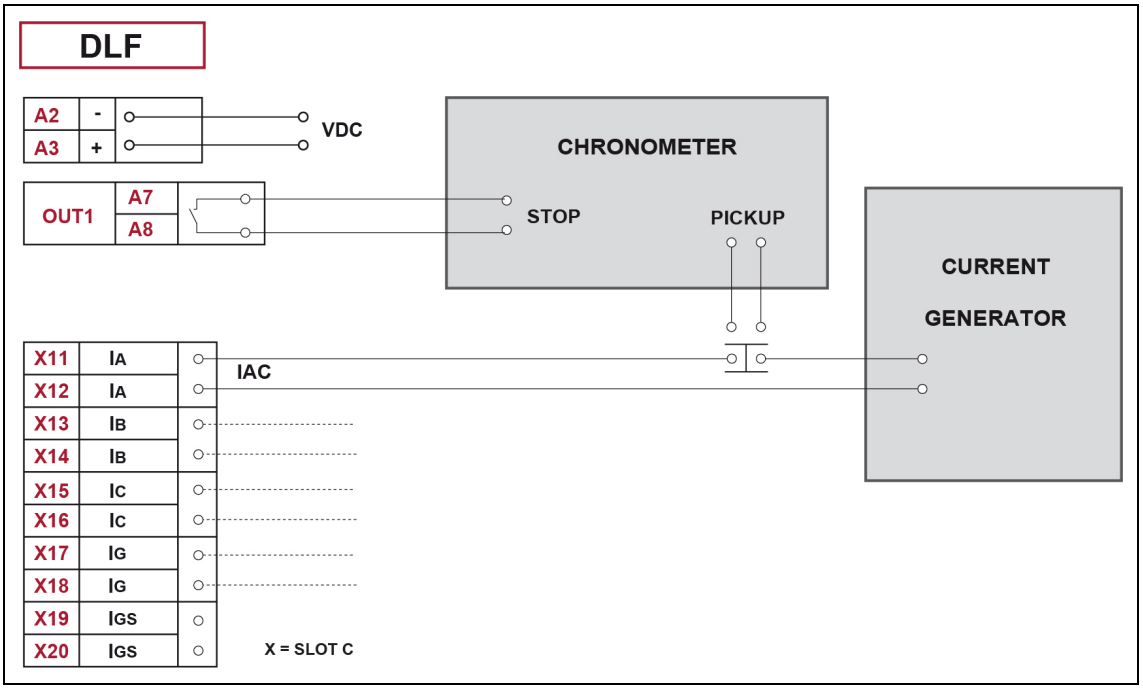


Figure 4.1.32 Operating Time Test Setup.

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- **Definite or Instantaneous Time**

A current equal to 1.5 times the selected pickup setting value will be applied. Operating time should be ±30ms (for 50Hz) or 25ms (for 60Hz) of the selected time delay setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 30 ms (for 50Hz) or between 15 and 25 ms (for 60Hz). The reset time will be equal to 1.5 cycles (30ms for 50Hz and 25ms for 60Hz) after stopping the injection.

- **Inverse Time**

For a given curve, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

Operating times can be checked for curves shown in paragraph 4.1.1.f according to IEC and IEEE/ANSI standards. RI Inverse Curve characteristic is added to these curves, mainly used in combination with electromechanical relays.

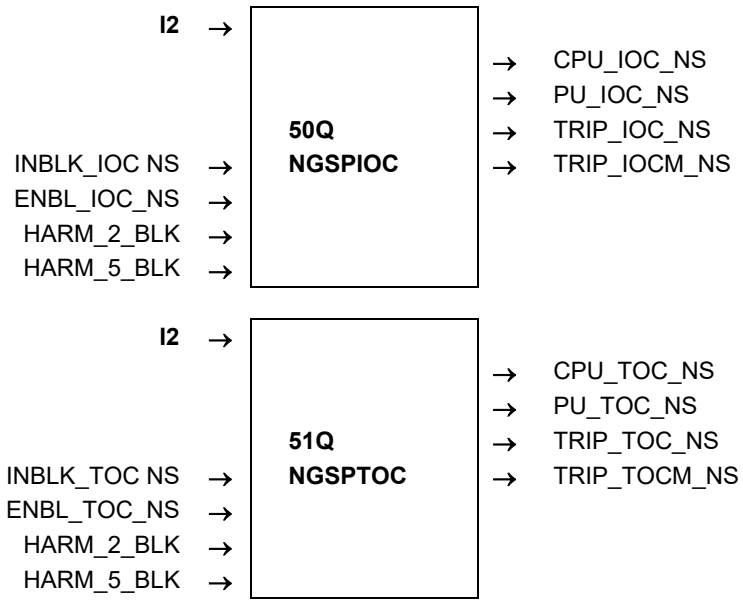
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4.1.5 Negative Sequence Elements

4.1.5.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Negative Sequence Instantaneous Overcurrent Unit 1	NGSPIOC1	I2>>	50Q1
Negative Sequence Instantaneous Overcurrent Unit 2	NGSPIOC2	I2>>	50Q2
Negative Sequence Instantaneous Overcurrent Unit 3	NGSPIOC3	I2>>	50Q3
Negative Sequence Time-Delayed Overcurrent Unit 1	NGSPTOC1	I2>	51Q1
Negative Sequence Time-Delayed Overcurrent Unit 2	NGSPTOC2	I2>	51Q2
Negative Sequence Time-Delayed Overcurrent Unit 3	NGSPTOC3	I2>	51Q3

4.1.5.b General Block



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4.1.5.c Operation Principles and Block Diagram

The Negative Sequence Instantaneous element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The neutral current value exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section.

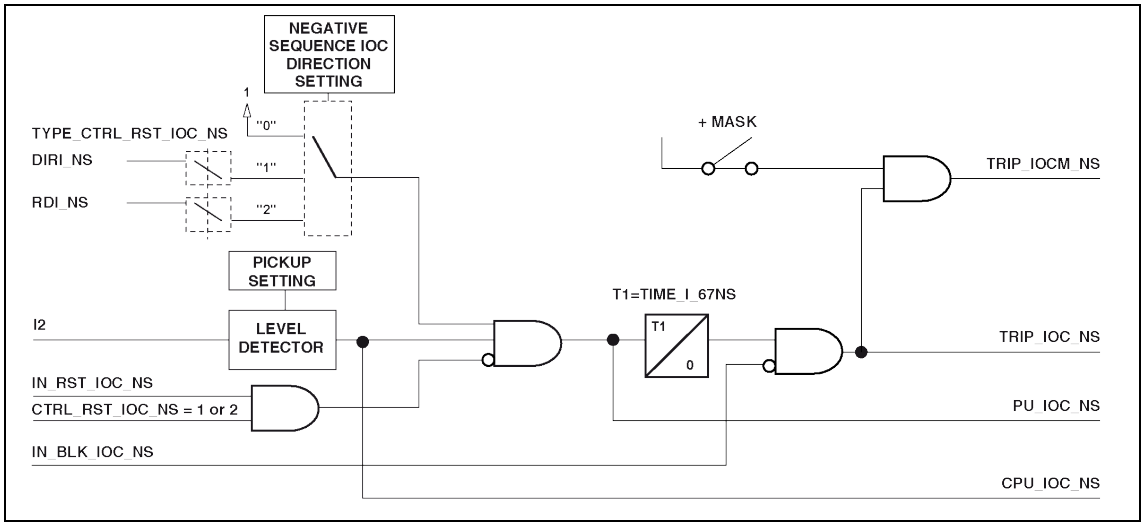


Figure 4.1.33 Block Diagram of a Negative Sequence Instantaneous Overcurrent Element.

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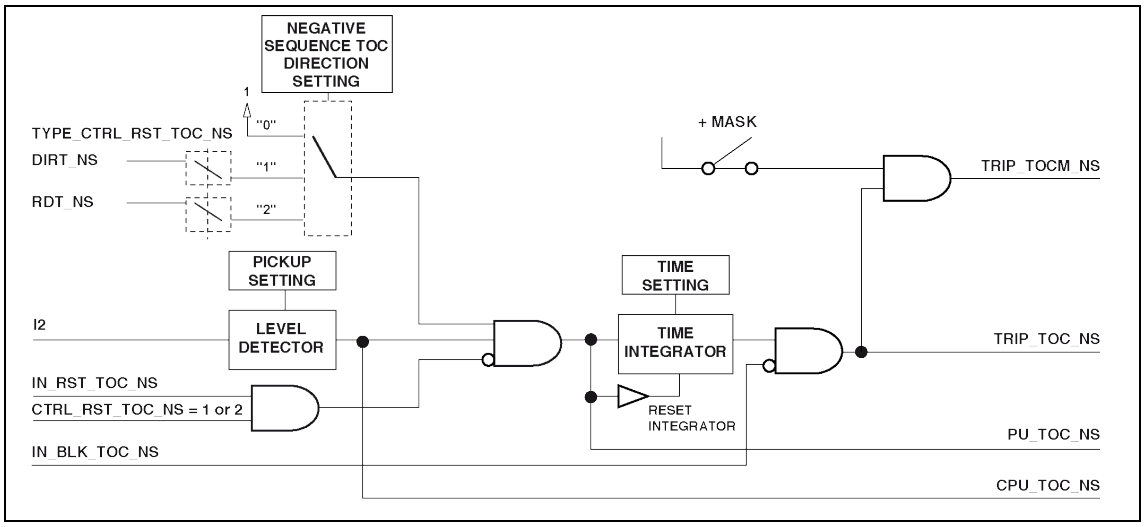


Figure 4.1.34 Block Diagram of a Negative Sequence Time-Delayed Overcurrent Element.

4.1.5.d Application

The Negative Sequence Overcurrent element detects unbalanced currents. Any type of fault (phase-phase or phase-ground) generates negative sequence current, so this element offers higher sensitivity, this sensitivity being lost in phase overcurrent elements as their settings must be above the maximum load value. Ground elements, mainly the Sensitive Ground elements, give good sensitivity, but they may not be able to detect certain types of faults.

The Negative Sequence Overcurrent element may be used as a system anomaly alarm indication, or as a backup protection element, which may provide higher sensitivity upon resistive faults where phase elements do not operate, or that may detect ground faults, which, because of the type of connection, a neutral or ground element would not detect, as could be the case of a ground fault in a star winding operating with a ground element in the delta winding.

4.1.5.e Example of Settings Calculation

The negative sequence element pickup value should be higher than the negative sequence current generated due to the unbalance existing with the normal maximum load of the system. This is why the setting of this element ought to be carried out with the relay installed, the setting being at least 20% higher than the relay reading.

As the negative sequence element is normally used as a backup element, the time delay setting will normally be high, it being higher than for the main protection elements: Phase, Ground, Open Phase, Thermal Image, etc. elements.

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4.1.5.f Setting Ranges

Protection / Overcurrent / Instantaneous / Negative Sequence Instantaneous (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
N.S. IOC Enable	N.S. IOC Enable	NGSPIOC.LNInSvc	YES / NO		NO
N.S. IOC Pickup	N.S. IOC Pickup	NGSPIOC.StrVal	(0.01-30) In	0.01 A	5.00 A
N.S. IOC Delay	N.S. IOC Delay	NGSPIOC.OpDlTmms	0-300 s	0.01 s	0 s
N.S. IOC Direction	N.S. IOC Direction	NGSPIOC.DirMod	None Direction Reverse		None
N.S. IOC Harm Blocking	N.S. IOC Harm Blk	NGSPIOC.HBlkEna	YES / NO		NO

Protection / Overcurrent / Time Overcurrent / Negative Sequence Time Overcurrent (1, 2 and 3 Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
N.S. TOC Enable	N.S. TOC Enable	NGSPTOC.LNInSvc	YES / NO		NO
N.S. TOC Pickup	N.S. TOC Pickup	NGSPTOC.StrVal	(0.01-30) In	0.01 A	5.00 A
N.S. TOC Curve	N.S. TOC Curve	NGSPTOC.TmACrv	See list of curves		Definite Time
N.S. TOC Dial	N.S. TOC Dial	NGSPTOC.TmMult	0.05-10 (inv)	0.01	1
			0.05-1 (IEC)	0.01	1
			0.1-10 (IEEE/US/RI)	0.01	1
N.S. TOC Definite Time	N.S. TOC Delay	NGSPTOC.OpDlTmms	0.05-300 s	0.01 s	0.05 s
N.S. TOC Direction	N.S. TOC Direction	NGSPTOC.DirMod	None Direction Reverse		None
Reset Type	Reset Type	NGSPTOC.TypRs	Instantaneous. Induction Disk Emulation.		Instant.
N.S. TOC Harm Blocking	N.S. TOC Harm Blk	NGSPTOC.HBlkEna	YES / NO		NO

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4.1.5.g Analog Inputs to the Unit

The operating magnitude of Negative Sequence Overcurrent elements will be the negative sequence current (I2) calculated from the IA, IB and IC fundamental currents. However, the relay will take into account the presence of harmonics when harmonic blocking is enabled, the relay being blocked when harmonic percentage exceeds the setting value.

Table 4.1-13:Analog Inputs of the Negative Sequence Overcurrent Modules		
Name	**Description**	**IEC 61850**
I2	Negative Sequence Calculated Current	MSQI1.SeqA.c2

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

4.1.5.h Digital Inputs to the Negative Sequence Overcurrent Element

Table 4.1-14: Digital Inputs to the Negative Sequence Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_IOC_NS1	Logic Inputs to Protection	NGSPIOC1.Mod	Block Negative Sequence Instantaneous Unit 1	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_IOC_NS2		NGSPIOC2.Mod	Block Negative Sequence Instantaneous Unit 2	I	
IN_BLK_IOC_NS3		NGSPIOC3.Mod	Block Negative Sequence Instantaneous Unit 3	I	
IN_BLK_TOC_NS1		NGSPTOC1.Mod	Block Negative Sequence Time Overcurrent Unit 1	I	
IN_BLK_TOC_NS2		NGSPTOC2.Mod	Block Negative Sequence Time Overcurrent Unit 2	I	
IN_BLK_TOC_NS3		NGSPTOC3.Mod	Block Negative Sequence Time Overcurrent Unit 3	I	
IN_RST_IOC_NS1	Logic Inputs to Protection	NGSPIOC1.DirInh	Disable Torque Control Negative Sequence Instantaneous Unit 1	I	It resets the element's timing functions and keeps them at 0 as long as it is active. With the element configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
IN_RST_IOC_NS2		NGSPIOC2.DirInh	Disable Torque Control Negative Sequence Instantaneous Unit 2	I	
IN_RST_IOC_NS3		NGSPIOC3.DirInh	Disable Torque Control Negative Sequence Instantaneous Unit 3	I	
IN_RST_TOC_NS1		NGSPTOC1.DirInh	Disable Torque Control Negative Sequence Time Overcurrent Unit 1	I	
IN_RST_TOC_NS2		NGSPTOC2.DirInh	Disable Torque Control Negative Sequence Time Overcurrent Unit 2	I	
IN_RST_TOC_NS3		NGSPTOC3.DirInh	Disable Torque Control Negative Sequence Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-14: Digital Inputs to the Negative Sequence Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BPT_NS1	Logic Inputs to Protection.	NGSPTOC1.OpDlInh	Negative Sequence Time Overcurrent Unit 1 Time Disable	I	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_NS2		NGSPTOC2.OpDlInh	Negative Sequence Time Overcurrent Unit 2 Time Disable	I	
IN_BPT_NS3		NGSPTOC3.OpDlInh	Negative Sequence Time Overcurrent Unit 3 Time Disable	I	
ENBL_IOC_NS1	Enabling Commands	NGSPIOC1.Mod	Enable Negative Sequence Instantaneous Unit 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_IOC_NS2		NGSPIOC2.Mod	Enable Negative Sequence Instantaneous Unit 2	I	
ENBL_IOC_NS3		NGSPIOC3.Mod	Enable Negative Sequence Instantaneous Unit 3	I	
ENBL_TOC_NS1		NGSPTOC1.Mod	Enable Negative Sequence Time Overcurrent Unit 1	I	
ENBL_TOC_NS2		NGSPTOC2.Mod	Enable Negative Sequence Time Overcurrent Unit 2	I	
ENBL_TOC_NS3		NGSPTOC3.Mod	Enable Negative Sequence Time Overcurrent Unit 3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.5.i Auxiliary Outputs and Events of the Negative Sequence Overcurrent Modules

Table 4.1-15: Auxiliary Outputs of the Negative Sequence Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IOC_NS1	Pickup Protection Outputs	NGSPIOC1.Str	Negative Sequence Instantaneous Unit 1 Pick Up	I,F	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_NS2		NGSPIOC2.Str	Negative Sequence Instantaneous Unit 2 Pick Up	I,F	
PU_IOC_NS3		NGSPIOC3.Str	Negative Sequence Instantaneous Unit 3 Pick Up	I,F	
PU_TOC_NS1		NGSPTOC1.Str	Negative Sequence Time Overcurrent Unit 1 Pick Up	I,F	
PU_TOC_NS2		NGSPTOC2.Str	Negative Sequence Time Overcurrent Unit 2 Pick Up	I,F	
PU_TOC_NS3		NGSPTOC3.Str	Negative Sequence Time Overcurrent Unit 3 Pick Up	I,F	
PU_IOC		PTRC1.Str	Instantaneous Pick Up (does not generate an event)		Pickup of the grouped current elements (50, 50N, 50G, 50Q).
PU_TOC		PTRC1.Str	Time Overc Pick Up (does not generate an event)		Pickup of the grouped current elements (51, 51N, 51G, 51Q).
CPU_IOC_NS1		NGSPIOC1.Str	Negative Sequence Instantaneous Unit 1 Pick Up Condition	I	Pickup of the current elements, unaffected by the torque control.
CPU_IOC_NS2		NGSPIOC2.Str	Negative Sequence Instantaneous Unit 2 Pick Up Condition	I	
CPU_IOC_NS3		NGSPIOC3.Str	Negative Sequence Instantaneous Unit 3 Pick Up Condition	I	
CPU_TOC_NS1		NGSPTOC1.Str	Negative Sequence Time Overcurrent Unit 1 Pick Up Condition	I	
CPU_TOC_NS2		NGSPTOC2.Str	Negative Sequence Time Overcurrent Unit 2 Pick Up Condition	I	
CPU_TOC_NS3		NGSPTOC3.Str	Negative Sequence Time Overcurrent Unit 3 Pick Up Condition	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-15: Auxiliary Outputs of the Negative Sequence Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_IOC_NS1	Trip Protection Outputs	NGSPIOC1.Op	Negative Sequence Instantaneous Unit 1 Trip	I,F	Trip of the current elements.
TRIP_IOC_NS2		NGSPIOC2.Op	Negative Sequence Instantaneous Unit 2 Trip	I,F	
TRIP_IOC_NS3		NGSPIOC3.Op	Negative Sequence Instantaneous Unit 3 Trip	I,F	
TRIP_TOC_NS1		NGSPTOC1.Op	Negative Sequence Time Overcurrent Unit 1 Trip	I,F	
TRIP_TOC_NS2		NGSPTOC2.Op	Negative Sequence Time Overcurrent Unit 2 Trip	I,F	
TRIP_TOC_NS3		NGSPTOC3.Op	Negative Sequence Time Overcurrent Unit 3 Trip	I,F	
TRIP_IOC		PTRC1.Op	Instantaneous Trip (does not generate an event)		Trip of the grouped current elements (50, 50N, 50G, 50Q).
TRIP_TOC		PTRC1.Op	Time Overc Trip (does not generate an event)		Trip of the grouped current elements (51, 51N, 51G, 51Q).
TRIP_IOC_NS1M	Masked Trips		Negative Sequence Instantaneous Unit 1 Masked Trip		Trip of the elements affected by their corresponding trip mask.
TRIP_IOC_NS2M			Negative Sequence Instantaneous Unit 2 Masked Trip		
TRIP_IOC_NS3M			Negative Sequence Instantaneous Unit 3 Masked Trip		
TRIP_TOC_NS1M			Negative Sequence Time Overcurrent Unit 1 Masked Trip		
TRIP_TOC_NS2M			Negative Sequence Time Overcurrent Unit 2 Masked Trip		
TRIP_TOC_NS3M			Negative Sequence Time Overcurrent Unit 3 Masked Trip		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.5.j IEC 61850 Logical Nodes

CLASS IRLNGSPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

CLASS IRLNGSPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
TypRs	ING	Type of Reset Curve
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirInh	EXT_SPC	Directional mode inhibition command
HBlkEna	EXT_SPG	Harmonic blocking enable

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4.1.5.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time. This test should be carried out with the relay directionality disabled, not to depend on the voltages (***Pickup Blocking Enable*** or ***Torque Control*** set to **NO**). Otherwise, voltages must be injected, in order for the elements to be in the trip enable zone. In case of using a time element, the reset will be instantaneous.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end. It may also be verified by checking the trip flags in **Information** - **Status** - **Elements** menu or the events generated by the IED. Likewise, it may also be checked that the trip flag in said menu activates when element trips as well as the trip indication in the HMI.

Table 4.1-16: Pickup and Reset of the Overcurrent Instantaneous Elements

Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

- **Operating Times**

For testing, at least one relay output must be configured with the trip signals of the element under test. The output configuration will be carried out with the ***ZIV e-NET tool***® changing the protection settings of the output to be used as shown in the Inputs, Outputs and LEDs Configuration section.

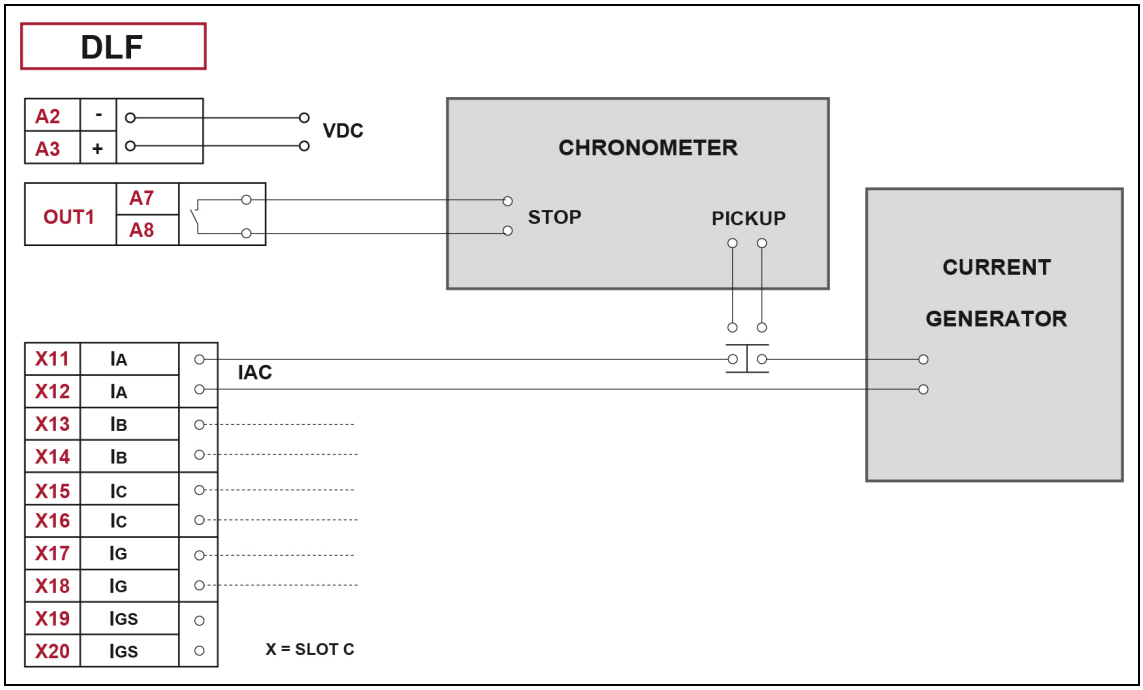


Figure 4.1.35 Operating Time Test Setup.

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- **Definite or Instantaneous Time**

A current equal to 1.5 times the selected pickup setting value will be applied. Operating time should be ±30ms (for 50Hz) or 25ms (for 60Hz) of the selected time delay setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 30 ms (for 50Hz) or between 15 and 25 ms (for 60Hz). The reset time will be equal to 1.5 cycles (30ms for 50Hz and 25ms for 60Hz) after stopping the injection.

- **Inverse Time**

For a given curve, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

Operating times can be checked for curves shown in paragraph 4.1.1.f according to IEC and IEEE/ANSI standards. RI Inverse Curve characteristic is added to these curves, mainly used in combination with electromechanical relays.

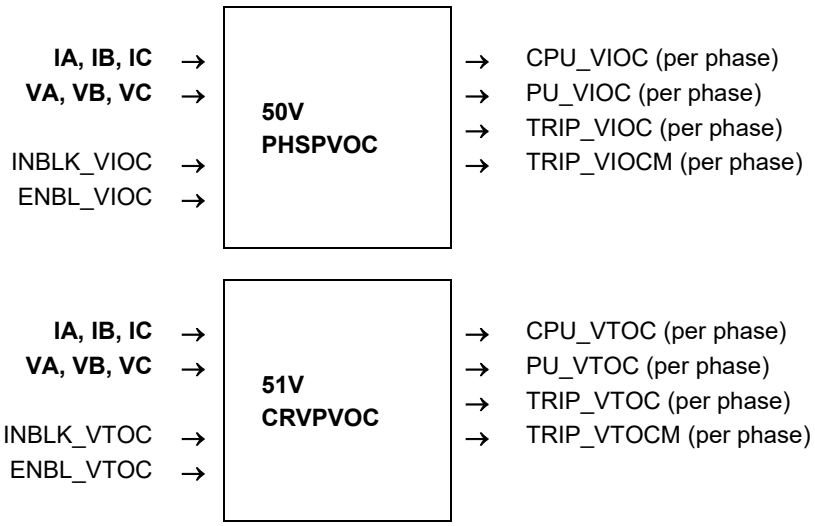
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4.1.6 Voltage Dependent Overcurrent Elements

4.1.6.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Instantaneous Voltage Dependent Overcurrent Unit	PHSPVOC	3IV>>	50V
Time-Delayed Voltage Dependent Overcurrent Unit	CRVPVOC	3IV>	51V

4.1.6.b General Block



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4.1.6.c Operation Principles and Block Diagram

The operation is based on a minimum voltage element that detects the fault and an overcurrent element that conveniently resets according to the voltage level. Two-mode operation is possible: **Voltage Restraint** or **Voltage Controlled**.

Voltage dependent elements consist of two elements: one instantaneous or fixed time and one time element settable through a curve. In both cases, the current elements pickup at 105 % of the pickup current value (either of the setting, or the calculated value as a function of the restraint depending on the operating mode of the element) and reset at 100%. Meanwhile, the operating voltage (always phase-to-phase) enables the pickup in **Voltage Controlled** mode at 100% of its setting and resets at 105%, the voltage setting value being a percentage of the rated relay working voltage.

- **Voltage Restraint Element**

Pickup value of this unit is variable as a function of measured voltage values, getting more sensitive with decaying voltage. There is one element per phase each current value being a function of the phase-to-phase voltages as shown below.

Table 4.1-17:Voltage Restraint Overcurrent Unit

Phase Current	Control Voltage (Phase Sequence ABC)	Control Voltage (Phase Sequence ACB)
IA	UAB	UAC
IB	UBC	UBA
IC	UCA	UCB

As a consequence of this variable characteristic, the coordination with downstream relays becomes more difficult. In any case, this mode is deemed the most appropriate when the generator is coupled to the network through a step-up transformer; in case a fault between phases occurs in the busbar connection, there would only be a partial reduction of the phase-to-phase voltage at the generator terminals.

Pickup setting multiplier is a function of the measured voltage as shown in figure 4.1.36 and in following table.

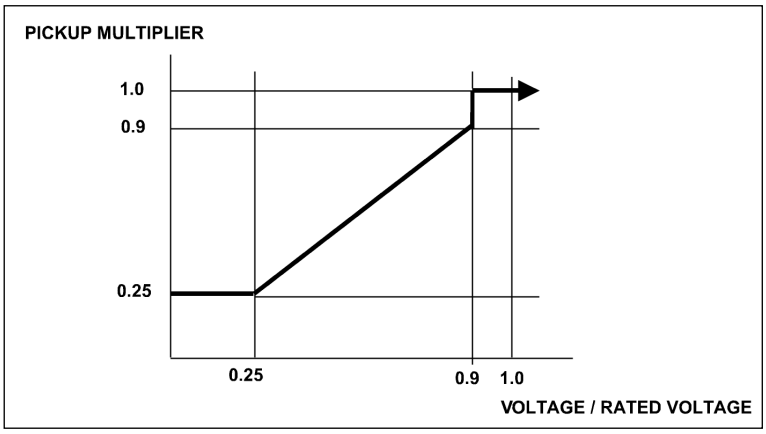


Figure 4.1.36 Voltage Restrained Time Overcurrent Element.

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Voltage ratio is allowed to go down to 90% keeping the same pickup setting. This is so because measurement errors may turn up caused by transformer inaccuracy, etc. If voltage ratio goes down below 25% the setting remains fixed at 25%.

% Nominal Voltage	Pickup Current % Pickup Setting
100	100
90	100
75	75
50	50
25	25
0	25

- **Voltage Controlled Element**

Pickup takes place only when voltage goes down below the voltage setting; so that one fixed pickup current setting and operate voltage setting are available. There is one element per phase each current depending on phase-to-phase voltage the same as for **Voltage Restraint** mode.

Coordination with downstream protections is easier for this mode. Furthermore, it is the most appropriate mode when the generator is directly connected to the busbar.

4.1.6.d Application

The application of this element is construed as a backup for the generator differential element. It also operates for downstream faults not cleared due to the failure of other relays or breakers, as a generator is a power supply for network faults until they are cleared.

Its voltage dependence ensures no operation upon overload conditions, providing the high sensitivity required by the limited capacity of the generator to supply sustained short circuit current. The fault current supplied by the generator decreases with time, the decreasing curve varying as a function of the operation of the generator voltage control systems; at worst, the fault current will drop below the maximum load current, and the single overcurrent protections will not operate.

Its operation must be coordinated with the operation of the overcurrent relays connected downstream, allowing for fast operation but preventing the operation under load conditions.

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4.1.6.e Setting Ranges

Protection / Voltage Restrained Overcurrent / Instantaneous					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
V Dependent Enable	V dependent enable	PHSPVOC.LNInSvc	YES / NO		NO
V Dependent Mode	V dependent mode	PHSPVOC.EvMod	V Restraint V Controlled		V Restraint
V Dependent Pickup	V dependent pickup	PHSPVOC.StrVal1	(0.2 - 20) In	0.01A	1A
Operating Voltage	Operating voltage	PHSPVOC.StrVal2	10 - 100%	1%	50%
V Dependent Time	V dependent time	PHSPVOC.OpDlTmms	05 - 300	0.01s	1s

Protection / Voltage Restrained Overcurrent / Temporized					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
V Dependent Enable	V dependent enable	CRVPVOC.LNInSvc	YES / NO		NO
V Dependent Mode	V dependent mode	CRVPVOC.EvMod	V Restraint V Controlled		V Restraint
V Dependent Pickup	V dependent pickup	CRVPVOC.StrVal1	(0.2-25) In	0.01A	1A
Phase TOC Curve	Phase TOC Curve	CRVPTOC.TmACrv	See list of curves		Definite Time
Phase TOC Dial	Phase TOC Dial	CRVPTOC.TmMult	0.05-10 (inv)	0.01	1
			0.05-1 (IEC)	0.01	1
			0.1-10 (IEEE/US/RI)	0.01	1
Operating Voltage	Operating voltage	CRVPVOC.StrVal2	10 - 100%	1%	50%
Phase TOC Definite Time	Phase TOC Delay	CRVPVOC.OpDlTmms	05 - 300	0.01s	1s

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4.1.6.f Analog Inputs to the Unit

The operating magnitude of Voltage Dependent Overcurrent elements will be the fundamental current IA, IB and IC of the reference winding and the Line voltages.

Table 4.1-18: Analog Inputs of the Overcurrent Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
VAB	AB Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsAB
VBC	BC Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsBC
VCA	CA Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsCA
VAC	AC Phase-to-Phase Voltage (ACB Sequence)	
VBA	BA Phase-to-Phase Voltage (ACB Sequence)	
VCB	CB Phase-to-Phase Voltage (ACB Sequence)	

4.1.6.g Digital Inputs to the Voltage Dependent Overcurrent Element

Table 4.1-19: Digital Inputs to the Voltage Dependent Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_VIOC	Logic Inputs to Protection	PHSPVOC1.Mod	Voltage Restrained Instantaneous Unit Blocking Input	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_VTOC		CRVPVOC1.Mod	Voltage Restrained Temporized Unit Blocking Input	I	
ENBL_VIOC	Enabling Commands	PHSPVOC1.Mod	Voltage Restrained Instantaneous Unit Habilitation Input	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_VTOC		CRVPVOC1.Mod	Voltage Restrained Temporized Unit Habilitation Input	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.6.h Auxiliary Outputs and Events of the Voltage Dependent Overcurrent Modules

Table 4.1-20: Auxiliary Outputs of the Voltage Dependent Overcurrent Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_VIOC_A	Pickup Protection Outputs	PHSPVOC1.Str	Voltage Restrained Instantaneous Unit Phase A Pickup	I,F	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_VIOC_B		PHSPVOC1.Str	Voltage Restrained Instantaneous Unit Phase B Pickup	I,F	
PU_VIOC_C		PHSPVOC1.Str	Voltage Restrained Instantaneous Unit Phase C Pickup	I,F	
PU_VTOC_A		CRVPVOC1.Str	Voltage Restrained Temporized Unit Phase A Pickup	I,F	
PU_VTOC_B		CRVPVOC1.Str	Voltage Restrained Temporized Unit Phase B Pickup	I,F	
PU_VTOC_C		CRVPVOC1.Str	Voltage Restrained Temporized Unit Phase C Pickup	I,F	
PU_IOC		PTRC1.Str	Instantaneous Pick Up (does not generate an event)		Pickup of the grouped current elements (50, 50N, 50G, 50Q, 50Ns).
PU_TOC		PTRC1.Str	Time Overc Pick Up (does not generate an event)		Pickup of the grouped current elements (51, 51N, 51G, 51Q, 51Ns).
TRIP_VIOC_A	Trip Protection Outputs	PHSPVOC1.Op	Voltage Restrained Instantaneous Unit Phase A Trip	I,F	Trip of the current elements.
TRIP_VIOC_B		PHSPVOC1.Op	Voltage Restrained Instantaneous Unit Phase B Trip	I,F	
TRIP_VIOC_C		PHSPVOC1.Op	Voltage Restrained Instantaneous Unit Phase C Trip	I,F	
TRIP_VTOC_A		CRVPVOC1.Op	Voltage Restrained Temporized Unit Phase A Trip	I,F	
TRIP_VTOC_B		CRVPVOC1.Op	Voltage Restrained Temporized Unit Phase B Trip	I,F	
TRIP_VTOC_C		CRVPVOC1.Op	Voltage Restrained Temporized Unit Phase C Trip	I,F	
TRIP_IOC		PTRC1.OP	Instantaneous Trip (does not generate an event)		Trip of the grouped current elements (50, 50N, 50G, 50Q, 50Ns).
TRIP_TOC		PTRC1.OP	Time Overc Trip (does not generate an event)		Trip of the grouped current elements (51, 51N, 51G, 51Q, 51Ns).

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.1-20: Auxiliary Outputs of the Voltage Dependent Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_VIOC_AM	Masked Trips.		Voltage Restrained Instantaneous Unit Phase A Masked Trip		Trip of the current elements affected by its trips masks.
TRIP_VIOC_BM			Voltage Restrained Instantaneous Unit Phase B Masked Trip		
TRIP_VIOC_CM			Voltage Restrained Instantaneous Unit Phase C Masked Trip		
TRIP_VTOC_AM			Voltage Restrained Temporized Unit Phase A Masked Trip		
TRIP_VTOC_BM			Voltage Restrained Temporized Unit Phase B Masked Trip		
TRIP_VTOC_CM			Voltage Restrained Temporized Unit Phase C Masked Trip		
VIOC_ ENBL	Units enabled Protection Outputs	PHSPVOC1.Mod	Voltage Restrained Instantaneous unit enable	I	Indication of enabled or disabled status of the current elements.
VTOC_ ENBL		CRVPVOC1.Mod	Voltage Restrained Temporized unit enable	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.1.6.i IEC 61850 Logical Nodes

CLASS IDFPHSPVOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
EvMod	EXT_ING_ENUM	V dependency type: restraint/blocked
StrVal1	EXT_ASG	Current start value
StrVal2	EXT_ASG	Operation voltage

CLASS IDFCRVPVOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
Extended Data		
LNInSvc	EXT_SPG	In service
EvMod	EXT_ING_ENUM	V dependency type: restraint/blocked
StrVal1	EXT_ASG	Current start value
StrVal2	EXT_ASG	Operation voltage
OpDlTmms	EXT_ING	Delay time

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4.1.6.j Protection Element Test

Element is set as follows:

Element enable	YES
Mode	0: V Restraint
Element pickup	1A
Operate voltage (Voltage Controlled mode)	50% Un
Element time delay	0.05 s

- **Pickup and Reset**

With nominal voltage setting at 110 VAC, a voltage of 22 VAC is applied to phase A; that represents 20% of nominal voltage.

Under these conditions, check that applying current through phase A element pickup takes place at (1.05 * 0.25 A) ± 3%, and resets at 0.25 A ± 3%.

Disconnect phase A voltage and apply 55 VAC through phase B; that represents 50% of nominal voltage.

Under these conditions, check that applying current through phase B element pickup takes place at (1.05 * 0.5 A) ± 3%, and resets at 0.5 A ± 3%.

Finally, disconnect phase B voltage and apply 104.5 VAC through phase C; that represents 95% of nominal voltage.

Under these conditions, check that applying current through phase C element pickup takes place at (1.05 * 1 A) ± 3%, and resets at 1A ± 3%.

- **Operating Times**

Apply the currents and voltages stated in paragraph for pickup and reset and check that tripping takes place within ±1% or ±30ms (for 50Hz) or 25ms (for 60Hz) of the selected time setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 30 ms (for 50Hz) or between 15 and 25 ms (for 60Hz).

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The equipments are provided with the following directional elements for overcurrent element control:

Directional Elements		
1	Phase Directional Element	**67**
1	Neutral Directional Element	**67N**
1	Ground Directional Element	**67G**
1	Negative Sequence Directional Element	**67Q**
1	Positive Sequence Directional Element	**67P**

4.2.1 Common Principles

The mission of the directional element is to determine the direction in which the operating current is flowing in order to control its associated overcurrent element. The direction is determined by comparing its phase with that of a reference value, the phase of which is maintained irrespective of the direction of the flow of the operating current.

Each directional element controls the corresponding overcurrent elements as long as the ***Torque Control*** setting is other than **Zero**. The control over the overcurrent element is carried out inhibiting the operation of the pickup elements in case the current flows in the reverse direction to that selected. If the directional element inhibits the operation of the overcurrent element, the timing function will not start. If the inhibition occurs once the timing has started, it will reset so that the timing will start again from zero if the inhibition disappears. In any case, a trip requires the timing function to be uninterrupted. For time elements, ***Coordination Time*** must time-out to enable their trip.

If the ***Torque Control*** is equal to **Zero**, the directional control is inhibited and allows the pickup of the overcurrent elements for current flows in both directions: direction and reverse direction.

In all cases, the directional element can enable and block trips in both directions (direction and reverse direction) with the ***Torque Control*** setting (**1** for the direction and **2** for the reverse direction). With **Torque Annulment** input activated, the corresponding directional element is not allowed to pick up.

The **Trip Direction Reversal** input (**IN_INV_TRIP**) changes, if activated, the direction of operation of all the directional elements.

All the directional elements generate direction and reverse direction outputs, instantaneous as well as timed, which exercise directional control over the instantaneous and time overcurrent elements, respectively. The timing of the timed outputs of the directional elements is given by the ***Coordination Time*** setting.

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The ***Coordination Time*** avoids erroneous trips in case of current reversal produced in double circuits. We consider the case of two parallel lines; the detection of a fault and its subsequent sequential trip in one of these may cause current reversal of one of the terminals of the parallel line, started as a result of this fault. In this case, the directional element will reverse its status and will go on not to allow the trip. If because of the **Permissive Overreach** scheme the timer is annulled, an instantaneous trip will be produced, since the channel reception signal has a reset time other than zero. To prevent this possibility, the ***Coordination Time*** may be used, which delays the application of the directional permission until the channel reception signal has disappeared. This delay only affects the time elements, provided that they are configured as directional.

The ***Neutral/Ground characteristic angle*** setting is common to the three types of ground (Calculated neutral, Ground and Sensitive Neutral). On the other hand, it must be taken into account that the phase characteristic angle is capacitive.

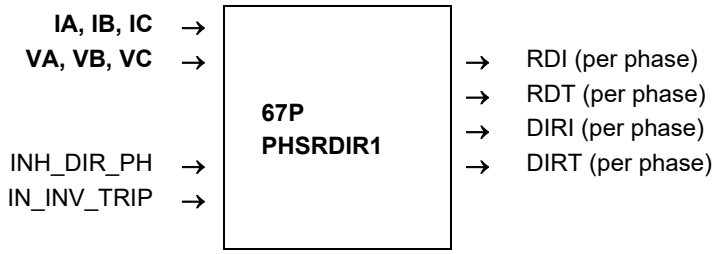
The ***Neutral/Ground V_POL Type*** setting will affect the polarization of the Neutral, Sensitive Neutral and Ground, since the polarization voltage of these elements can be selected through this setting, namely, the calculated neutral voltage **VN** (calculated from the three phase voltages) or the ground voltage **VG** (directly obtained through an open delta transformer connected to the terminals used to this end). This setting will not have any impact on the neutral directional units when they are set to be polarized by **67Q**.

4.2.2 Phase Directional Unit

4.2.2.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Phase Directional Overcurrent Unit	PHSRDIR1	3I →	67P

4.2.2.b General Block



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4.2.2.c Operation Principles and Block Diagram

There is one directional element per phase. Phase operate magnitude is phase current and polarization magnitude is phase-to-phase voltage corresponding to the other two phases taken 2 cycles before of the current moment.

Table 4.2-1 shows operation and polarization magnitudes applied to each of three phases.

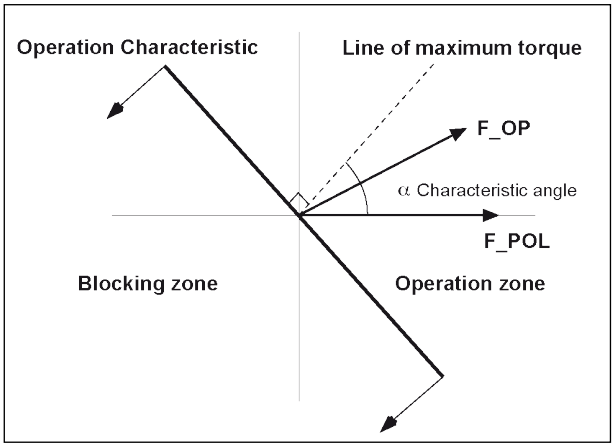


Figure 4.2.1 Vector Diagram of the Directional Phase Element.

The aim of directional phase elements is to check whether phase currents and voltages exceed a given value. This value is settable for voltage (***Min Phase Voltage*** setting) and has **60 mA** setting for current. If current or voltage do not exceed the threshold values the ***Lack of Polarization Blocking*** setting is checked. If set to **NO** proceed as for the case of directional inhibition, but if set to **YES** indicates lack of polarization blocking and trips in both directions are blocked.

Following table shows the operating and polarization values applied to each of the three phases.

Table 4.2-1: Phase Directional Element

ABC Phase Sequence			
Phase	**F_OP**	**F_POL**	**Criteria**
A	I_A	$U_{BCM} = (V_B - V_C)_M$	$-(90^o - ANG_67) \le [\arg(Fop) - \arg(Fpol)] \le (90^o + ANG_67)$
B	I_B	$U_{CAM} = (V_C - V_A)_M$	
C	I_C	$U_{ABM} = (V_A - V_B)_M$	
ACB Phase Sequence			
Phase	**F_OP**	**F_POL**	**Criteria**
A	I_A	$U_{CBM} = (V_C - V_B)_M$	$-(90^o - ANG_67) \le [\arg(Fop) - \arg(Fpol)] \le (90^o + ANG_67)$
B	I_B	$U_{ACM} = (V_A - V_C)_M$	
C	I_C	$U_{BAM} = (V_B - V_A)_M$	

The operate characteristic, drawn on a polar diagram, is a straight line, the perpendicular of which (maximum torque line) is rotated a given angle counter clockwise, known as phase characteristic angle, with respect to polarization magnitude. Said straight line divides the plane into two half planes. It is worth highlighting that said characteristic angle is complementary to the angle of the line positive sequence impedance (see the following application example).

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When the directional element is set to **Direction**, it enables the overcurrent element when the operating magnitude phasor is within the operating zone, ±90° with respect to the maximum torque line, and disables it if is in the opposite half plane. When the element is set to **Reverse** direction, it enables the overcurrent element when this criterion is not complied with, namely, in the opposite half plane. As mentioned above, the directional control is carried phase by phase.

The logic diagram of operation of the phase directional element is shown in Figure 4.2.2.

The activation of the **Phase Directional Element Inhibition** (**INH_DIR_IN**) input converts the element to **Non-directional**.

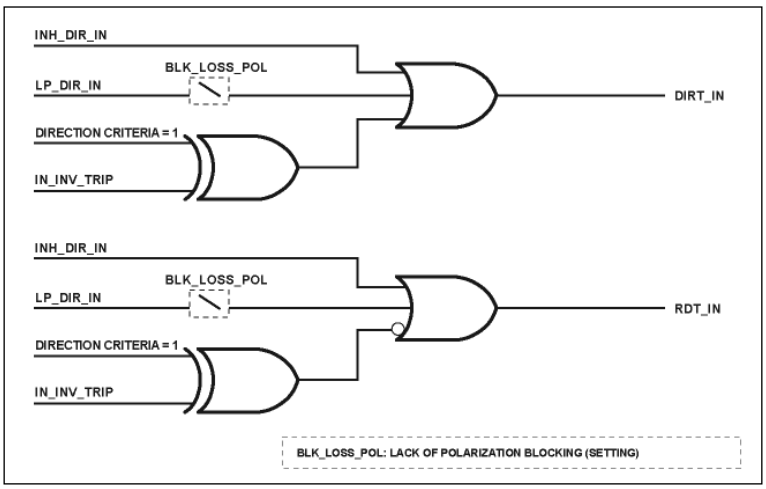


Figure 4.2.2 Block Diagram of a Directional Phase Element.

The **Inversion of the Trip Direction** (**IN_INV_TRIP**) input changes, if activated, the direction of operation of the directional element.

4.2.2.d Self-Polarized Function

The phase directional unit has the ***Phase Polarization Mode*** setting which allows the polarization phasor to be changed, by default Cross-Polarized (according to Table 4.2-2), to work with self-polarization (voltage of the faulted phase).

In the case of working with own polarization, the characteristic angle used by the unit is 90 - Phase Characteristic Angle setting.

Table 4.2-2: Ground Directional Unit

Fop	Fpol	Criteria
IA	VA	−(180º −ANG _ 67) ≤ [arg(Fop) − arg(Fpol)] ≤ (ANG _ 67)
IB	VB	
IC	VC	

The Self-Polarized function depends on a polarization magnitude that can be very weak, because the faulted phase can suffer a considerable voltage drop, while the cross polarization guarantees a stronger polarization magnitude, involving the voltages of the two phases that are different from the phase of the operating magnitude.

For this reason, it is recommended to leave the ***Phase Polarization Mode*** setting at its default value (**Cross-Polarized**).

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4.2.2.e Application

In parallel transformer systems and busbar coupling, Directional Instantaneous Overcurrent elements are normally applied at first instance to prevent the opening of the busbar power supply upon transformer faults, it being possible to use non directional elements with higher delay times as backup.

In ring systems, as for secondary substations to supply power to airports or underground systems, the current can flow in any direction and so directional elements are used to detect faults between bays.

4.2.2.f Examples of Settings Calculation

In this section, the analysis of the phase ***Characteristic Angle*** setting value with respect to the ***Polarization Magnitude*** used by the relay to establish the **Maximum Torque Line** resulting into the **Operation** and **Blocking** zones of the phase differential elements in **Direction** mode is carried out.

Let us assume the simple case of a single A- phase to ground fault with no fault impedance in a three phase line opened at one end. If $\mathbf{Z_{la}}$ is line impedance, fault current $\mathbf{I_A}$ will be produced by voltage $\mathbf{V_A}$ with phase lag angle α.

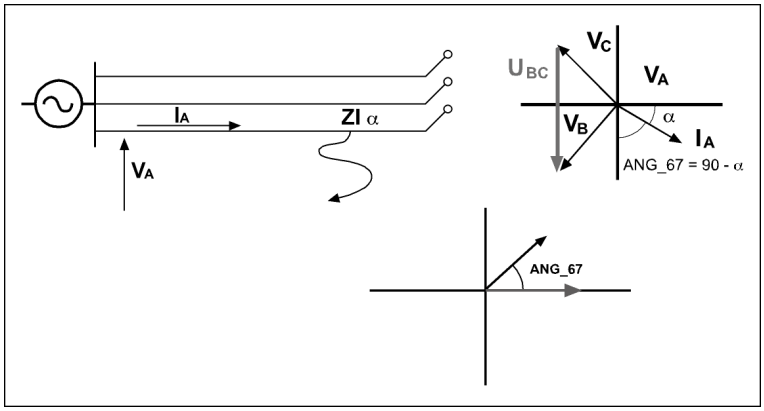


Figure 4.2.3 Graphics for the Application Example.

Relays with phase directional elements do not use phase-to-neutral voltages as polarization magnitudes for the corresponding operate magnitudes (phase currents). They use phase-to-phase voltages of the other phases not involved with the possible single phase to ground fault as **Polarization Magnitudes** (see Table 4.2-1).

As shown in the above graphics, for an A-phase to ground fault as described above, the polarization magnitude used by the relay in order to decide tripping or not, is voltage $U_{BC} = V_B - V_C$, with a phase lag of 90º with respect to the phase to neutral voltage of the faulted phase V_A .

As the **Phase Characteristic Angle** (**ANG_67**) set at the relay is the angle between **Operate Magnitude** and **Polarization Magnitude** (see Figure 4.2.1), the value to be assigned is the complementary angle to the **Line Impedance** angle.

All comments made so far for phase A can be directly extrapolated to phases B and C.

In conclusion, if **ZIα** is the line impedance, the setting of the phase characteristic angle (**ANG_67**) is:

ANG_67 = 90 - α

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4.2.2.g Setting Ranges

Protection / Overcurrent / Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase Characteristic Angle	Phase Charac Angle	PHSRDIR1.ChrAng	-90º - +90º	1º	15º
Lack of Direction Blocking	Lack Polariz Block	GNDRDCF1.BlkLosPol	YES / NO		NO
Min Phase Voltage	Min. Phase Voltage	PHSRDIR1.BlkValV	0.05 - 10V	0.01V	0.2V
Coordinating Time	Coord. Time	GNDRDCF1.CrdTmms	0 - 30ms	1ms	0ms
Phase Polarization Mode	Phase Polariz Mode		Cross-Polarized Self-Polarized		Cross-polarized

4.2.2.h Analog Inputs to the Unit

The operating magnitude of the Phase Directional Elements will be the fundamental current IA, IB and IC. Also, it will use the memorized phase voltages as polarization magnitude.

Table 4.2-3: Analog Inputs of the Overcurrent Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
VAB	AB Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsAB
VBC	BC Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsBC
VCA	CA Phase-to-Phase Voltage (ABC Sequence)	MMXU1.PPV.phsCA
VAC	AC Phase-to-Phase Voltage (ACB Sequence)	
VBA	BA Phase-to-Phase Voltage (ACB Sequence)	
VCB	CB Phase-to-Phase Voltage (ACB Sequence)	

4.2.2.i Digital Inputs to the Phase Directional Element

Table 4.2-4: Digital Inputs to the Phase Directional Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_DIR_PH	Logic Inputs to protection	PHSRDIR1.Mod	Phase Directional Inhibit	I	The activation of that input converts the directional elements into non-directional.
IN_INV_TRIP		RDCF1.ChgTrDir	Reverse Polarization	I	When the input is quiescent, the operation zone is the indicated in settings. If it is activated, the operation zone is inverted.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.2.j Auxiliary Outputs and Events of the Phase Directional Module

Table 4.2-5: Auxiliary Outputs of the Phase Directional Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RDI_A	Directional Protection Outputs	PHSRDIR1.Dir1	Phase A Instantaneous Trip Reverse Direction	I,F	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the "coordination time" is up.
RDI_B		PHSRDIR1.Dir1	Phase B Instantaneous Trip Reverse Direction	I,F	
RDI_C		PHSRDIR1.Dir1	Phase C Instantaneous Trip Reverse Direction	I,F	
RDT_A		PHSRDIR1.Dir2	Phase A Time Overcurrent Trip Reverse Direction	I,F	
RDT_B		PHSRDIR1.Dir2	Phase B Time Overcurrent Trip Reverse Direction	I,F	
RDT_C		PHSRDIR1.Dir2	Phase C Time Overcurrent Trip Reverse Direction	I,F	
DIRI_A		PHSRDIR1.Dir1	Phase A Instantaneous Trip Direction	I,F	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the "coordination time" is up.
DIRI_B		PHSRDIR1.Dir1	Phase B Instantaneous Trip Direction	I,F	
DIRI_C		PHSRDIR1.Dir1	Phase C Instantaneous Trip Direction	I,F	
DIRT_A		PHSRDIR1.Dir2	Phase A Time Overcurrent Trip Direction	I,F	
DIRT_B		PHSRDIR1.Dir2	Phase B Time Overcurrent Trip Direction	I,F	
DIRT_C		PHSRDIR1.Dir2	Phase C Time Overcurrent Trip Direction	I,F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.2.k IEC 61850 Logical Nodes

CLASS IRLRDCF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Extended Data		
ChgTrdir	EXT_SPC	Polarization inversion command
BlkLosPol	EXT_SPG	Block due to loss of polarization
CrdTmms	EXT_ING	Coordination time

CLASS IRLPHSRDIR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Dir1	ACD	Phase instantaneous units direction
Dir2	ACD	Phase time units direction
Settings		
ChrAng	ASG	Characteristic angle
BlkValV	ASG	Minimum operating polarization voltage

4.2.2.l Protection Element Test

Prior to testing check that ***Pickup Blocking Enable*** setting or ***Torque Control*** setting are set **Direction**, and that **Direction Reversal** input is disabled.

Testing can be carried out: Ia with Vb, Ib with Vc and Ic with Va. Following Table shows the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not go to menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Overcurrent** and check the state of flags corresponding to the tested phase.

Table 4.2-6: Phase Directional	
V APPLIED	I APPLIED
Vb = 64V ⌊0º	Ia = 1A ⌊(270º+α charact to 90º + α charact) ± 2º
Vc = 64V ⌊0º	Ib = 1A ⌊(270º+α charact to 90º + α charact) ± 2º
Va = 64V ⌊0º	Ic = 1A ⌊(270º+α charact to 90º + α charact) ± 2º

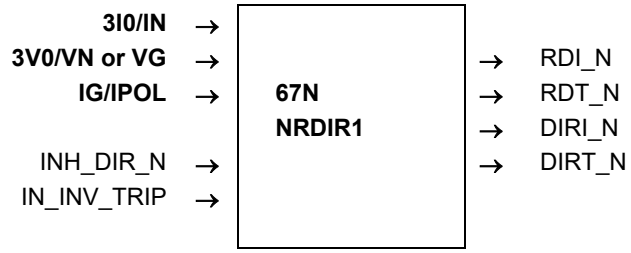
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4.2.3 Neutral Directional Element

4.2.3.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Neutral Directional Overcurrent Unit	NRDIR1	3Io →	67N

4.2.3.b General Block



4.2.3.c Operation Principles and Block Diagram

The operation of the Neutral Directional Element is based on neutral sequence magnitudes. The neutral current (310) calculated by the relay from phase currents and compensated through the setting ***Neutral Voltage Compensation Factor*** (Neutr Volt. Comp.: K_{COMP_67N}) is taken as operating magnitude.

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

The polarization magnitude will be the neutral voltage measured by the relay through the channel used to measure **VG**, when the ***Neutral/Ground V_POL Type*** setting is set to **VG**, whereas the relay will use the neutral zero sequence voltage calculated from the phase voltages, when the ***Neutral/Ground V_POL Type*** setting is set to **VN**.

$$\overline{V_N} = \overline{VA} + \overline{VB} + \overline{VC} \quad (\textbf{\textit{Neutral/Ground V_POL Type}} = \textbf{VN } \textbf{\textit{Type}})$$

In this case Neutral Directional Element operating principle rests on finding the angle difference between the compensated zero-sequence current and zero-sequence voltage. Figure 4.2.4 shows the associated to the Neutral Directional Element.

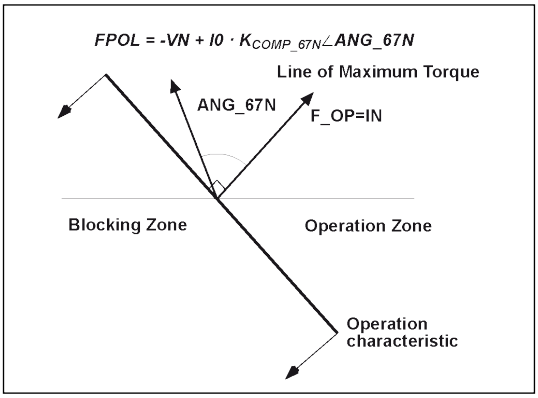


Figure 4.2.4 Vector Diagram of the Neutral Directional Element.

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The Neutral Directional Element checks that the operating and polarization phasors exceed a given value. This value is **6.9 mA** for the operating phasor, regardless the value of the ***Torque Control*** *setting* (***67N*** or ***67G***), the value to be exceeded by the polarization phasor being settable as a function of the ***Neutral/Ground V_POL Type*** selected.

- If option ***VN*** is selected, the ***Minimum Neutral Voltage*** setting must be exceeded (since the setting refers to the calculated neutral voltage).
- If option ***VG*** is selected, the ***Minimum Ground Voltage*** setting must be exceeded (since the setting refers to the measured ground voltage).

If the operating or polarization phasor does not exceed its values, the ***Lack of Direction Blocking*** setting is checked. If this setting is set to **NO,** it operates the same as for directional element disabled, but if set to **YES,** it indicates blocking by lack of polarization and trips in both directions are blocked.

The following table shows the operation and polarization phasors which intervene in the Neutral Directional Element, as well as the operation criteria applied.

Table 4.2-7: Neutral Directional Element

Fop	Fpol	Criteria
IN	$-VN + IN \cdot K_{COMP_67N}\angle ANG_67N$	$-\left(90º + ANG_67N/G\right) \le \left[\arg\left(Fop\right) - \arg\left(Fpol\right)\right] \le \left(90º - ANG_67N/G\right)$

However, the K_{COMP_67N} factor is used for the following two reasons:

- **Increase the polarization phasor magnitude**, in order that this exceeds the ***Minimum Neutral Voltage***:

  When the zero sequence impedance of the local source is small, in case of forward fault, the $3V0$ voltage which measures the relay may present values under the ***Minimum Neutral Voltage*** setting [it was previously deduced that $3V0 = ZA0 \cdot (-3I0)$]. In order to have sufficient voltage to polarize the Neutral directional element, a new voltage with the same phase is added to the $-3V0$ phasor, which will correspond to the voltage drop in an impedance with **ANG_67N/G** angle (it is assumed that this adjustment will be equal to the $ZA0$ angle) and with a magnitude equal to K_{COMP_67N}. The effect of the new polarization phasor is that of expanding the zero sequence impedance magnitude of the local source with a value equal to K_{COMP_67N}.

- **Compensate the inversion that the V0 voltage** may undergo in lines with series compensation:

  In case of faults in a forward direction, in a line with series compensation, $3V0$ will be reversed (approximately 180º considering that the angle of source impedance is close to 90º), provided that the zero sequence impedance existing between the voltage transformer and the local source is capacitive. In this case, the directional element will act erroneously since it will consider that the fault is in the reverse direction. In order to rotate the reversed $-3V0$ voltage 180º, such that the directional element can see the fault in a forward direction, a K_{COMP_67N} factor should be applied whose value exceeds the capacitive reactance value introduced.

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The activation of the **Directional Neutral Element Inhibit** (**INH_DIR_N**) input converts the element to non-directional.

The logic diagram of operation of the Neutral Directional Element is shown in Figure 4.2.5.

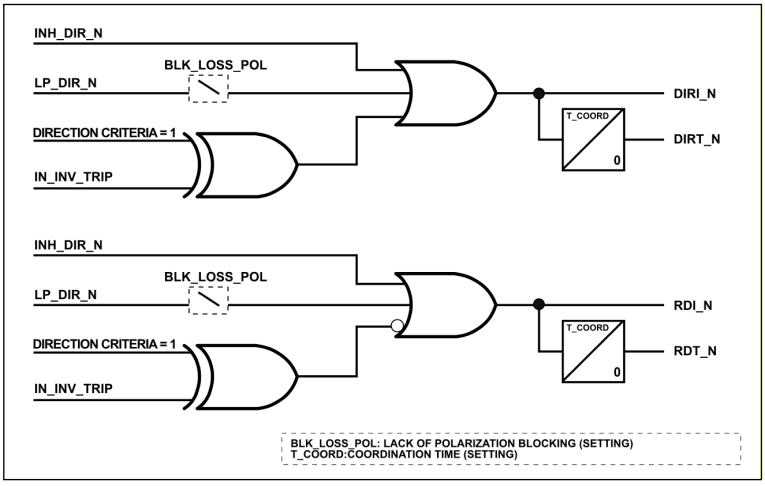


Figure 4.2.5 Block Diagram of a Neutral Directional Element.

4.2.3.d Polarization by Current

Determining the phase displacement between the residual current and the current circulating through the grounding is simple because the phase displacements between the two magnitudes can only be 0º and 180º or, what is the same, the characteristic angle must always be 0º.

When it is configured in direction, the operation zone is the zone in which the fault or operating current **In** is in phase 0º with respect to the current flowing through the grounding. As in the figure **F_POL** is equal to the **IPT**, therefore, **F_POL** and **In** must be in phase to be in the operation zone. When it is configured in reverse direction, it enables the overcurrent element in the opposite semiplane. Figure 4.2.6 shows the vector diagram associated with the neutral directional element when the polarization by current is used

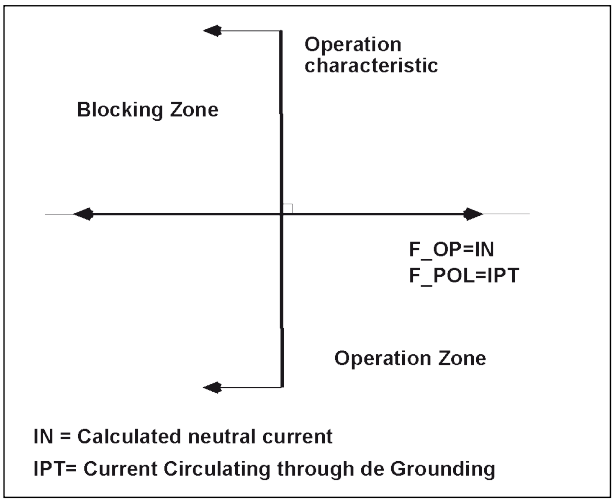


Figure 4.2.6 Vector Diagram of the Directional Ground Element (Polarization by Current).

Note: Current polarization may be present when setting the *TYPE of IG* as IG, otherwise, when the *TYPE of IG* is set to IN, current polarization will not affect the neutral directional element.

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4.2.3.e Example of Settings Calculation

Figures 4.2.7 and 4.2.8 show the zero sequence network for a ground fault (single phase or two phase) in a forward and reverse direction, respectively.

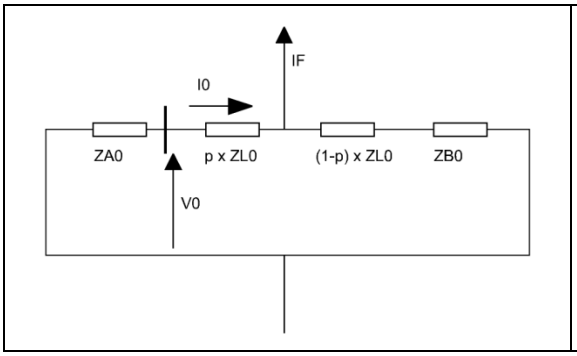


Figure 4.2.7 Zero Sequence Network for Forward Fault.

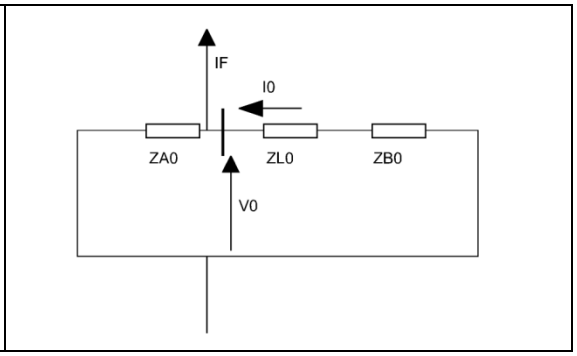


Figure 4.2.8 Zero Sequence Network for Reverse Fault.

As the ground directional element operates with **3V0** (VN) and **3I0**, the formulas below will include the factor 3 in both members of equation.

If the fault is in forward direction, it can be deduced that $3V0 = ZA0 \cdot (-3I0)$, where $ZA0$ is the zero sequence impedance of the local source. It is seen, consequently, that the angle between $-3V0$ and $3I0$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the ground directional element (***ANG_67N/G*** setting).

If the fault is in the reverse direction, the following expression will be obtained: $3V0 = (ZL0 + ZB0) \cdot 3I0$, where $ZL0$ and $ZB0$ are the zero sequence impedance of the line and the remote source, respectively. Consequently, the angle between $-3V0$ and $3I0$ will be supplementary of the angle of $ZL0 + ZB0$ impedance (which will be similar to the $ZA0$ angle).

Through the relative phase difference between $-3V0$ and $3I0$, the directionality of the fault can be deduced.

The K_{COMP_67N} value should be restricted in order that the Neutral Directional Element does not take any erroneous directional decisions in case of faults in the reverse direction. When the fault is in the reverse direction $3V0 = (ZL0 + ZB0) \cdot 3I0$, as was deduced previously. If we assume that the $ZL0 + ZB0$ angle is similar to the ***ANG_67N/G*** setting (assumption equal to $ZA0$ angle), $-3V0$ and $3I0 \cdot K_{COMP_67N}$ will be in anti-phase, for which the sum of $3I0 \cdot K_{COMP_67N}$ reduces the polarization phasor value, with it being possible to even reverse its direction. The latter would occur if $K_{COMP_67N} > (ZL0 + ZB0)$; in this case, the directional element would consider that the fault is in forward direction. For this reason, the K_{COMP_67N} value is restricted by the $ZL0 + ZB0$ value.

In order to avoid erroneous directional decisions in case of reverse directional faults, as was indicated previously, K_{COMP_67N} should be less than $ZL0 + ZB0$ (impedance existing between the voltage transformer and the remote source).

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4.2.3.f Setting Ranges

Protection / Overcurrent / Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutr./Gnd Characteristic Angle	Neu/gnd Char Angle	RDCF1.ChrAngNGnd	-90º - +90º	1º	75º
Lack of Direction Blocking	Lack Polariz Block	RDCF1.BlkLosPol	YES / NO		NO
Min Neutr Voltage	Min. Neutr Voltage	NRDIR1.BlkValV	0.05 - 10V	0.01V	0.2V
Min Gnd. Voltage	Min. Gnd Voltage	GNDRDIR1.BlkValV	0.05 - 10V	0.01V	0.2V
Neutr Volt. Comp.	Gnd Volt. Comp.	NRDIR1.KFactPol	0 - 50	0.01	0
Coordinating Time	Coord. Time	GNDRDCF1.CrdTmms	0 - 30ms	1ms	0ms
Neutral/Ground V_POL Type	Tipo V_POL Neu/gnd	RDCF1.VPolTyp	VN VG		VN

4.2.3.g Analog Inputs to the Unit

The operating magnitude of the Neutral Directional Elements will be the neutral calculated current from the fundamental currents IA, IB and IC. Also, it will use the measured or calculated neutral voltage from the phase voltages as a function of the ***Neutral/Ground V_POL Type*** setting and the **IG** as polarization magnitudes.

The current polarization magnitude for the ground directional element will be the measured ground current (**IG**) as a function of the setting ***Type of IG***.

Table 4.2-8: Analog Inputs to the Neutral Directional Module		
Name	**Description**	**IEC 61850**
3I0 / IN	Neutral calculated current	MMXU1.A.res
IG / IPOL	Neutral polarization current	MMXU1.A.neut
VG	Measured neutral voltage	MMXU1.PhV.neut
3V0 / VN	Neutral calculated voltage	MMXU1.PhV.res

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C} \quad (\textbf{\textit{Neutral/Ground V_POL Type}})$$

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4.2.3.h Digital Inputs to the Neutral Directional Element

Table 4.2-9: Digital Inputs to the Neutral Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_DIR_N	Logic Inputs to Protection	NRDIR1.Mod	Neutr Directional Inhibit	I	The activation of these inputs converts the directional elements into non-directional.
IN_INV_TRIP		RDCF1.ChgTrDir	Reverse Polarization	I	When the input is quiescent, the operation zone is the indicated in settings. If it is activated, the operation zone is inverted.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.2.3.i Auxiliary Outputs and Events of the Neutral Directional Module

Table 4.2-10: Auxiliary Outputs of the Neutral Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RDI_N	Directional Protection Outputs	NRDIR1.Dir1	Neutr Instantaneous Trip Reverse Direction	I,F	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
RDT_N		NRDIR1.Dir2	Neutr Time Overcurrent Trip Reverse Direction	I,F	
DIRI_N		NRDIR1.Dir1	Neutr Instantaneous Trip Direction	I,F	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
DIRT_N		NRDIR1.Dir2	Neutr Time Overcurrent Trip Direction	I,F	
	Generic Outputs of Protection	NRDIR1.LosPol	Loss of Polarization for Neutr Directional Unit	I	Indication that the polarization magnitude does not exceeds the minimum values.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.3.j IEC 61850 Logical Node

CLASS IRLNRDIR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Dir1	ACD	Instantaneous units direction
Dir2	ACD	Time units direction
Settings		
ChrAng	ASG	Characteristic angle
BlkValV	ASG	Minimum operating polarization voltage
Extended Data		
KFactPol	EXT_ASG	Compensation factor
LosPol	EXT_ACT	Polarization signal is lost

4.2.3.k Protection Element Test

Prior to testing check that ***Pickup Blocking Enable*** setting or ***Torque Control*** setting are set **Direction**, and that **Direction Reversal** input is disabled.

Testing can be carried out: In with Va (provided the ***Neutral/Ground V_POL Type = VN***) or with the **VG** channel (provided the ***Neutral/Ground V_POL Type = VG***). Following Table shows the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not go to menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Overcurrent** and check the state of flags corresponding to the tested phase.

Table 4.2-11: Neutral Directional Control			
Neutral Directional and Sensitive Ground Directional by Vpol		**Neutral Directional by Ipol**	
V APPLIED	I APPLIED	I APPLIED	
Vpol = 64V⌊0º	In = 1A⌊ (90º - α caract to 270º - α caract) $\pm$ 2º	Ip = 1A⌊180º	In = 1A⌊-90º a 90º

Depending on the value of the ***Neutral/Ground V_POL Type*** setting, the Vpol will become what is injected into **VA** or **VG**.

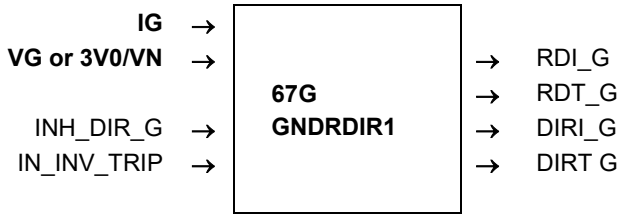
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4.2.4 Ground Directional Element

4.2.4.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Ground Directional Overcurrent Unit	GNDRDIR1	3Io →	67G

4.2.4.b General Block



4.2.4.c Operation Principles and Block Diagram

The operation of the Ground Directional Element is based on the use of zero sequence magnitudes. The ground current (IG) measured and compensated through the setting ***Ground Voltage Compensation Factor*** (Ground Volt. Comp.: K_{COMP_67G}) is taken as operating magnitude.

The polarization magnitude will be the neutral voltage measured by the relay through the channel used to measure **VG**, when the ***Neutral/Ground V_POL Type*** setting is set to **VG**, whereas the relay will use the neutral zero sequence voltage calculated from the phase voltages, when the ***Neutral/Ground V_POL Type*** setting is set to **VN**.

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C} \quad (\textbf{\textit{Neutral/Ground V_POL Type = VN}})$$

The operating principle of the ground directional element rests on the determination of the phase difference between the "compensated" zero sequence current and zero sequence voltage. Figure 4.2.9 shows the vector diagram associated to the Ground Directional Unit.

Note: If the grounding channel (IG) is used for ground directional element current polarization, the directional function should not be used in the ground directional elements, this being meaningless.

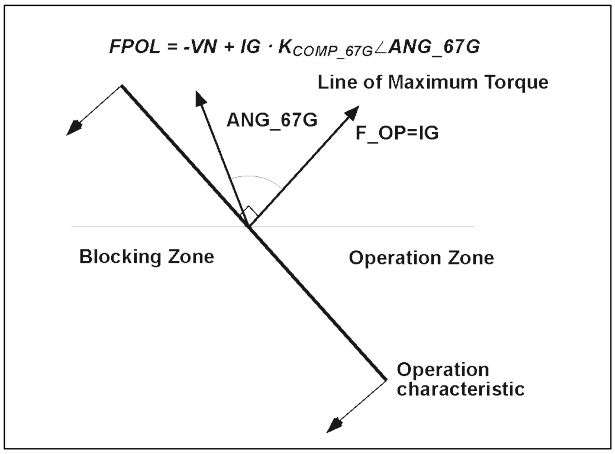


Figure 4.2.9 Vector Diagram of the Directional Ground Element.

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The ground directional element checks that operating and polarization phasors exceed given values. This value is **6.9 mA** for the operating phasor, regardless the value of the ***Torque control*** *setting* (***67N*** or ***67G***), the value to be exceeded by the polarization phasor being settable as a function of the ***Neutral/Ground V_POL Type*** selected.

- If option ***VG*** is selected, the ***Minimum Ground Voltage*** setting must be exceeded (since the setting refers to the measured ground voltage).
- If option ***VN*** is selected, the ***Minimum Neutral Voltage*** setting must be exceeded (since the setting refers to the calculated neutral voltage).

If the operating or polarization phasor does not exceed its values, the ***Lack of Direction Blocking*** setting is checked. If this setting is set to **NO,** it operates the same as for directional element disabled, but if set to **YES,** it indicates blocking by lack of polarization and trips in both directions are blocked.

The following table shows the operation and polarization phasors which intervene in the Ground Directional Element, as well as the operation criteria applied.

Table 4.2-12: Ground Directional Element

Fop	Fpol	Criteria
IG	$-VN + IG \cdot K_{COMP_67G} \angle ANG_67N/G$	$-\left(90º + ANG_67N/G\right) \le \left[\arg\left(Fop\right) - \arg\left(Fpol\right)\right] \le \left(90º - ANG_67N/G\right)$

However, the K_{COMP_67G} factor is used for the following two reasons:

- **Increase the polarization phasor magnitude**, in order that this exceeds the ***Minimum Ground Voltage***:

  When the zero sequence impedance of the local source is small, in case of forward fault, the VN voltage which measures the relay may present values under the ***Minimum Ground Voltage*** setting [it was previously deduced that $3V0 = ZA0 \cdot (-IG)$]. In order to have sufficient voltage to polarize the Ground directional element, a new voltage with the same phase is added to the $-3V0$ phasor, which will correspond to the voltage drop in an impedance with **ANG_67N/G** angle (it is assumed that this adjustment will be equal to the $ZA0$ angle) and with a magnitude equal to K_{COMP_67G}. The effect of the new polarization phasor is that of expanding the zero sequence impedance magnitude of the local source with a value equal to K_{COMP_67G}.

- **Compensate the inversion that the V0 voltage** may undergo in lines with series compensation:

  In case of faults in a forward direction, in a line with series compensation, $3V0$ will be reversed (approximately 180º considering that the angle of source impedance is close to 90º), provided that the zero sequence impedance existing between the voltage transformer and the local source is capacitive. In this case, the directional element will act erroneously since it will consider that the fault is in the reverse direction. In order to rotate the reversed $-3V0$ voltage 180º, such that the directional element can see the fault in a forward direction, a K_{COMP_67G} factor should be applied whose value exceeds the capacitive reactance value introduced.

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The activation of the **Directional Ground Element Inhibit** (**INH_DIR_G**) input converts the element to non-directional.

The logic diagram of operation of the Ground Directional Element is shown in Figure 4.2.10.

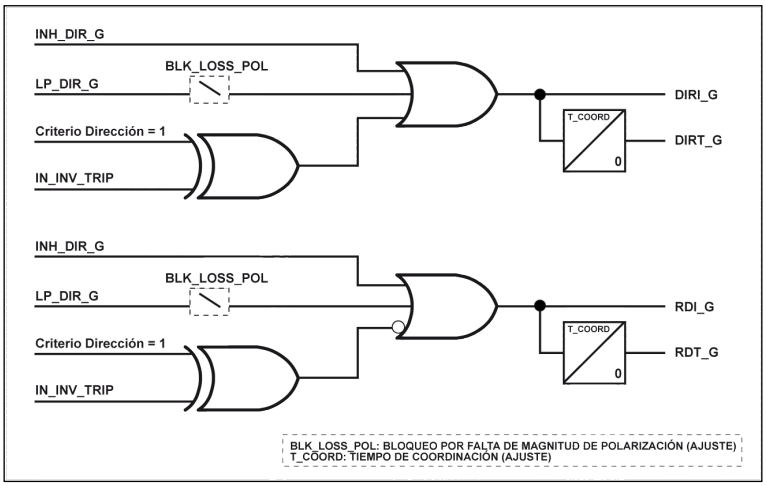


Figure 4.2.10 Block Diagram of a Ground Directional Element.

4.2.4.d Example of Settings Calculation

Figures 4.2.11 and 4.2.12 show the zero sequence network for a ground fault (single phase or two phase) in a forward and reverse direction, respectively.

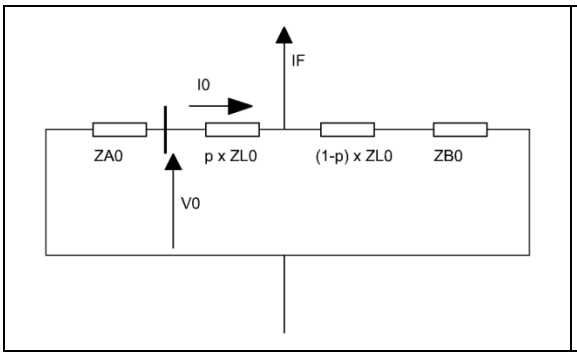


Figure 4.2.11 Zero Sequence Network for Forward Fault.

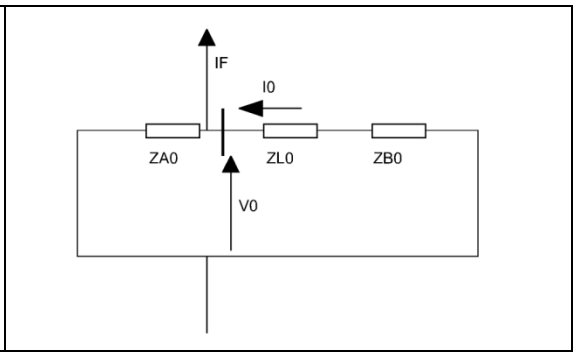


Figure 4.2.12 Zero Sequence Network for Reverse Fault.

As the ground directional element operates with **3V0** (VN) and **IG**, the formulas below will include the factor 3 in one side of the equation and **IG** instead of **I0** in the other side.

If the fault is in forward direction, it can be deduced that $3V0 = ZA0 \cdot (-IG)$, where $ZA0$ is the zero sequence impedance of the local source. It is seen, consequently, that the angle between $-3V0$ and IG will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the ground directional element (***ANG_67N/G*** setting).

If the fault is in the reverse direction, the following expression will be obtained: $3V0 = (ZL0 + ZB0) \cdot IG$, where $ZL0$ and $ZB0$ are the zero sequence impedance of the line and the remote source, respectively. Consequently, the angle between $-3V0$ and IG will be supplementary of the angle of $ZL0 + ZB0$ impedance (which will be similar to the $ZA0$ angle).

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Through the relative phase difference between $-3V0$ and IG the directionality of the fault can be deduced.

The ***KCOMP_67G*** value should be restricted in order that the Ground Directional Element does not take any erroneous directional decisions in case of faults in the reverse direction. When the fault is in the reverse direction $3V0 = (ZL0 + ZB0) \cdot IG$, as was deduced previously. If we assume that the $ZL0 + ZB0$ angle is similar to the ***ANG_67N/G*** setting (assumption equal to $ZA0$ angle), $-3V0$ and $IG \cdot K_{COMP_67G}$ will be in anti-phase, for which the sum of $IG \cdot K_{COMP_67G}$ reduces the polarization phasor value, with it being possible to even reverse its direction. The latter would occur if $\boldsymbol{K}_{\boldsymbol{COMP_67G}} > \left(\boldsymbol{ZL}0 + \boldsymbol{ZB}0\right)$; in this case, the directional element would consider that the fault is in forward direction. For this reason, the ***KCOMP_67G*** value is restricted by the $ZL0 + ZB0$ value.

In order to avoid erroneous directional decisions in case of reverse directional faults, as was indicated previously, ***KCOMP_67G*** should be less than $ZL0 + ZB0$ (impedance existing between the voltage transformer and the remote source).

4.2.4.e Setting Ranges

Protection / Overcurrent / Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutr./Gnd Characteristic Angle	Neu/gnd Char Angle	RDCF1.ChrAngNGnd	-90º - +90º	1º	75º
Lack of Direction Blocking	Lack Polariz Block	RDCF1.BlkLosPol	YES / NO		NO
Min. Gnd Voltage	Min. Gnd Voltage	GNDRDIR1.BlkValV	0.05 - 10V	0.01V	0.2V
Min. Neutr Voltage	Min. Neutr Voltage	NRDIR1.BlkValV	0.05 - 10V	0.01V	0.2V
Coordinating Time	Coord. Time	RDCF1.CrdTmms	0 - 30ms	1ms	0ms
Neutral/Ground V_POL Type	Tipo V_POL Neu/gnd	RDCF1.VPolTyp	VN VG		VN

4.2.4.f Analog Inputs to the Unit

The ground directional element operating magnitude will be the measured ground current. Also, it will use the measured ground voltage or calculated from the phase voltages as a function of the setting ***Neutral/Ground V_POL Type***.

Table 4.2-13: Analog Inputs to the Ground Directional Module		
Name	**Description**	**IEC 61850**
IG	Ground Measured Current	MMXU1.A.neut
VG	Neutral Measured Voltage	MMXU1.PhV.neut
3V0/VN	Neutral Calculated Voltage	MMXU1.PhV.res

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4.2.4.g Digital Inputs to the Ground Directional Element

Table 4.2-14: Digital Inputs to the Ground Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_DIR_G	Logic Inputs to Protection	GNDRDIR1.Mod	Ground Directional Inhibit	I	The activation of these inputs converts the directional elements into non-directional.
IN_INV_TRIP		RDCF1.ChgTrDir	Reverse Polarization	I	When the input is quiescent, the operation zone is the indicated in settings. If it is activated, the operation zone is inverted.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.2.4.h Auxiliary Outputs and Events of the Ground Directional Module

Table 4.2-15: Auxiliary Outputs of the Ground Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RDI_G	Directional Protection Outputs	GNDNRDIR1.Dir1	Ground Instantaneous Trip Reverse Direction	I,F	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
RDT_G		GNDRDIR1.Dir2	Ground Time Overcurrent Trip Reverse Direction	I,F	
DIRI_G		GNDNRDIR1.Dir1	Ground Instantaneous Trip Direction	I,F	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
DIRT_G		GNDRDIR1.Dir2	Ground Time Overcurrent Trip Direction	I,F	
	Generic Outputs of Protection	GNDRDIR1.LosPol	Loss of Polarization for Ground Directional Unit	I	Indication that the polarization magnitude does not exceeds the minimum values.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.4.i IEC 61850 Logical Node

CLASS IRLGNDRDIR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Dir1	ACD	Instantaneous units direction
Dir2	ACD	Time units direction
Settings		
ChrAng	ASG	Characteristic angle
BlkValV	ASG	Minimum operating polarization voltage
Extended Data		
KFactPol	EXT_ASG	Compensation factor
LosPol	EXT_ACT	Polarization signal is lost

4.2.4.j Protection Element Test

Prior to testing check that ***Pickup Blocking Enable*** setting or ***Torque Control*** setting are set **Direction**, and that **Direction Reversal** input is disabled.

Testing can be carried out: Ig with Va (provided the ***Neutral/Ground V_POL Type = VN***) or with the **VG** channel (provided the ***Neutral/Ground V_POL Type = VG***). Following Table shows the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not go to menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Overcurrent** and check the state of flags corresponding to the tested phase.

Table 4.2-16: Ground Directional Control

Ground Directional and Sensitive Ground Directional by Vpol		Ground Directional by Ipol	
V APPLIED	I APPLIED	I APPLIED	
Vpol = 64V⌊0º	IG = 1A⌊ (90º - α caract to 270º - α caract) ± 2º	Ip = 1A⌊180º	IG = 1A⌊-90º a 90º

Depending on the value of the ***Neutral/Ground V_POL Type*** setting, the Vpol will become what is injected into **VA** or **VG**.

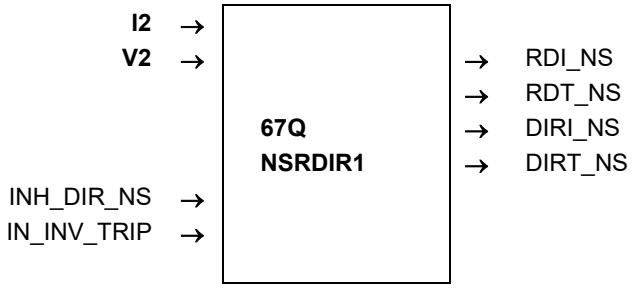
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4.2.5 Negative Sequence Directional Element

4.2.5.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Negative Sequence Directional Overcurrent Unit	NSRDIR1	I2 →	67Q

4.2.5.b General Block



4.2.5.c Operation Principles and Block Diagram

The operating principle is based on calculating the phase angle difference between the compensated Negative Sequence current and the negative sequence voltage. Figure 4.2.13 shows the vector diagram associated to a Negative Sequence Directional element.

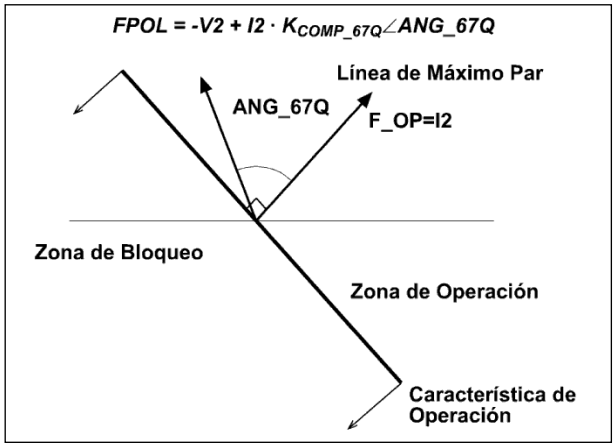


Figure 4.2.13 Vector Diagram of the Negative Sequence Directional Element.

The devices use the compensated zero sequence voltage as directional element polarization phasor, through setting ***Negative Sequence Voltage Compensation Factor*** (K_{COMP_67Q}): $-V2 + I2 \cdot K_{COMP_67Q}\angle ANG_67Q$.

Table 4.2-17: Negative Sequence Directional Unit		
Fop	**Fpol**	**Criteria**
I2	$-V2 + I2 \cdot K_{COMP_67Q}\angle ANG_67Q$	$-(90° + ANG_67Q) \le [\arg(Fop) - \arg(Fpol)] \le (90° - ANG_67Q)$

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Everything said for ***Zero sequence compensation factor*** is applicable to ***Sequence voltage compensation factor***, if the negative sequence network is taken into account instead of the zero sequence network. The purpose of factor K_{COMP_67Q} is as follows:

- Increase the polarization phasor magnitude, in order that this exceeds the ***Minimum Zero Sequence Voltage***.
- Compensate the inversion that the V2 voltage may undergo in lines with series compensation.

The logic diagram of operation of the Directional Negative Sequence element is shown in Figure 4.2.14.

If the **Inversion of Directionality** (**IN_INV_TRIP**) input is active, the direction of calculated direction is changed.

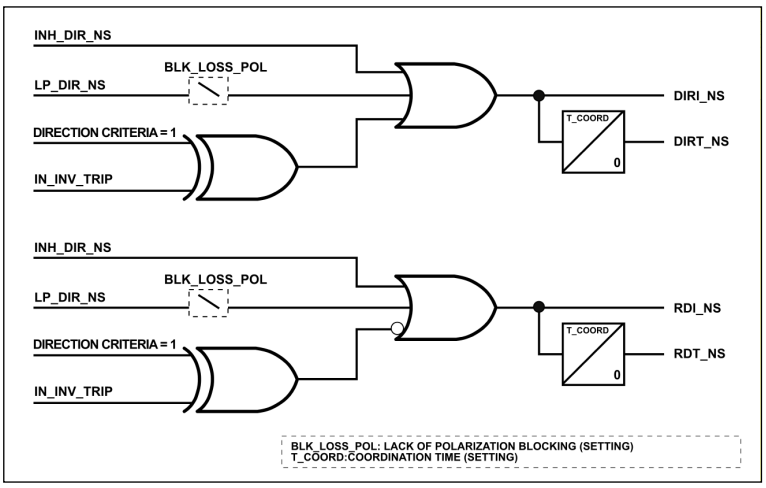


Figure 4.2.14 Block Diagram of a Directional Negative Sequence Element.

The activation of the **Negative Sequence Directional Element Inhibit** (**INH_DIR_NS**) input converts the element into non-directional.

4.2.5.d Example of Settings Calculation

Figures 4.2.15 and 4.2.16 show the negative sequence network for un unbalanced forward or reverse fault respectively (single phase or double phase).

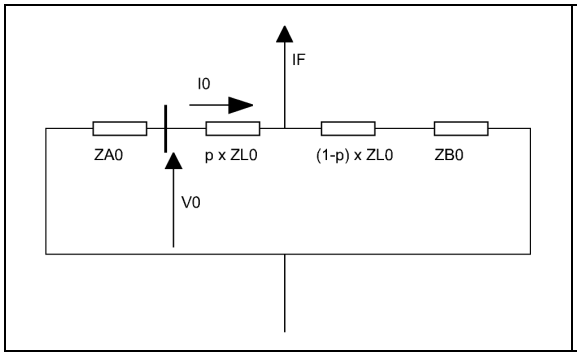


Figure 4.2.15 Negative Sequence Network for Forward Fault.

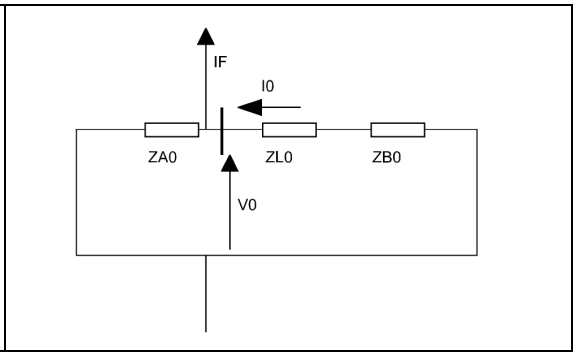


Figure 4.2.16 Negative Sequence Network for Reverse Fault.

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If the fault is in forward direction, it can be deduced that $-V2 = ZA2 \cdot (-I2)$, where $ZA2$ is the negative sequence impedance of the local source. It is seen, consequently, that the angle between $-V2$ and $I2$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the ground directional element (**ANG_67Q** setting).

Everything said for ***Zero Sequence Compensation Factor*** in the paragraphs relative to the Neutral and Sensitive Ground Directional elements is applicable to ***Sequence Voltage Compensation Factor***.

4.2.5.e Setting Ranges

Protection / Overcurrent / Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
NegSeq Characteristic Angle	NegSeq Char. Angle	NSRDIR1.ChrAng	-90º - +90º	1º	75º
Lack of Direction Blocking	Lack Polariz Block	RDCF1.BlkLosPol	YES / NO		NO
Min Neg Seq Voltage	Min NegSeq Voltage	NSRDIR1.MinVN	0.05 - 10V	0.01V	1V
Coordinating Time	Coord. Time	RDCF1.CrdTmms	0 - 30ms	1ms	0ms

4.2.5.f Analog Inputs to the Unit

The operation magnitude of the Negative Sequence Directional element will be the negative sequence calculated current. It will also make use of the negative sequence calculated voltage as polarization magnitude.

Table 4.2-18: Analog Inputs to the Negative Sequence Directional Module		
Name	**Description**	**IEC 61850**
I2	Negative Sequence Calculated Current	MSQI1.SeqA.c2
V2	Negative Sequence Calculated Voltage	MSQI1.SeqV.c2

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

$$|V_2| = \left| \frac{V_A + V_B \cdot 1\angle 240° + V_C \cdot 1\angle 120°}{3} \right|$$

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4.2.5.g Digital Inputs to the Negative Sequence Directional Element

Table 4.2-19: Digital Inputs to the Negative Sequence Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_DIR_NS	Logic Inputs to Protection	NSRDIR1.Mod	Negative Sequence Directional Inhibit	I	The activation of these inputs converts the directional elements into non-directional.
IN_INV_TRIP		RDCF1.ChgTrDir	Reverse Polarization	I	When the input is quiescent, the operation zone is the indicated in settings. If it is activated, the operation zone is inverted.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.2.5.h Auxiliary Outputs and Events of the Negative Sequence Directional Module

Table 4.2-20: Auxiliary Outputs of the Negative Sequence Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RDI_NS	Directional Protection Outputs	NSRDIR1.Dir1	Negative Sequence Instantaneous Trip Reverse Direction	I,F	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
RDT_NS		NSRDIR1.Dir2	Negative Sequence Time Overcurrent Trip Reverse Direction	I,F	
DIRI_NS		NSRDIR1.Dir1	Negative Sequence Instantaneous Trip Direction	I,F	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the “coordination time” is up.
DIRT_NS		NSRDIR1.Dir2	Negative Sequence Time Overcurrent Trip Direction	I,F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.5.i IEC 61850 Logical Node

CLASS IRLNSRDIR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Dir1	ACD	Instantaneous units direction
Dir2	ACD	Time units direction
Settings		
ChrAng	ASG	Characteristic angle
BlkValV	ASG	Minimum operating polarization voltage
Extended Data		
KFactPol	EXT_ASG	Compensation factor
LosPol	EXT_ACT	Polarization signal is lost

4.2.5.j Protection Element Test

Prior to testing check that ***Pickup Blocking Enable*** setting or ***Torque Control*** setting are set **Direction**, and that **Direction Reversal** input is disabled.

Testing can be carried out: Ia with Va. Following Table shows the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not go to menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Overcurrent** and check the state of flags corresponding to the tested phase.

Table 4.2-21: Negative Sequence Directional Control	
V APPLIED	I APPLIED
Va = 64V⌊180º	Ia = 1A⌊ (270º α charact to 90º - α charact) ± 2º

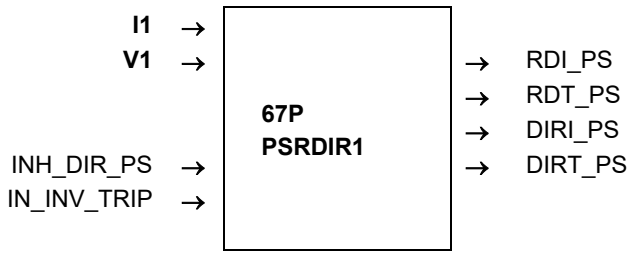
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4.2.6 Positive Sequence Directional Element

4.2.6.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Positive Sequence Directional Overcurrent Unit	PSRDIR1	I1 →	67P

4.2.6.b General Block



4.2.6.c Operation Principles and Block Diagram

The operating principle is based on calculating the phase angle difference between the Positive Sequence current and the positive sequence voltage memorized two cycles before the activation of the Fault Detector. Figure 4.2.17 shows the vector diagram associated to a Positive Sequence Directional element.

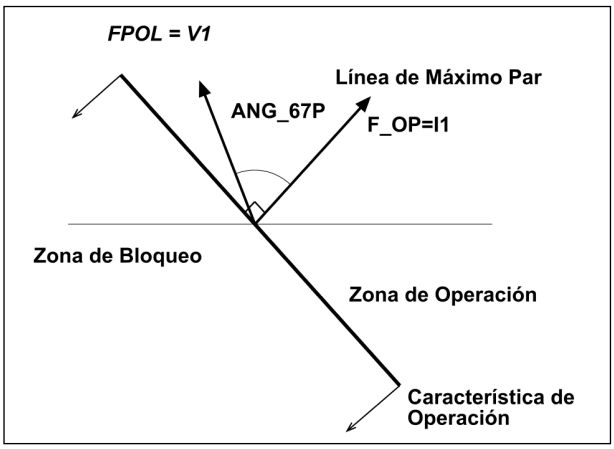


Figure 4.2.17 Vector Diagram of the Positive Sequence Directional Element.

The Positive Sequence Directional Element checks that operation and polarization phasors exceed given values. This value is adjustable for the polarization phasor (**Minimum Positive Sequence Voltage** setting) and **0.02 In** (with **In** being the rated current of the IED) for the operation phasor. If the operation or polarization phasors do not exceed the threshold values the **Lack of Polarization of Positive Sequence** (**LP_DIR_PS**) signal will be activated and ***Blocking due to Lack of Polarization*** setting is shown. If set to **NO** proceed as for the case of directional inhibition, but if set to **YES** indicates lack of polarization blocking and trips in both directions are blocked.

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The following table shows the operation and polarization phasors which intervene in the Positive Sequence Directional element, as well as the operation criteria applied.

Table 4.2-22: Positive Sequence Directional Element		
Fop	**Fpol**	**Criteria**
I1	V1	$-\left(90^{o}+ANG_67P\right) \le \left[\arg\left(Fop\right)-\arg\left(Fpol\right)\right] \le \left(90^{o}-ANG_67P\right)$

The directional element, if configured in direction, enables the overcurrent element when the previous criteria is fulfilled (operation zone indicated in the diagram), while if configured in reverse direction, it enables the overcurrent element when this criteria is not fulfilled (blocking zone indicated in the diagram).

The Positive Sequence Directional element can supervise the operation of phase overcurrent elements, if their ***Torque Control Type*** setting is set to **67P**. Thanks to the type of polarization used (positive sequence voltage with memory), the Positive Sequence Directional element operates correctly on voltage reversals produced in series compensated lines.

The logic diagram of operation of the Positive Sequence Directional element is shown in Figure 4.2.18.

If the **Direction Inversion Input** (**IN_INV_TRIP**) is active, the calculated direction is changed.

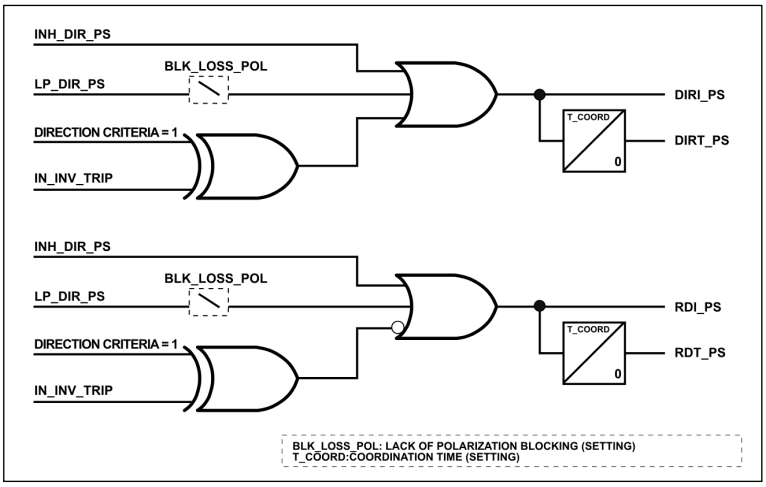


Figure 4.2.18 Block Diagram of a Directional Positive Sequence Element.

The activation of the **Inhibit of the Directional Positive Sequence** (**INH_DIR_NS**) input converts the element to non-directional.

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4.2.6.d Setting Ranges

Protection / Overcurrent / Directional					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
PosSeq Characteristic Angle	PosSeq Charact Ang	PSRDIR1.ChrAng	-90º - +90º	1º	75º
Lack of Direction Blocking	Lack Polariz Block	RDCF1.BlkLosPol	YES / NO		NO
Min. Pos Seq Voltage	Min PosSeq Voltage	PSRDIR1.MinVN	0.05 - 10V	0.01V	1V
Coordinating Time	Coord. Time	RDCF1.CrdTmms	0 - 30ms	1ms	0ms

4.2.6.e Analog Inputs to the Unit

The operation magnitude of the Positive Sequence Directional element will be the positive sequence calculated current. It will also make use of the positive sequence calculated voltage as polarization magnitude.

Table 4.2-23: Analog Inputs to the Positive Sequence Directional Module		
Name	**Description**	**IEC 61850**
I1	Positive Sequence Calculated Current	MSQI1.SeqA.c1
V1	Positive Sequence Calculated Voltage	MSQI1.SeqV.c1

$$|I_1| = \left| \frac{I_A + I_B \cdot 1\angle 120° + I_C \cdot 1\angle 240°}{3} \right|$$

$$|V_1| = \left| \frac{V_A + V_B \cdot 1\angle 120° + V_C \cdot 1\angle 240°}{3} \right|$$

4.2.6.f Digital Inputs to the Positive Sequence Directional Element

Table 4.2-24: Digital Inputs to the Positive Sequence Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_DIR_PS	Logic Inputs to Protection	PSRDIR1.Mod	Positive Sequence Directional Inhibit	I	The activation of these inputs converts the directional elements into non-directional.
IN_INV_TRIP		RDCF1.ChgTrDir	Reverse Polarization	I	When the input is quiescent, the operation zone is the indicated in settings. If it is activated, the operation zone is inverted.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.2.6.g Auxiliary Outputs and Events of the Positive Sequence Directional Module

Table 4.2-25: Auxiliary Outputs of the Positive Sequence Directional Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RDI_PS	Generic Outputs of Protection	PSRDIR1.Dir1	Positive Sequence Instantaneous Trip Reverse Direction	I,F	Indication that the current flows in the direction opposite to that of the trip. The signals of time overcurrent elements are activated when the "coordination time" is up.
RDT_PS		PSRDIR1.Dir2	Positive Sequence Time Overcurrent Trip Reverse Direction	I,F	
DIRI_PS		PSRDIR1.Dir1	Positive Sequence Instantaneous Trip Direction	I,F	Indication that the current flows in the direction of the trip. The signals of time overcurrent elements are activated when the "coordination time" is up.
DIRT_PS		PSRDIR1.Dir2	Positive Sequence Time Overcurrent Trip Direction	I,F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.2.6.h IEC 61850 Logical Node

CLASS IRLPSRDIR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Dir1	ACD	Instantaneous units direction
Dir2	ACD	Time units direction
Settings		
ChrAng	ASG	Characteristic angle
BlkValV	ASG	Minimum operating polarization voltage
Extended Data		
LosPol	EXT_ACT	Polarization signal is lost

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4.2.6.i Protection Element Test

Prior to testing check that ***Pickup Blocking Enable*** setting or ***Torque Control*** setting are set **Direction**, and that **Direction Reversal** input is disabled.

Testing can be carried out: Ia with Va. Following Table shows the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not go to menu **Information** - **Status** - **Measuring Elements** - **Overcurrent** - **Directional Overcurrent** and check the state of flags corresponding to the tested phase.

Table 4.2-26: Positive Sequence Directional Control

V APPLIED	I APPLIED
Va = 64V∟0º	Ia = 1A∟ (270º - α charact to 90º - α charact) ± 2º

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4.3 Overcurrent Protection Schemes

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4.3.1 Overcurrent Protection Schemes

4.3.1.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Overcurrent Protection Schemes	PSCH1	-	85

4.3.2 Description

The equipment offers the possibility of complementing the Neutral and Negative Sequence Directional Overcurrent elements with protection schemes.

All schemes will use an overreaching element that will pickup on the activation of **Overreach Element Pickup** logic input, to which the pickup signal of any overcurrent element can be assigned through the programmable logic. The underreaching element will coincide with the Neutral or Negative Sequence instantaneous overcurrent element 1 (OR both).

Underreach and overreach elements must be forward looking. The underreach element must only operate with faults internal to the line, so that time delay must be zero, whereas the overreach element will also cover faults external to the line and must be time delayed.

The ***Overcurrent Protection Scheme*** settings can be the following four options:

1. None.
2. Permissive Underreach Trip.
3. Direct Transfer Trip.
4. Permissive Overreach Trip.
5. Directional Comparison Unblocking.
6. Directional Comparison Blocking (Trip Blocking due to Directional Comparison).

Equipment also comprises **Weak Infeed** logic and **Reverse Current Blocking** logic, which could supplement those protection schemes that so require. Said logics and the Directional Comparison Blocking scheme require the use of a reverse direction monitoring element. The pickup of said element will coincide with the activation of the **Reverse Direction Element Pickup** logic input.

4.3.2.a Programmable Schemes

Apart from the Protection Schemes available, any other protection scheme can be configured, through the equipment programmable logic.

Teleprotection schemes can be generated requiring the transmission of several signals between both line terminals (faulted phase, single phase and three phase permissive signals, etc), for which the communication system used can be a digital network.

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4.3.3 Logics Common to Protection Schemes

4.3.3.a Weak Infeed Logic

The **Weak Infeed Logic**, if enable, can work in parallel with all permissive teleprotection schemes.

As mentioned before, if a Permissive Overreaching Scheme has been selected (or Directional Comparison Unblocking) and one of the line ends is in a weak infeed condition, so that overreaching unit is not picked up at said end, none of the line terminals can trip instantaneously. To this end, the teleprotection scheme must be supplemented by the **Weak Infeed Logic**, which presents two options: ***Echo Transmission*** and ***Weak Infeed Tripping***.

- **Echo Logic**

This function is enabled by setting ***O/C WI Logic Output*** (Overcurrent Weak Infeed Logic Output) to **Echo**.

The Echo function allows sending a permissive trip signal to the “strong” end (as echo of the signal transmitted by said end).

The echo signal will be activated provided a signal from the other end has been received and the reverse direction unit has not picked up.

- **Weak Infeed Tripping**

This function is enabled by setting ***O/C WI Logic Output*** (Overcurrent Weak Infeed Logic Output) to **Echo + Trip**.

The echo transmission allows the trip (instantaneous) of the “strong” end, but not the “weak” end trip. The weak infeed trip allows tripping this latter end when undervoltage conditions are detected, a permissive trip signal has been received and the reverse direction unit or the Overreaching unit is not picked up.

The weak infeed function is always associated to echo transmission.

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- **Operation**

Figure 4.3.1 shows the logic operating diagram.

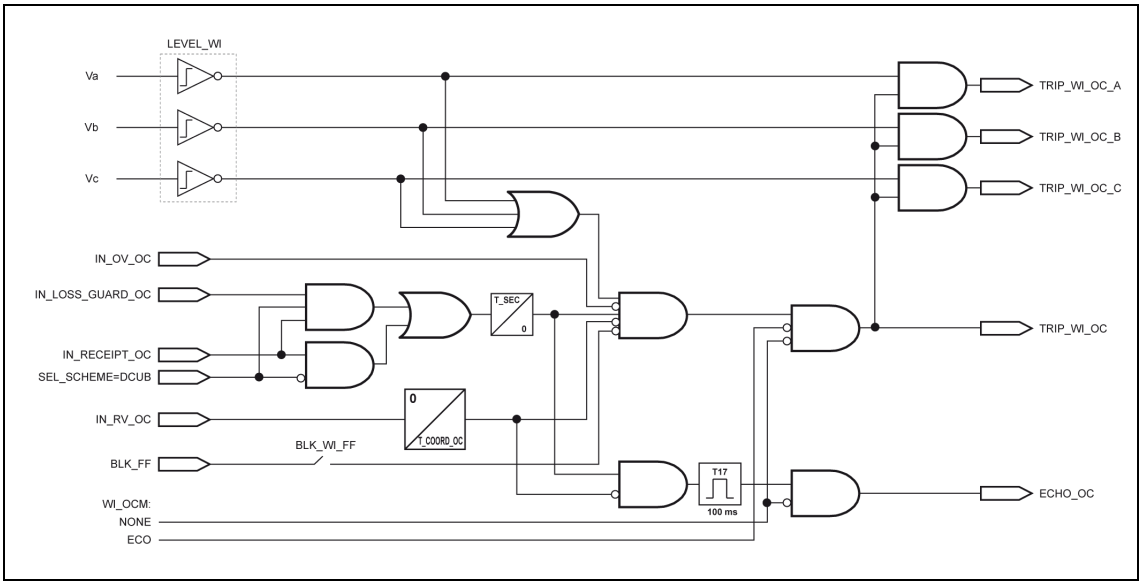


Figure 4.3.1 Weak Infeed Logic Block Diagram.

LEGEND:	
LEVEL_WI: WEAK INFEED VOLTAGE THRESHOLD SETTING.	T_SEC: SECURITY TIME SETTING.
BLK_WI_FF: FUSE FAILURE WEAK INFEED BLOCKING SETTING.	T_COORD_OC: OVERCURRENT COORDINATION TIME SETTING.
SEL_SCHEME: TELEPROTECTION SCHEME SELECTION SETTING.	

Undervoltage detectors (represented as negated overvoltage detectors) pickup and reset with only one value, equal to ***WI Undervoltage Level*** setting in Phase Selector settings.

The purpose of ***Security Time*** setting is guaranteeing a channel receipt time to avoid echo transmission upon channel noise.

If a **Directional Comparison Unblocking** scheme has been selected, the **Channel Receipt** (**IN_RECEIPT_OC**) must be supplemented with **Guard Loss** (**IN_LOSS_GUARD_OC**) input activation.

The setting ***O/C Coord Time*** (Overcurrent Coordination Time) is used to prevent weak infeed trips upon current reversal in double circuits.

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4.3.3.b Transient Blocking by Current Reversal Logic

In double circuits, the sequential trips of the breakers associated to one of the lines, as a consequence of the clearance of a fault in the same, can produce a current reversal in the parallel line. Said current reversal will cause the activation of the overreaching unit hitherto deactivated at one end and the reset of said unit at the opposite end. As these events do not occur at the same time, overreaching teleprotection schemes can give way to wrong trips in the healthy line.

Figure 4.3.2 represents a current reversal event.

In case of a Permissive Overreaching Scheme, a current reversal in line 2 takes place upon the trip of the breaker in B1, and the B2 relay overreaching unit picks up. If the trip permissive signal coming from the relay in A2 has not yet reset a channel trip will be produced in B2. In order to avoid these types of wrong trips the B2 relay overreaching unit should be temporarily blocked.

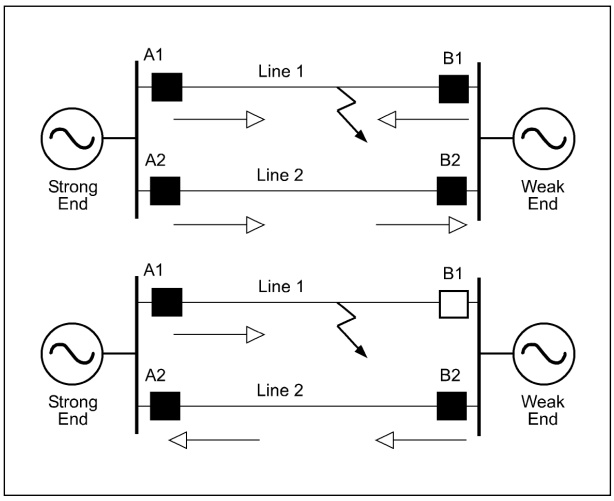


Figure 4.3.2 Current Reversal Event.

- **Operation**

The **Transient Blocking by Current Reversal Logic** generates **Overcurrent Reverse Current Blocking** (**BLK_INV_A_OC**) signal when the reverse direction unit picks up. Said signal **BLK_INV_A_OC** will stay active during ***O/C Coord Time*** (Overcurrent Coordination Time) setting from the reset of the reverse direction unit.

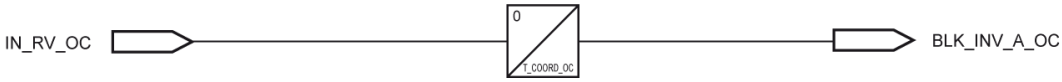


Figure 4.3.3 Block Diagram for Transient Blocking by Current Reversal Logic.

LEGEND:
T_COORD_OC: OVERCURRENT COORDINATION TIME SETTING.

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4.3.4 Permissive Underreach Trip

Permissive Underreach Scheme is activated when selected in the ***O/C Protec Scheme*** (Overcurrent Protection Scheme) setting.

With this scheme, the pickup of the Underreach unit at one of the line ends will generate an (instantaneous) trip and transmit this channel signal to the other end to allow tripping. The remote terminal will trip instantaneously when the channel signal is received if the overreach unit has picked up.

If weak or zero infeed conditions exist at one of the line ends and the overreach unit is not activated, this end could be tripped in an instantaneous mode, by means of **Weak Infeed Tripping Logic**, if the Underreach unit has picked up at the "strong" end and has therefore sent a permissive tripping signal towards the "weak" end. To this end, ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) should be set to **Echo + Trip**, even if the Echo signal is not used in the permissive underreach scheme, it being considered useless.

If, because of weak or zero infeed conditions at one of the line ends, underreach unit does not pick up at no end, it is preferable to select a **Permissive Overreach** scheme together with the **Weak Infeed** logic.

4.3.4.a Channel Activation Conditions ("Overcurrent Channel Transmission")

The communications channel will be activated by any of the following conditions:

1. Pick up of the Underreach unit.
2. Pick up of the Overreach unit, provided the channel reception input is activated.
3. The three breaker poles tripped if **Carrier by 52 Open** is set to **YES**.

4.3.4.b Tripping Conditions ("Overcurrent Protection Scheme Trip")

The channel trip will take place upon channel reception and the pickup of the overreach unit or else signal **Overcurrent Weak Infeed Trip** is activated, (**TRIP_WI_OC**), for which ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) setting must be set to **Echo + Trip**.

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4.3.4.c Operation

Channel activation and trip command generation are shown in the block diagram.

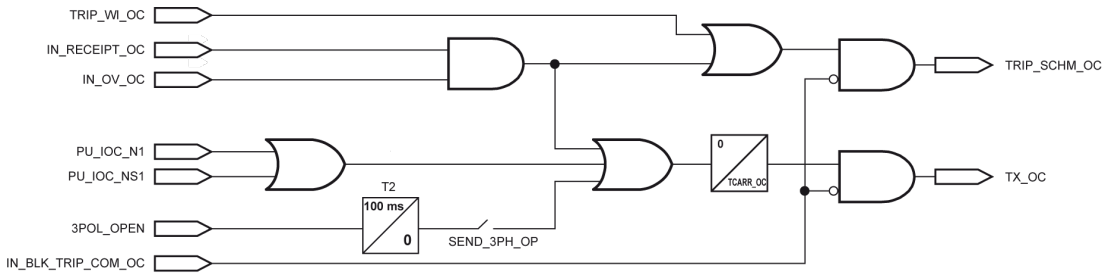


Figure 4.3.4 Permissive Underreach Trip Scheme Block Diagram.

LEGEND:	
SEND_3PH_OP: CARRIER BY 52 OPEN SETTING.	TCARR_OC: OVERCURRENT CARRIER TIME SETTING.

The purpose of ***O/C Carrier Time*** (**TCARR_OC**) setting on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

Carrier by 52 Open setting allows activating the channel upon the opening of the three breaker poles. The purpose of **T2** time delay of 100ms is delaying carrier transmission when this is produced by breaker trip.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**IN_BLK_TRIP_COM_OC**).

4.3.5 Direct Transfer Trip

The **Direct Transfer Trip** Scheme is activated when selected the ***O/C Protec Scheme*** (Overcurrent Protection Scheme) setting is defined as **Direct Transfer**.

The main feature is that a signal received from the other terminal produces a direct trip, without supervising the activation of any protection element at that end.

4.3.5.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

Communications channel activates on any of the following conditions:

1. Underreach element pickup
2. Open breaker if ***Carrier by 52 Open*** is set to YES.

4.3.5.b Trip Condition (“Overcurrent Protection Scheme Trip”)

Transfer trip occurs whenever channel is received.

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4.3.5.c Operation

Channel activation and trip conditions are depicted in block diagram of figure 4.3.5.

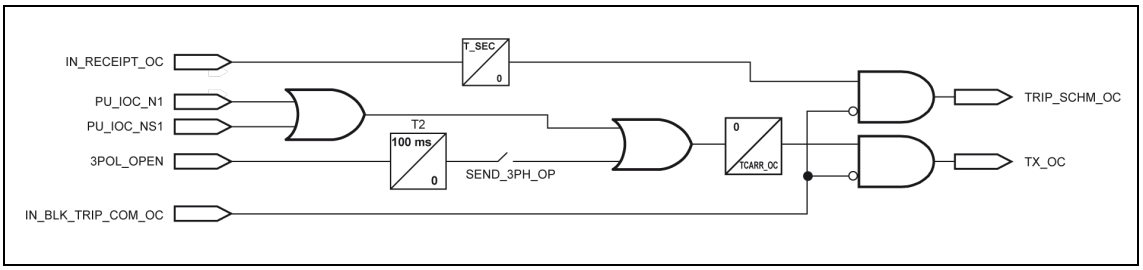


Figure 4.3.5 Direct Transfer Trip Scheme Block Diagram.

LEGEND:	
SEND_3PH_OP: CARRIER BY 52 OPEN SETTING.	TCARR_OC: OVERCURRENT CARRIER TIME SETTING.
T_SEC: SECURITY TIME SETTING.	

O/C Carrier Time setting (**TCARR_OC**) shown in diagram guarantees a minimum time requirement for channel activation (**TX_OC**).

Carrier by 52 Open setting allows channel activation with open breaker. The 100 ms delay **T2** is to delay carrier transmission caused by open breaker.

Security Time setting guarantees minimum duration of received condition, preventing ill-timed operation due to channel noise.

Transfer trip and channel activation may be blocked by the activation of **Overcurrent Channel Trip Blocking** digital input (**IN_BLK_TRIP_COM_OC**).

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4.3.6 Permissive Overreach Trip

The **Permissive Overreach Trip** Scheme is activated when selected the ***O/C Protec Scheme*** (Overcurrent Protection Scheme) setting is defined as **Permissive Overreach**.

Under this scheme, overreach element pickup at one terminal sends permissive trip signal to the other end. The received permissive signal produces an instantaneous trip if the overreach element is picked up.

Overcurrent Reverse Current Blocking (**BLK_INV_A_OC**) signal, coming from **Reverse Current Logic** (for overcurrent), blocks, provided it is activated, the input coming from the Overreach unit, to prevent wrong trips upon current reversal produced as a consequence of the sequential clearance of faults in a parallel line.

If weak or zero infeed conditions exist in one of the line ends, so that the Overreach unit is not picked up, neither end may trip under this scheme (they will trip under time delayed conditions). In this case, the permissive overreach scheme should be supplemented by the **Weak Infeed** logic, which allows sending a trip permissive signal to the “strong” end (as an echo of the signal sent by said end) to achieve its tripping (***O/C WI Logic Output*** -Overcurrent Weak Infeed Output- must be set to **Echo** or **Echo + Trip**), apart from giving the option for tripping the “weak” end (***O/C WI Logic Output*** -Overcurrent Weak Infeed Output- must be set to **Echo + Trip**).

4.3.6.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

For communication channel activation at one terminal (permissive signal transmission), any of the following conditions must be present:

1. Underreach or overreach element pickup.
2. Open breaker if ***Carrier by 52 Open*** is set to **YES**.
3. **Overcurrent Echo** (**ECHO_OC**) activated, output of **Weak Infeed Logic**, for which ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) setting of said logic must be set to **Echo** or **Echo + Trip**.

4.3.6.b Trip Condition (“Overcurrent Protection Scheme Trip”)

Channel trip will take place upon channel reception and pickup of the overreach unit or if **Overcurrent Weak Infeed Trip** (**TRIP_WI_OC**) is activated, for which ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) setting of the **Weak Infeed Logic** (for overcurrent elements) must be set to **Echo + Trip**.

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4.3.6.c Operation

Channel and trip activation conditions are depicted in block diagram of Figure 4.3.6.

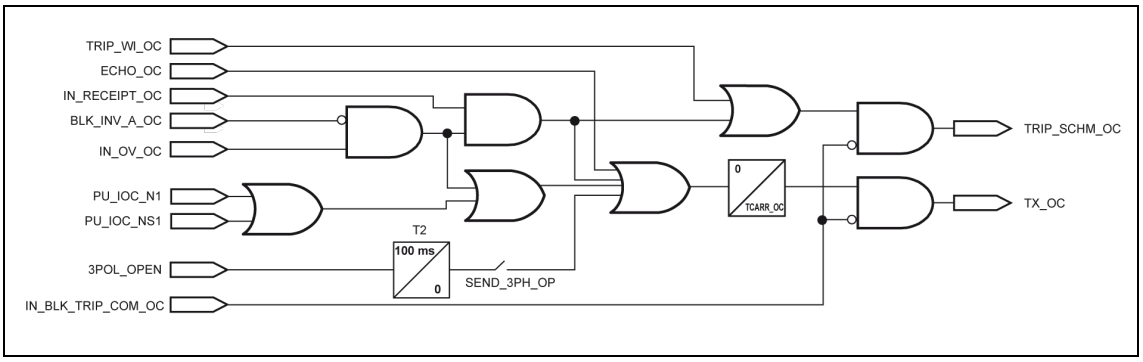


Figure 4.3.6 Permissive Overreach Trip Scheme Block Diagram.

LEGEND:	
SEND_3PH_OP: CARRIER BY 52 OPEN SETTING.	TCARR_OC: OVERCURRENT CARRIER TIME SETTING.

O/C Carrier Time setting (**TCARR_OC**) shown in diagram guarantees a minimum time requirement for channel activation (**TX_OC**).

Carrier by 52 Open setting allows channel activation with open breaker. The 100 ms delay **T2** is to delay carrier transmission caused by open breaker.

Transfer trip and channel activation may be blocked by the activation of **Overcurrent Channel Trip Blocking** digital input (**IN_BLK_TRIP_COM_OC**).

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4.3.7 Directional Comparison Unblocking

Directional Comparison Unblocking is activated when selected in the ***Overcurrent Protection Scheme*** setting.

In permissive schemes using carrier wave channels, the trip permissive signal is frequently transmitted through the faulted phase/s, and the signal is attenuated, in a number of cases, to such a low level that the signal does not reach the other end. The end not receiving the trip permissive signal will not be able to trip following the Permissive Overreach Scheme (it will produce time delayed trip). In order to avoid timed trips upon this type of situations, the Directional Comparison Unblocking Scheme is used, which is an extension of the Permissive Overreach Tripping Scheme.

The **Directional Comparison Unblocking** Scheme has been introduced to be used with switched frequency carrier wave equipment. When no fault is present in the line, this equipment continuously sends a signal at a “guard” frequency (guard signal) for channel supervision. Upon detecting a fault, the relay commands the carrier wave equipment to switch the guard frequency to other frequency known as “trip frequency” (trip signal). Thus, but for the time elapsed in the switching process, the teleprotection equipment will never send both signals at the same time.

Upon receipt of the trip signal and non-receipt of the guard signal at one end, said end will trip following the same criteria set up in a Permissive Overreach Scheme (provided the overreach unit is picked up). On the contrary, upon non-receipt of the trip signal and non-receipt of the guard signal, the Directional Comparison Unblocking Scheme will allow, during a time window, the instantaneous tripping of the overreaching unit.

Overcurrent Reverse Current Blocking (**BLK_INV_A_OC**) signal coming from the **Reverse Current Blocking Logic** (associated to overcurrent schemes), blocks, while activated, the input coming from the pickup of the overreaching unit, with the purpose of preventing wrong trips upon current reversals as a consequence of clearing faults in a parallel line in case of double circuits.

The same as for the Permissive Overreach Scheme, if weak or zero infeed conditions exist at one of the line ends, so that the overreaching unit of said end does not pick up, none of the ends can trip with this scheme (it would produce time delayed trip). In this case, the **Directional Comparison Unblocking Scheme** should be supplemented by the **Weak Infeed Logic**, which allows the transmission of a trip permissive signal to the “strong” end (as echo of the signal transmitted by said end) in order to achieve its trip (***O/C WI Logic Output*** -Overcurrent Weak Infeed Output- must be set to **Echo** or **Echo + Trip**), apart from giving the option to trip the “weak” end (***O/C WI Logic Output*** -Overcurrent Weak Infeed Output- must be set to **Echo + Trip**).

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4.3.7.a Channel Activation Conditions ("Overcurrent Channel Transmission")

For communication channel activation at a terminal (transmission of the permissive signal), any of the following conditions must be present:

1. Pick up of the Underreach or Overreach unit.
2. The three breaker poles tripped if ***Carrier by 52 Open*** is set to **YES**.
3. Activation of **Overcurrent Echo** (**ECHO_OC**) signal, **Weak Infeed Logic** output, for which ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) setting of said logic must be set to **Echo** or **Echo + Trip**.

4.3.7.b Tripping Conditions ("Overcurrent Protection Scheme Trip")

Tripping by channel signal reception will occur under the following conditions:

1. Channel reception and loss of guard and Overreach unit picked up.
2. Loss of guard, without channel activation, and Overreach unit picked up before **T_TRIP** times out.
3. **Overcurrent Weak Infeed Trip** (**TRIP_WI_OC**) activated, for which ***O/C WI Logic Output*** (Overcurrent Weak Infeed Output) setting of **Weak Infeed Logic** (for Overcurrent elements) must be set to **Echo + Trip**.

4.3.7.c Operation

Activation of a channel and generation of a trip command are shown in the following block diagram.

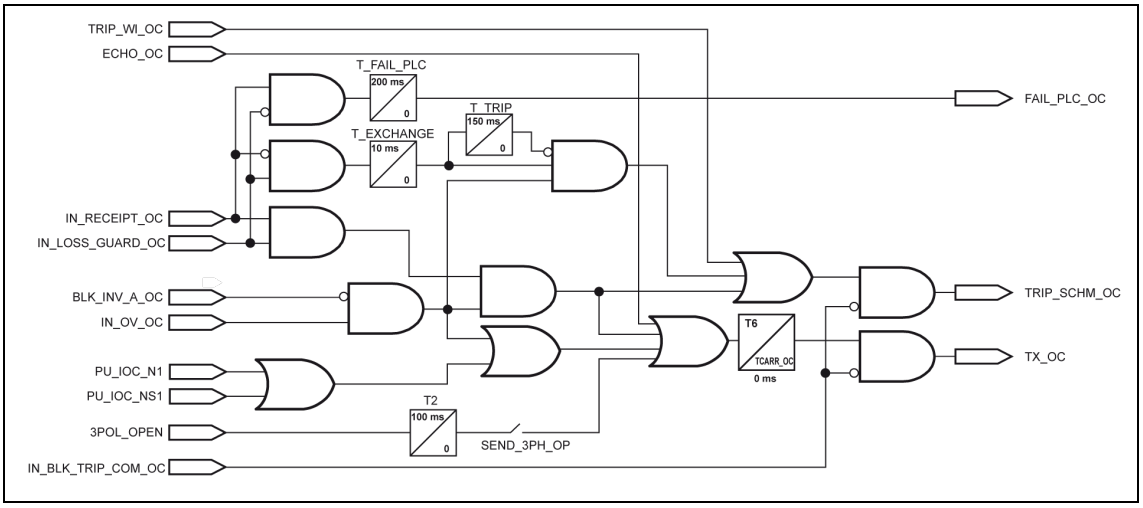


Figure 4.3.7 Directional Comparison Unblocking Scheme Block Diagram.

LEGEND:	
T_FAIL_PLC: CARRIER WAVE EQUIPMENT FAILURE TIME.	SEND_3PH_OP: CARRIER BY 52 OPEN SETTING.
T_EXCHANGE: SWITCHING TIME.	TCARR_OC: OVERCURRENT CARRIER TIME SETTING.
T_TRIP: TRIP TIME.	

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The purpose of ***O/C Carrier Time*** on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

The purpose of ***Carrier by 52 Open*** setting is activating the channel when the three breaker poles trip. The purpose of **T2** timing of 100 ms is delaying the carrier transmission caused by breaker tripping.

The carrier wave equipment features the following output contacts: one normally closed (hereafter called **Guard**), which remains open when the guard signal is being received, and other normally open (hereafter called **Trip**) which closes upon the reception of the trip signal from the other end. The guard contact must be wired to the **Overcurrent Guard Loss** input -**IN_LOSS_GUARD_OC**-, whereas the contact trip will be wired to the **IN_RECEIPT_OC** (**Overcurrent Channel Reception**) input. On the other hand, the **TX_OC** (**Overcurrent Channel Activation**) output must be wired to the wave carrier equipment input, which will give the command for frequency switching.

When both **IN_LOSS_GUARD_OC** and **IN_RECEIPT_OC** inputs are activated, the response is exactly equal to a Permissive Overreach Scheme, an instantaneous tripping being produced provided the overreaching unit is picked up.

In case only **IN_LOSS_GUARD_OC** input is activated, which might indicate a complete attenuation of the trip permissive signal from the other end, if this situation remains during the switching time **T_EXCHANGE**=10 ms (enough for the carrier wave equipment to switch from guard frequency to trip frequency), the overreaching unit will be allowed to trip instantaneously during the time **T_TRIP**=150 ms.

If only **IN_RECEIPT_OC** input has been activated, after time **T_FAIL_PLC**, the signal **FAIL_PLC**=200 ms will be activated, which indicates failure in the carrier wave equipment.

Channel tripping and channel activation can be disabled using the status contact input **Overcurrent Channel Trip Blocking** (**IN_BLK_TRIP_COM_OC**).

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4.3.8 Directional Comparison Blocking

The **Directional Comparison Blocking** scheme is activated when ***Overcurrent Protection Scheme*** sets to **Directional Comparison Blocking**.

This scheme essentially differs from the above schemes (permissive schemes) in that the transferred signal is used for remote terminal trip blocking instead of speed up tripping.

For this scheme to operate correctly a Neutral or Negative Sequence Overcurrent element set reverse direction is necessary, which is used for channel activation. Said element will pickup on the activation of the **Reverse Direction Element Pickup** logic input, to which the pickup signal of any overcurrent element can be assigned.

Pickup of reverse direction element at one terminal transmits a blocking signal to the remote terminal to block overreach element trip. This way, trip only occurs if blocking signal from the remote terminal is not received.

For the correct application of this scheme two conditions must be taken into account:

1. Reverse direction pickup setting must be set to a lower value than that for overreach elements at the other terminals, so that blocking all faults external to the line, for which said overreach elements pickup, is guaranteed.
2. Overreach element trip must be delayed to allow time to transmit the blocking signal from the remote to the local terminal. Said delay is given by ***O/C Delay DCB*** (Directional Comparison Blocking Overcurrent Delay) setting.

Echo and **Weak Infeed Trip Logic** are purposeless under this scheme. On the other hand, this scheme needs not be supplemented by the **Reverse Current Blocking Logic** because this scheme can detect the current reversal thanks to the use of the reverse direction unit.

4.3.8.a Channel Activation Conditions ("Overcurrent Channel Transmission")

Channel activation at one terminal (blocking signal transmission) takes place under any of the following conditions:

1. Reverse direction element activated, with overreach element deactivated, provided transmission stop conditions are not present.
2. **Overcurrent Channel Trip Blocking** input activated, provided transmission stop conditions are not present. In this case, as it is a blocking system, channel activated means trip blocking.

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4.3.8.b Channel Disable Conditions ("Overcurrent Channel Stop")

Deactivating or blocking a terminal communications channel (end of block signal transmission) takes place under any of the following conditions:

1. **Overcurrent Scheme Channel Stop** input activated.
2. Overreach element activated neither through received channel nor through reverse direction asserted nor through channel trip blocking input activation.
3. Underreach element activated.

4.3.8.c Trip Conditions ("Overcurrent Protection Scheme Trip")

A trip occurs with this scheme under simultaneous compliance with the following conditions:

1. Overreach element enabled.
2. No channel received (blocking signal from the other terminal).
3. Reverse direction element not activated.

4.3.8.d Operation

Channel activation and trip conditions are depicted in block diagram of Figure 4.3.8.

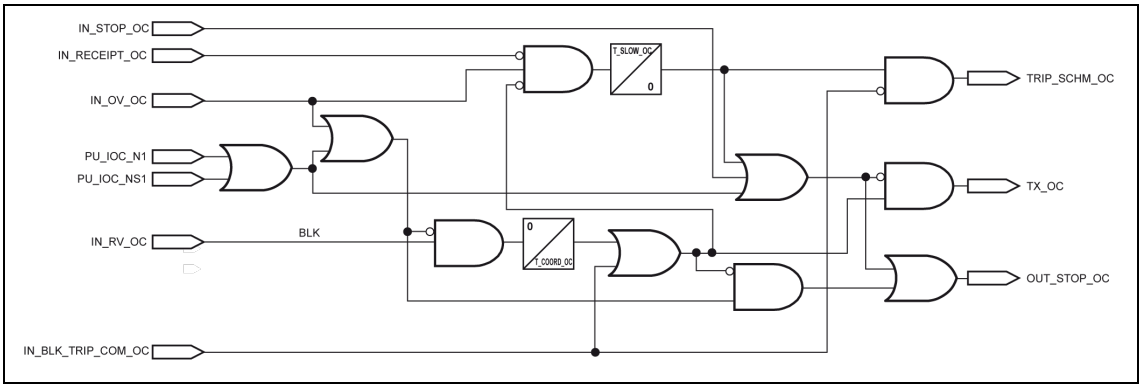


Figure 4.3.8 Directional Comparison Blocking Scheme Block Diagram.

LEGEND:	
T_SLOW_OC: OVERCURRENT DELAY TIME SETTING.	T_COORD_OC: OVERCURRENT COORDINATION TIME SETTING.

O/C Delay DCB (Directional Comparison Blocking Overcurrent Delay) setting allows, as mentioned above, for external faults, time for reception of the blocking signal from the remote terminal.

O/C Coord Time (Overcurrent Coordination Time) sets a reset time of the reverse direction element pickup signal preventing channel stop due to current reversal in double lines, as a result of parallel line sequential breaker trips caused by a fault of the parallel line. It is worth mentioning that the underreach element can stop the blocking signal transmission without reverse direction element activated, as the underreach element is only activated by faults internal to the line.

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Overcurrent Scheme Channel Stop (**OUT_STOP_OC**) output must be hard wired to teleprotection equipment **Overcurrent Scheme Channel Stop** (**IN_STOP_OC**) input to disable the channel. Nevertheless said output also cancels channel activation output in order to prevent against the fact that **IN_STOP_OC** input is not configured in the teleprotection equipment with priority over **IN_RECEIPT_OC** input, in case both are active.

Transfer trip and channel activation can be blocked by activating **Overcurrent Channel Trip Blocking** (**IN_BLK_TRIP_COM_OC**) digital input.

4.3.9 Setting Ranges

Protection / Overcurrent Protection Scheme					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Carrier by 52 Open	Carrier Open Brkr	PSCF1.CarOpnCB	YES / NO		NO
Security Time	Security Time	PSCF1.SecTmms	0-50 ms	1 ms	0 ms
O/C Protec Scheme (*)	O/C Protec Scheme	OCPSCH1.SchTyp	None PUTT DTT POTT DCUB DCB		None
O/C Carrier Time	O/C Carrier Time	OCPSCH1.DurTmms	0-200 ms	10 ms	50 ms
O/C Coord Time	O/C Coord Time	OCPSCH1.RvRsTmms	0-50 ms	1 ms	25 ms
O/C Delay DCB	O/C Delay DCB	OCPSCH1.CrdTmms	0-200 ms	10 ms	50 ms
O/C WI Logic Output	O/C WI Logic Out.	OCPSCH1.WeiMod	None Echo Echo + Trip		None
O/C Curr Inv Block Enable	O/C Cur Inv Block	OCPSCH1.RvAMod	YES / NO		NO
Weak Infeed Block FF	FF WI Block	PSCF1.WeiBlkFF	YES / NO		NO

(*) Permissive Underreach Trip.
Direct Transfer Trip.
Permissive Overreach Trip.
Directional Comparison Unblocking.
Directional Comparison Blocking.

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4.3.10 Digital Inputs to the Overcurrent Protection Schemes Module

Table 4.3-1: Digital Inputs to the Overcurrent Protection Schemes Module

Name	Group	IEC 61850	Description	Vis.	Function
IN_RECEIPT_OC	Logic Inputs to Protection	OCPSCH1.ProRx	Overcurrent Scheme Carrier Reception Input	I	The activation of this input means a signal receipt (trip permissive or blocking, as a function of the selected scheme) from the other end.
IN_BLK_TRIP_COM_OC		OCPSCH1.Mod	Overcurrent Scheme Trip Blocking Input	I	The activation of this input blocks the trip of any overcurrent protection scheme.
IN_LOSS_GUARD_OC		OCPSCH1.LosOfGrd	Overcurrent Scheme Loss of Guard Input	I	The activation of this input means that the guard signal receipt has ceased. It is used in the Directional Comparison Unblocking scheme.
IN_STOP_C		OCPSCH1.CarStop	Overcurrent Scheme Channel Stop Input	I	The activation of this input generates Channel Disable output. It is used in the Directional Comparison Blocking scheme.
IN_OV_OC		OCPSCH1.OvStr	Overreaching Unit Pickup Input	I	Overreach overcurrent element pickup.
IN_RV_OC		OCPSCH1.RvStr	Reverse Unit Pickup Input	I	Reverse looking overcurrent element pickup.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.3.11 Auxiliary Outputs and Events of the Overcurrent Protection Schemes Module

Table 4.3-2: Auxiliary Outputs and Events of the Overcurrent Protection Schemes Module

Name	Group	IEC 61850	Description	Vis.	Function
TX_OC	Generic Outputs of Protection	OCPSCH1.ProTx	Overcurrent Scheme Carrier Sending	I	Channel activation by the selected overcurrent protection scheme.
ECHO_OC		OCPSCH1.Echo	Overcurrent Scheme Echo Sending	I	Echo transmission in overcurrent protection scheme.
FAIL_PLC_OC		OCPSCH1.CarWavFail	Power Line Carrier Equipment Failure	I	Power Line Carrier Equipment Failure.
BLK_INV_A_OC		OCPSCH1.RvABlk	Overcurrent Scheme Reversal Current Blocking	I	Overreaching unit blocking in overcurrent protection scheme by current reversal detection.
OUT_STOP_OC		OCPSCH1.CarStopOut	Overcurrent Scheme Channel Stop	I	Output for channel disabling used in Directional Comparison Blocking scheme.
TRIP_SCHM_OC	Trip Protection Outputs	OCPSCH1.Op	Overcurrent Protection Scheme Trip	I,F	Selected overcurrent protection scheme trip.
TRIP_WI_OC		OCPSCH1.WeiOp	Overcurrent Scheme Weak Infeed Trip	I	Weak infeed condition trip in overcurrent protection scheme
TRIP_WI_OC_A		OCPSCH1.WeiOp	Overcurrent Scheme Phase A Weak Infeed Trip	I	Trip by weak infeed condition in the corresponding phase in overcurrent protection scheme.
TRIP_WI_OC_B		OCPSCH1.WeiOp	Overcurrent Scheme Phase B Weak Infeed Trip	I	
TRIP_WI_OC_C		OCPSCH1.WeiOp	Overcurrent Scheme Phase C Weak Infeed Trip	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.3.12 IEC61850 Logical Node

CLASS IRLPSCH		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
ProTx	SPS	Teleprotection signal transmitted
ProRx	SPS	Teleprotection signal received
Str	ACD	Carrier send
Op	ACT	Operate
LosOfGrd	SPS	Loss of guard
Echo	ACT	Echo signal from weak end infeed function
WeiOp	ACT	Operate signal from weak end infeed function
RvABlk	ACT	Block signal from current reversal function
Settings		
SchTyp	ENG	Scheme Type
CrdTmms	ING	Co-ordination timer for blocking scheme
DurTmms	ING	Minimum duration of carrier send signal
SecTmms	ING	Pickup security timer on loss of carrier guard signal
WeiMod	ENG	Mode of weak end infeed function
RvAMod	ENG	Enable of current reversal function
RvRsTmms	ING	Delay time for coordination
Extended Data		
CarStop	EXT_SPC	Stop of the channel input in directional comparison block scheme
OvStr	EXT_ACD	Start of the overreach overcurrent unit input
RvStr	EXT_ACD	Start of the inverse overcurrent unit input
CarWavFail	EXT_SPS	Fail in the communication equipment
CarStopOut	EXT_SPS	Stop of the channel in directional comparison block scheme
CarOpnCB	EXT_SPG	Sent due to breaker open status
PhGndVal	EXT_ASG	Undervoltage level for weak infeed function

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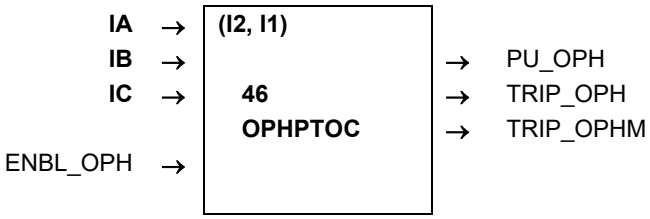
4.4 Open Phase Detector

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4.4.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Open Phase Detector	OPHPTOC1	I2/I1>	46

4.4.2 General Block



4.4.3 Operation Principles and Block Diagram

The purpose of the Open Phase element is to detect unbalance of the phases of the protected line. It functions by measuring the negative sequence content of the circulating current. Both the negative sequence (I2) and the positive sequence (I1) are calculated to obtain their ratio (I2/I1). Once picked up, the element acts if the pickup is maintained for a period of time equal to or greater than the set value.

The operation of this function is conditioned to the position of the breaker and to the level of the positive sequence current: if the breaker is open or the positive sequence current is below the ***Min. Load Open Phase*** setting, the element will be disabled. In addition, the function is annulled when any one of the phase or ground time or instantaneous elements picks up.

Pickup occurs when the value measured exceeds 1.05 times the pickup setting and resets at 1.00 times the pickup setting.

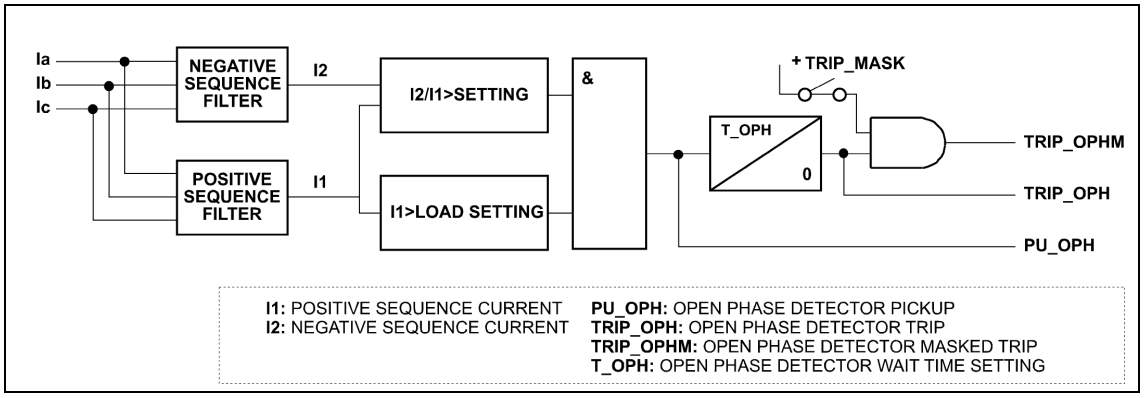


Figure 4.4.1 Block Diagram of the Open Phase Detector.

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4.4.4 Application

The function of the Open Phase element is to detect a fallen or broken conductor. It uses the ratio between the negative sequence current, **I2**, and the positive sequence current, **I1**. When the load is normal and balanced, this ratio is zero or very low, but when a severe load fault occurs, an imbalance raises this ratio.

To avoid trips or pickups with no load or very low loads, this function is inhibited when the positive sequence current **I1** value is below the ***Min. Load Open Phase*** setting.

4.4.5 Range Settings

Protection / Open Phase					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Open Phase Enable	Open Phase Enable	OPHPTOC1.LNInSvc	OPHPTOC1.LNInSvc		NO
Open Phase Pickup	Open Phase PU	OPHPTOC1.StrVal1	0.05-0.4	0.01	0.05 I2/I1
Open Phase Wait Time	Open Phase Wait T.	OPHPTOC1.OpDlTmms	0.05-300 s	0.01 s	0.05 s
Min. Load Open Phase	Min Load Open Pha.	OPHPTOC1.StrVal2	0.02-5 A	0.01 A	0.10 A

4.4.6 Analog Inputs to the Unit

The Open Phase Element operating magnitude is the ratio between the negative sequence current, **I2**, and the positive sequence current, **I1**, calculated from phase currents.

Table 4.4-1: Analog Inputs to the Open Phase Module

Name	Description	IEC 61850
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
I2	Negative Sequence Current	MSQI1.SeqA.c2
I1	Positive Sequence Current	MSQI1.SeqA.c1

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

$$|I_1| = \left| \frac{I_A + I_B \cdot 1\angle 120° + I_C \cdot 1\angle 240°}{3} \right|$$

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4.4.7 Digital Inputs to the Open Phase Detector

Table 4.4-2: Digital Inputs to the Open Phase Detector					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_OPH	Enabling Commands	OPHPTOC1.Mod	Enable Open Phase Detector	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.4.8 Auxiliary Outputs and Events of the Open Phase Module

Table 4.4-3: Auxiliary Outputs of the Open Phase Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_OPH	Pickup Protection Outputs	OPHPTOC1.Str	Open Phase Detector Pick Up	I,F	Pickup of the Open Phase Detector and start of the time count.
TRIP_OPH	Trip Protection Outputs	OPHPTOC1.Op	Open Phase Detector Trip	I,F	Trip of the Open Phase Detector
TRIP_OPHM	Masked Trips		Open Phase Detector Masked Trip		Pickup of the Open Phase Detector affected by its trip mask.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.4.9 IEC 61850 Logical Node

CLASS IRLOPHPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
StrVal1	ASG	Start value I2/I1
StrVal2	ASG	Start value direct sequence sensibility

4.4.10 Open Phase Detector Test

After putting all the phase and ground elements out of service, this two-current system is applied:

Ia = 1/0º and Ib = 1/60º (it is understood that these angles are inductive).

After setting the element to 0.2 I2/I1, it must not be picked up. After increasing the phase B current, the element must pick up (the pickup flag at "1") with a current value in phase B between 1.493 Aac and 1.348 Aac.

With the trip time set to 10 s, a current of 2 A / 60º in phase B is applied. A trip must be initiated between 10.1 s and 9.9 s. Also, the trip contacts must close.

It will also be checked that by adjusting the unit to 0.2 I2/I1 and the ***Min. Load Open Phase*** to 1.2 A, if we apply Ia = 1/0º and Ib = 2/60º, the unit should not operate. If, under the same conditions, the ***Min. Load Open Phase*** is set to 0.8 A, the unit should pick up.

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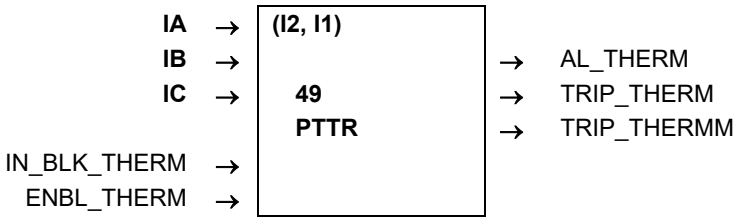
4.5 Thermal Image

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4.5.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Thermal Image Unit	PTTR1	3Ith>	49

4.5.2 General Block



4.5.3 Operation Principles

Using mathematical algorithms based on the material's physics, thermal relays estimate the temperature of the machine/device/line to be protected using the currents that flow through it. The unit estimates the thermal state by measuring the current flow and resolving the thermal differential equation in order to generate a trip when high temperature levels are reached.

The algorithms are based on modeling the heating of a resistive element when running an electric current through it. The effect of radiation is not considered (since the impact is considered negligible given the temperatures reached by the elements to be protected, less than 400 ºC), nor are heat dissipation sources other than that deriving from the Joule effect. Cooling of the equipment is also simulated if the current value returns to the nominal value after a relatively short overload period.

The Thermal Image Unit does not have a threshold at which pickup starts: it is always "picked up". The trip time depends on the current flowing from a given instant up to when the temperature limit is reached and the temperature value at a specific instant. The prior temperature depends on what has happened before, the measured current and the time applied.

The differential equation that controls any thermal phenomenon is the following:

$$I^2 = \theta + \tau \cdot \frac{d\theta}{dt}$$

Where:

I: Is the RMS value of the measured current.
τ: Is the cooling and heating time constant (***Constant 1*** and ***Constant 2*** settings).
Imax: Value of the maximum admissible sustained current. ***Max. Operating Current*** Setting.

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The time constant is represented by τ and it represents the time needed for a body that will go from an initial temperature θ_0 to a final temperature θ_∞ to reach 63% of the temperature increase necessary for θ_∞; that is, the time it will take to reach the intermediate temperature θ_i starting from θ_0, where:

$$\theta_i = \theta_0 + (\theta_\infty - \theta_0) * 0.63$$

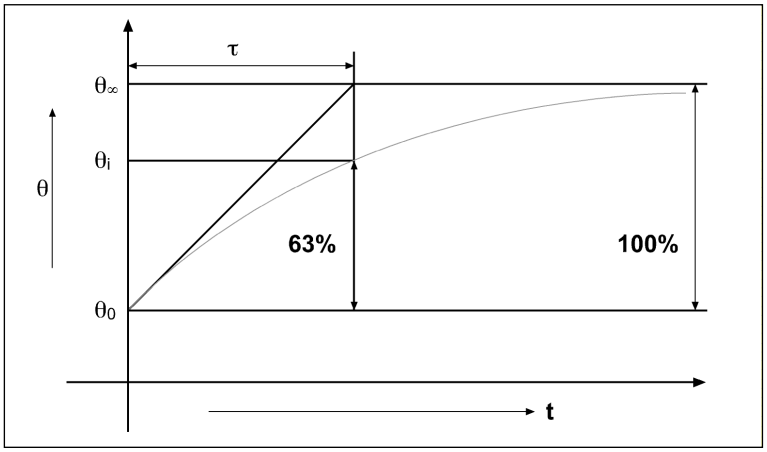


Figure 4.5.1 Time Constant (Thermal Image).

Temperature values (θ) are always stored in case there is a failure in the IED's power supply. There is a ***Thermal Memory Enable*** setting that you can set to **YES** so that the initial temperature value will be the stored one whenever the IED is reinitialized. The saved value can be reset by activating the digital signal **Thermal Image Dropout Input**.

This element is prepared to protect lines, motors or transformers from overheating. The type to be protected can be selected through the setting ***Type of Device***. According to this selection, the element will use different ways to calculate the thermal status.

- **Lines**. In case of lines, the square of the maximum current is taken as measurement current (the element will use the maximum current flow, namely, the maximum value between phase A, phase B or phase C currents). It has two time constants, one for heating (as long as there is current flow, setting ***Constant 1***) and one for cooling (when the positive sequence current is below 0.1 A, setting ***Constant 2***).

- **Motors**. For motors, the measuring current used is the sum of the square of the positive sequence and the square of the negative sequence. This last value is multiplied by a scaling factor (***Motor Scaling Factor***). It has two time constants, one for motor stopped (when the positive sequence is under 0.15 times the maximum current, ***Constant 1*** Setting) and another for motor running (when the positive sequence is above 0.30 times the maximum current, ***Constant 2*** Setting)

- **Transformers**. In case of transformers, the square of the current flowing through the reference winding current is taken as measurement current (the element will use the maximum current flow, namely, the maximum value between phase A, phase B or phase C currents of the reference winding). It has two time constants, one in case it is ventilated (***Constant 1***) and one in case it is not (***Constant 2***). They are switched from one to another by means of a digital input named **Thermal Constant Switched**. By default, the time constant is **With Ventilation**. It can be changed by configuring the **Thermal Constant Switched** input. When this input is activated, the constant switches to **Without Ventilation**.

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When the element is using the maximum current flow, it will use the maximum fundamental current RMS value for the calculations according to the setting ***Type of Magnitude***.

The thermal element estimates the thermal status in each case (line / motor / transformer) and, when this reaches the set ***Alarm level***, it activates the signal **Thermal Image Alarm**. When it reaches the level equivalent to the level obtained by steady state Imax flow (***Max. Operating Current)***, a trip output is issued.

The thermal state is estimated thus:

- The initial value is θ = 0 or θ ≠ 0, depending on the initial thermal state.
- The thermal image unit is activated every 500 milliseconds. Each time, it subtracts the θ value of the preceding sample from the current value squared:

  $$A = I^2 - \theta$$
- The value obtained is divided by the time constant and multiplied by 500 milliseconds.

  $$B = A\frac{0.5s}{\tau(s)}$$
- This value is added to the preceding θ to obtain the current

  $$\theta = \theta + B$$

The value of θ is calculated as a % of the maximum value. The **Thermal Image Trip** output is activated when the corresponding θ value reaches the maximum current:

$$\theta_{trip} = Imax^2$$

Thermal Image Trip signal resets taking into account the setting ***Reset Threshold***:

$$\theta_{Reset_trip} = \theta_{trip}\frac{Reset\ Threshold(\%)}{100}$$

Thermal Image Alarm output activates when θ reaches a value defined by the setting ***Alarm Level***:

$$\theta alarm = \theta_{trip}\frac{AlarmLevel(\%)}{100}$$

The **Thermal Image Alarm** signal resets when θ descends below 95%:

$$\theta_{Reset_alarm} = 0.95 * \theta_{alarm}$$

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4.5.3.a Operation Curves

Two different types of curves can be selected as a function of the setting ***Type of Curve***. Later, the trip time will be calculated as follows:

- **Curve 1 (Standard Curve)**

$$t = \tau \cdot Ln \frac{I^2 - I_p^2}{I^2 - Imax^2}$$

Where:

I: Measured current used by the element.
I_p: Steady state pre-load current before applying the overload.
τ: Is the cooling and heating time constant (***Constant 1*** and ***Constant 2*** settings).
Imax: Value of the maximum admissible sustained current. ***Max. Operating Current*** Setting.

As τ is expressed in minutes, the result of the equation, namely, the calculated time, is also in minutes.

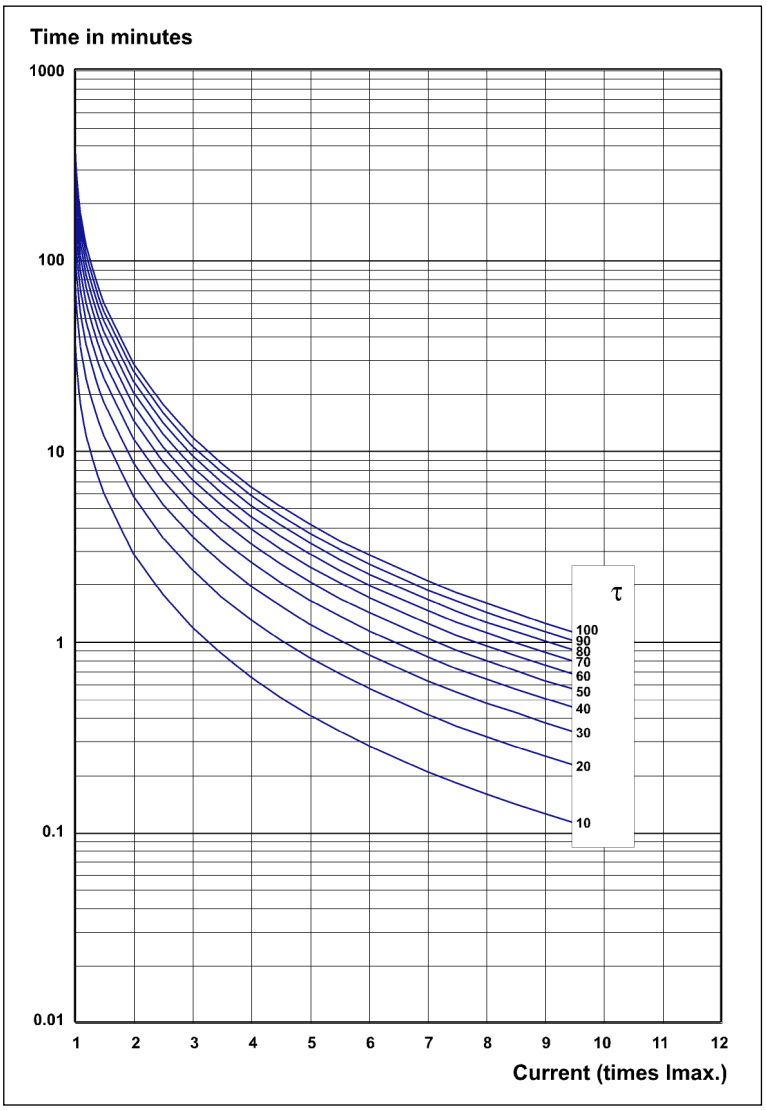


Figure 4.5.2 Operating Time Curves of the Thermal Image Unit.

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- **Curve 2 (TDL2002 Single Curve)**

$$t = \tau \cdot Ln \frac{I^2 - (K * Imax)^2}{I^2 - I_p^2}$$

Where:

I: Measured current used by the element.
I_p: Steady state pre-load current before applying the overload.
K: Adjustable constant that limits the operation of the unit.
τ: Time constant (***Constant 1*** setting).
Imax: Value of the maximum admissible sustained current. ***Max. Operating Current*** Setting.

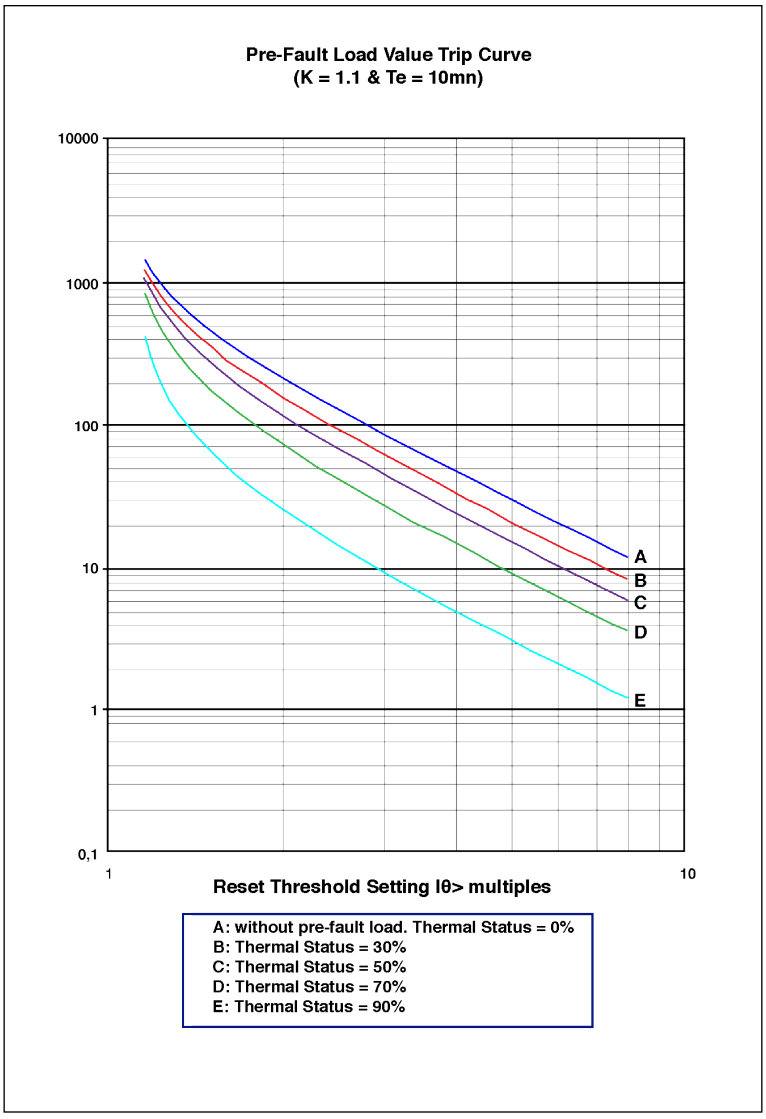


Figure 4.5.3 Curve 2 (TDL2002 Single Curve).

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4.5.4 Block Diagram

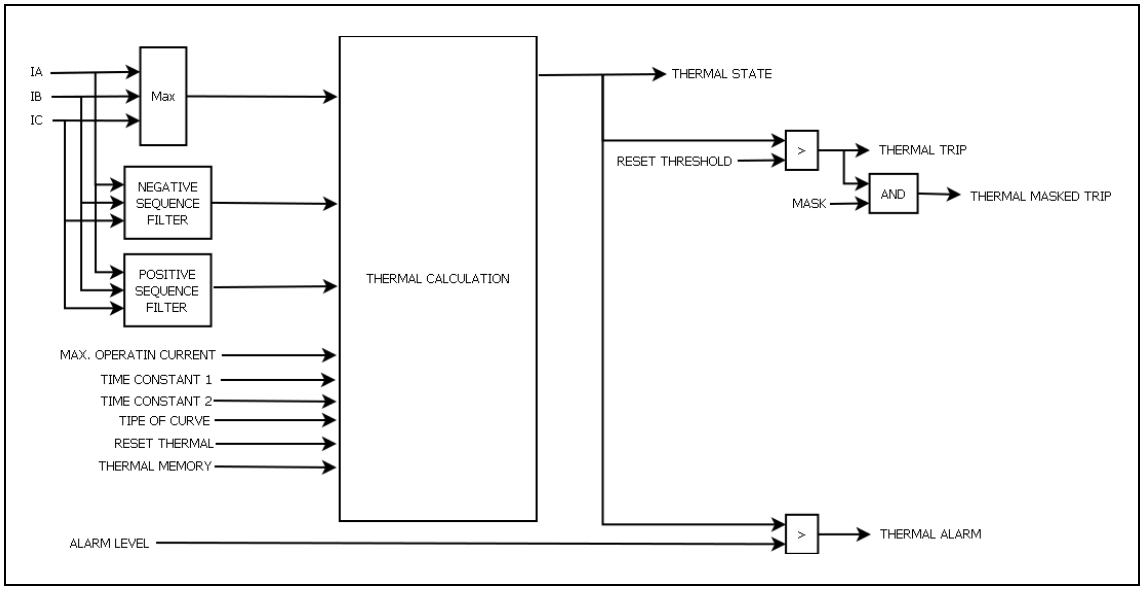


Figure 4.5.4 Block Diagram of the Thermal Image Unit.

4.5.5 Application of the Thermal Image Function

On most occasions, electric system faults generate currents higher than the rated current of the system's elements. In these cases, the thermal effects can quickly produce damages.

The protections that are regularly used in these cases use overcurrent, causing trips both instantly and after a timed sequence using inverse "current / time" characteristics or set fixed times. However, in some applications, this protection system presents certain limitations.

An example might be a system with two transformers set in parallel powering the same bus, each of them running at loads below the rated load. If one of the transformers is out of service, the other transformer steps in and takes on the full load, very likely running at a load above its rated load.

With an overcurrent protection it can be disconnected in a very short period of time even when power transformers are designed to run with excess loads for several minutes without suffering any damage. During this period of time, there is no possibility of performing any action to reset the situation.

Given its operating principle, the Thermal Image unit is highly indicated in these types of situations. In general, it can be said that this function is complementary to other protection types for cables or all kinds of machines (transformers, generators, etc.).

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4.5.6 Setting Ranges

Protection / Thermal Image					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Thermal Image Enable	Thermal Img. Ena	PTTR.LNInSvc	YES / NO		NO
Type of Magnitude	Type of Magnitude	PTTR.MagTyp	Fundamental RMS		Fundamental
Type of Device	Type of Device	PTTR.ProTyp	Lines Motor Transformer		Lines
Type of Curve	Type of Curve	PTTR.CrvTyp	Standard TDL2002 Simple Curve		Standard
Constant 1 (Heating)	Constant 1	PTTR.ConsTms1	0.5-300 min	0.01min	0.5min
Constant 2 (Cooling)	Constant 2	PTTR.ConsTms2	0.5-300 min	0.01min	0.5min
Max. Operating Current	Max. Sust. Curr.	PTTR.StrVal	0.2-12.5	0.01A	1A
Alarm Level	Alarm Level	PTTR-AlmVal	50-100%	1%	50%
Reset Threshold	Reset Threshold	PTTR.RsLev	50-100%	1%	80%
Motor Scaling Factor	Motor Constant	PTTR.SetMot	1-10	1	1
Thermal Memory Enable	Thermal Memory	PTTR.ThmMem	YES / NO		NO
K Factor	K Factor	PTTR.KFact	1-1.5	0.01	1.05

4.5.7 Analog Inputs to the Thermal Image Unit

Table 4.5-1: Analog Inputs to the Thermal Image Unit

Name	Description	IEC 61850
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
I1	Positive Sequence Current	MSQI1.SeqA.c1
I2	Negative Sequence Current	MSQI1.SeqA.c2

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4.5.8 Digital Inputs to the Thermal Image Unit

Table 4.5-2: Digital Inputs to the Thermal Image Unit

Name	Group	IEC 61850	Description	Vis.	Function
C_CONST_T	Logic Inputs to Protection	PTTR.ChgSet	Thermal Constant Switched	I	Its activation changes the constant in the thermal image unit.
RST_MEM_T		PTTR.RsThm	Thermal Image Dropout Input	I	Its activation resets the memorized value.
IN_BLK_THERM		PTTR.LNBlk	Thermal Image Block Input	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_THERM	Enabling Commands	PTTR.LNEna	Enable Thermal Unit	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.5.9 Auxiliary Outputs and Events of the Thermal Image Unit

Table 4.5-3: Auxiliary Outputs and Events of the Thermal Image Unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
AL_THERM	Generic Outputs of Protection	PTTR.AlmThm	Thermal Unit Alarm	I	Alarm of the Thermal Image Unit.
TRIP_THERM	Trip Protection Outputs	PTTR.Op	Thermal Unit Trip	I,F	Trip of the Thermal Image Unit.
TRIP_THERMM	Masked Trips		Thermal Unit Masked Trip		Trip of the Thermal Image Unit affected by its trip mask.
THERM_ENBLD	Enabled Units Protection Outputs		Thermal Unit Enabled	I	Indication of enabled or disabled status of the Thermal Image Unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.5.10 IEC 61850 Logical Node

CLASS IRVHGNDPIOCsg		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Op	ACTnotr	Trip
AlmThm	ACTg	Thermal Alarm
Settings		
StrVal	ASGsg	Start value
ConsTms1	INGsg	Time constant of the thermal model (heating)
ConsTms2	INGsg	Time constant of the thermal model (cooling)
AlmVal	ASGsg	Alarm Value
Measured Values		
TmpRl	MVro	Relation between temperature and max. temperature
Extended Data		
LNInSvc	EXT_SPGsg	In service
LNEna	EXT_SPC	Unit enable command
LNBlk	EXT_SPC	Unit blocking command
MagTyp	EXT_ING_ENUMsg	Magnitude type
ProTyp	EXT_ING_ENUMsg	Device type
CrvTyp	EXT_ING_ENUMsg	Curve Type
RsLev	EXT_ASGsg	Reset Threshold
SetMot	EXT_INGsg	Motor Scaling Factor
ThmMem	EXT_SPGsg	Thermal Memory Enable setting
ChgSet	EXT_SPCtr	Constant change command
ThmRs	EXT_SPCtr	Thermal Image value reposition command
KFact	EXT_ASGsg	K Factor

4.5.11 Thermal Image Unit Test

Before performing this test, the protection should be turned off and then back on to reset the thermal level. A current greater than the set maximum sustained current (I_{max}) is applied through phase A. The trip time must be:

$$t = \tau \cdot \mathrm{Ln} \frac{(I \pm 1\%)^2}{(I \pm 1\%)^2 - I_{max}{}^2}$$

where τ is the set time constant ζ1.

An example: a time constant without ventilation of 0.5 minutes and a maximum current of 5 A. A current of 6 A is injected in phase A of the first winding. The time transpired until the unit trips must be between 33.05 s and 38.18 s.

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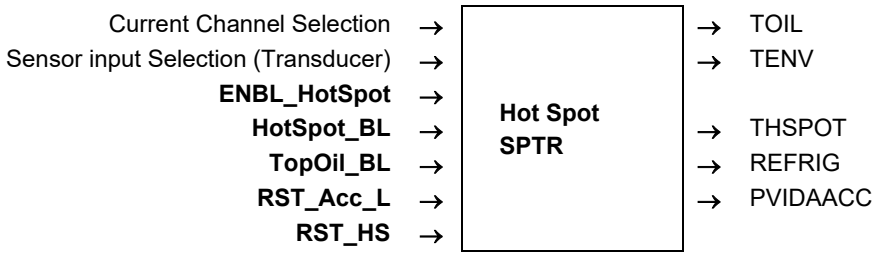
4.6 Hot Spot Thermal Image Unit

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4.6.1 Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Hot Spot unit	SPTR		26

4.6.2 General Block



4.6.3 Operation Principles

The operation of this unit is based on the IEC 60076-7 loading guide.

The degradation or aging of an oil immersed power transformer is dependent on the thermal condition of its components, mainly the temperature of the hottest point on the winding (called the Hot Spot) and the oil temperature (coolant). Operating a transformer above the nominal conditions can cause excessive temperatures within the components. This causes accelerated aging of the machine (premature degradation of the insulation material, temporary loss of dielectric strength through the formation of gas bubbles, increase of losses, etc.). These conditions brought to the extreme will cause a fault in the transformer. Depending on the temperature level reached, it is preferable to maintain the transformer overloaded and to assume an allowable loss of life, than to cause a failure in the electrical supply.

Therefore, three operating conditions are defined below according to load and Hot Spot temperature:

- Normal conditions: Nominal conditions, or temporarily high, that throughout time does not cause considerable transformer loss of life.
- Long term emergency conditions: Overload and Hot Spot high temperature conditions that cause considerable loss of life, but can persist over long periods of time (weeks, months).
- Short term emergency conditions: Overload and Hot Spot high temperature conditions that must be reduced in a short period of time (trip in 30 minutes).

The Hot Spot thermal image unit measures the transformer load (ratio between circulating current and transformer nominal current), and the temperature of the top oil layer using a thermal sensor. The units have the capability to determine Hot Spot temperature with greater accuracy than thermal image units based solely on transformer load measurements.

Hot Spot thermal image units are designed for long term emergency conditions, whereas short term emergency conditions are handled by the overload unit.

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4.6.3.a Temperature Measurement

The unit operates according to both the top oil layer temperature measurement (to calculate the Hot Spot) and the ambient temperature measurement (to calculate the efficiency of the cooling system). These temperature measurements are obtained using PT100 sensors installed in the transformer, connected to the device by two converter inputs (configurable as -2.5 to 2.5 mA or 0 to 5 mA converters). The temperature is set for the top oil layer and the ambient temperature at each converter input by adjusting the ***Sensor Input Selection***.

The sensor temperature ranges are related to the converter input ranges by settings, assigning the sensor temperature maximum and minimum values to the maximum and minimum values for each converter input. Therefore, different sensors can be used by simply modifying the unit settings.

4.6.3.b Hot Spot Temperature Calculation

The Hot Spot calculation (HS_TEMP) is performed by direct measurement of the top oil layer temperature (TopOilProbe) at each instant, taking into account the increase in the Hot Spot temperature (ΔThs) that occurs between the actual instant and the previous instant, according to the following expression:

$$HS_TEMP_i = TopOilProbe_i + \Delta Ths_i,$$

where: $\Delta Ths_i = \Delta Ths1_i - \Delta Ths2_i$

and:

$$\Delta Ths1_i := \frac{\Delta t}{k22 \cdot \tau w}\left[k21 \cdot HS_Grad \cdot (k_i)^{Win_Exp} - \Delta Ths1_{i-1}\right] + \Delta Ths1_{i-1}$$

$$\Delta Ths2_i := \frac{\Delta t \cdot k22}{\tau o}\left[(k21 - 1) \cdot HS_Grad \cdot (k_i)^{Win_Exp} - \Delta Ths2_{i-1}\right] + \Delta Ths2_{i-1}$$

The parameters used in the above expressions are described below:

TopOilProbe: Top oil layer temperature.
HS_TEMP: Actual Hot Spot temperature.
i : Number of samples at the actual instant of the calculation.
i-1: Number of samples at the instant of the previous calculation.
Δt : Time interval between the actual instant and the previous instant (1 minute).
K11, **K21**, **K22**: Transformer thermal model constants.
τo : Oil thermal constant.
τw : Winding thermal constant.
Wind_Exp: Winding exponent.
HS_Grad: Temperature gradient between the oil and the winding, measured under nominal load conditions.
K: load (IWngX/Inom_XF). ratio between the mean current through the channel selected in Current channel setting and transformer rated current.

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The initial conditions for the Hot Spot calculation are defined assuming that the temperature and the transformer load are maintained stable (steady state), following the equations:

$$\Delta Ths1_0 := k21 \cdot HS_Grad \cdot \left(k_0\right)^{Win_Exp}$$

$$\Delta Ths2_0 := (k21 - 1) \cdot HS_Grad \cdot \left(k_0\right)^{Win_Exp}$$

Initializing the unit before reaching steady state could cause a transient in the thermal image unit that calculates the relay. This could (if initialized at no load) generate an unwanted trip after a certain time. To prevent an unwanted trip, the unit includes the ***Hot Spot Start Threshold Current*** setting. This setting prevents the unit from initializing until the load (winding n phase X current, where n = 1, 2 or 3) exceeds the setting value. This setting is only valid during unit initialization.

One possible case is as follows: During startup of the relay, the transformer is unloaded and in steady state (cold transformer) or the transformer is loaded in steady state, but the relay thermal image unit has not reached steady state (due to initialization in non-steady state conditions). In this case, activating the **Hot Spot Initiate Order** signal (configurable using programmable logic) initializes the unit in any situation. Therefore, the user is responsible for activating the signal when the transformer reaches steady state in regard to temperature and load.

It is also worth mentioning that changing the setting ***Current Channel*** (hot/cold) may also required to change the rated current (as the magnitude considered is the load **K= IDevX/Inom**, where **Inom** is the rated current set in the thermal image element), that can generate untimely trips after a certain time. To this end, after changing this setting (***Current Channel***), the user must be able to find the right moment (if the situation requires) to activate the signal ***Hot Spot Start Command*** adapting in this way the algorithm to the actual situation.

One specific case pertaining to the Hot Spot calculation is as follows: In fault conditions where the current may exceed the nominal current various times over short periods (ms), the Hot Spot temperature may increase considerably, possibly causing the unit to trip even after the fault has been cleared. A similar situation could arise during a short term emergency condition where the Hot Spot thermal unit could trip before the overload unit. This would cause a fault in the supply before anticipated. The Hot Spot unit is immune to these situations since the Hot Spot temperature calculation adapts while winding n (where n = 1, 2 or 3) phase X, by means of **Current Channel** setting, is equal or higher than the ***Fault Detection Current*** setting. Fault conditions are finished when phase X current value is less than ***Fault Detection Current*** setting value.

4.6.3.c Hot Spot Temperature Trip and Top Oil Layer Temperature Trip

Once the Hot Spot temperature is calculated, it is compared to the ***Trip Level*** setting. If the level is reached, it causes a trip. The Hot Spot trip reset value is adjustable. The user can define the Hot Spot temperature value at which the transformer will reconnect (this setting is expressed as a % of the Hot Spot temperature trip value).

In addition to the Hot Spot trip level, the unit includes a Hot Spot alarm level that activates an alarm signal when the level is reached. The alarm is reset when the Hot Spot temperature lowers below 95% of the alarm level setting.

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In addition to the Hot Spot temperature alarm and trip levels, the unit has a top oil layer temperature alarm and trip level. The signals are activated when the top oil layer temperature (measured directly by the sensor) reaches the respective level settings. The trip reset is adjustable (expressed as a % of the top oil layer temperature trip value). The alarm resets when the top oil layer temperature lowers below 95% of the alarm level setting.

Both the oil temperature trip and the Hot Spot temperature trip can be disabled using the corresponding trip mask setting.

The unit trip logic includes both a Hot Spot trip block signal and a top oil layer temperature trip block signal. Activating the block signals prevents the corresponding trip, if it has not already occurred, or resets the trip in case the signal is still activated. These two blocks apply to situations in which after a trip, the transformer needs to be reconnected before the temperature lowers below the trip reset level.

4.6.3.d Accumulated Loss of Life

With the Hot Spot temperature calculated as a reference (HS_TEMP), and depending on the thermal treatment of the winding insulation (cellulose), the loss of life or accelerated aging of the transformer (Acc_L) can be estimated according to the following expressions:

$$Acc_L_i := \left(\Delta t \cdot 2^{\frac{HS_TEMP_i - 98}{6}} \right) + Acc_L_{i-1}$$ if the cellulose is not thermally treated, or

$$Acc_L_i := \left(\Delta t \cdot e^{\frac{15000}{110+273} - \frac{15000}{HS_TEMP_i + 273}} \right) + Acc_L_{i-1}$$ if the cellulose is thermally treated.

Therefore, a day of operating at the Hot Spot temperature limit (98ºC or 110ºC, according to the case) assumes a day of aging. An increase in the Hot Spot temperature accelerates transformer aging, while operating at temperatures lower than the Hot Spot reduces the degree of transformer aging.

There are many situations in which transformer startup does not coincide with the protection device startup (protection renovations, replacement of faulty devices). The ***Initial Loss of Life*** setting initiates the accumulated loss of life calculation using the value setting. The initialization is made effective when the **Accumulated Loss of Life Initialization Order** signal is activated (this signal must be configured in the programmable logic).

The accumulated loss of life is a magnitude that is saved in the non-volatile memory and remains immune to power faults in the device. The maximum value of this magnitude is 432000 hours (an unattainable limit for any transformer).

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4.6.3.e Cooling System Efficiency

The cooling system efficiency measurement is based on comparing the top oil layer temperature measured directly by the sensor (TopOilProbe) with the estimated top oil layer temperature. This temperature is calculated from the load current and from the ambient temperature (Topoil_cal). Therefore, a second thermal sensor is required to obtain the ambient temperature measurement (AmbientProbe).

When a fault is produced in the cooling system, the direct measurement of the top oil layer increases. The calculated measurement remains constant, since it can be assumed that the load and the ambient temperature will remain constant. The device activates the **Cooling System Alarm** signal when the difference between the direct measurement of the oil temperature (TopOilProbe) and the calculated temperature (Topoil_cal) exceed the value setting for the ***Cooling System Alarm Level***. The alarm resets at 95% of the set value.

The calculation of the top oil layer temperature using the ambient temperature follows the expression:

$$Topoil_cal_i := \frac{\Delta t}{k11 \cdot \tau o} \cdot \left[\left[\frac{1 + (k_i)^2 \cdot R}{1 + R} \right]^{Oil_Exp} \cdot Oil_Grad + AmbientProbe_i - Topoil_cal_{i-1} \right] + Topoil_cal_{i-1}$$

Where the following parameters are defined in addition to the ones above:

R: Ratio between the nominal load losses and the unloaded losses.
Oil_Exp: Oil exponent.
Oil_Grad: Temperature gradient between the air and the oil, measured under nominal load conditions

The initial conditions assume a steady state temperature and load according to the expression:

$$Topoil_cal_0 := \left[\left[\frac{1 + (k_0)^2 \cdot R}{1 + R} \right]^{Oil_Exp} \cdot Oil_Grad + AmbientProbe_0 \right]$$

The initialization of the calculated oil temperature occurs at the same instant as the initialization of the Hot Spot calculation.

The following magnitudes are monitored by the Hot Spot thermal image unit: top oil layer temperature, Hot Spot temperature, ambient temperature, cooling efficiency, and transformer accumulated loss of life. All of these magnitudes (similar to other device magnitudes) can be configured in the events log or in the history log. They are also available for the device programmable logic where they can be configured as measurements for a SCADA system, or as user defined algorithms (control logic for commands, blocks, etc.).

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4.6.4 Recommended Settings according to the IEC 60076-7 Loading Guide

	Distribution Transformers	Medium and High Power Transformers						
	ONANd	ONANr(*)	ONAN	ONAFr(*)	ONAF	OFr(*)	OF	OD
Oil_Exp	0.8	0.8	0.8	0.8	0.8	1	1	1
Wind_Exp	1.6	1.3	1.3	1.3	1.3	1.3	1.3	2
K11	1	0.5	0.5	0.5	0.5	1	1	1
K21	1	3	2	3	2	1.45	1.3	1
K22	2	2	2	2	2	1	1	1
τo	180	210	210	150	150	90	90	90
τw	4	10	10	7	7	7	7	7

(*) Applicable to zig-zag windings where oil circulation may be limited due to radial separators less than 3 mm.

4.6.5 Setting Ranges

Protection / Thermal Image					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Current Channel	Current channel	SPTR1.ACh (ENG) SP	IA IB IC		IA 1
Enable	Enable	SPTR1.LnInSvc (SPG)	YES / NO		NO
Sensor input selection: 0-TR-IN1 Oil / TR-IN2 Ambient 1-TR-IN1 Ambient / TR-IN2 Oil 2-TR-IN1 Oil 3-TR-IN2 Oil	Oil Probe select.	SPTR1.TmpAlmVal (ING)	0 - 3	1	0
Minimum oil sensor temp	Min Temp Oil	SPTR1.TmpTripVal (ING)	-20 - 20 ºC	0.01	-20 ºC
Maximum oil sensor temp	Max Temp Oil	SPTR1. TmpRsLev (ING)	95 - 200 ºC	0.01	140ºC
Minimum ambient sensor temp	Min Temp Ambient	SPTR1.OilTmpVal1 (ING)	-50 - 10 ºC	0.01	-20ºC
Maximum ambient sensor temp	Max Temp Ambient	SPTR1.OilTmpVal2 (ING)	30 - 85 ºC	0.01	50 ºC
Transformer nominal current	Nominal Current	SPTR1.OilTmpRsLev (ING)	0.5 - 10 A	0.01	5 A
Transformer thermal model k11 constant	Th constant K11	SPTR1.CECtlAlmVal (ING)	0.1 - 3	0.01	0.5
Transformer thermal model k21 constant	Th constant K21	SPTR1.AHPStrVal (ASG)	0.1 - 3	0.01	2
Transformer thermal model k22 constant	Th constant K22	SPTR1.AFltStrVal (ASG)	0.1 - 3	0.01	2

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Protection / Thermal Image					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Oil heating time constant	Oil Time constant	SPTR1.ProbInSel (ENG) SP	20-250 min	0.1	150 min
Winding heating time constant	Winding time const	SPTR1.MinOilTmp (ASG) SP	2 - 20 min	0.1	7 min
Winding exponent	Winding Exp	SPTR1.MaxOilTmp (ASG) SP	1 - 3	0.01	1.3
Winding temperature gradient for oil at nominal load	Hot Spot-Oil Grad	SPTR1.MinEnvTmp (ASG) SP	10 - 60 ºC	0.1	20 ºC
Hot spot start threshold current	HS Current Thresh	SPTR1.MaxEnvTmp (ASG) SP	0.05 - 5 A	0.01	0.1 A
Hot spot temperature alarm level	Hot Spot Alarm	SPTR1.ARtg (ASG) SP	80 - 200 ºC	1	100 ºC
Hot spot temperature trip level	Hot Spot Trip	SPTR1.ConsThmK11 (ASG) SP	80 - 200 ºC	1	120 ºC
Winding temp trip reset level	Hot Spot Reset	SPTR1.ConsThmK21 (ASG) SP	50 - 100 %	1	79 %
Oil layer temp alarm level	Oil Alarm	SPTR1.ConsThmK22 (ASG) SP	50 - 200 ºC	1	90 ºC
Oil layer temp trip level	Oil Trip	SPTR1.ConsTmmsOil (ASG) SP	50 - 200 ºC	1	105 ºC
Oil layer temp trip reset level	Oil Reset	SPTR1.ConsTmmsCol (ASG) SP	50 - 100 %	1	90 %
Cooling control alarm level	Cooling Alarm	SPTR1.ColFact (ASG) SP	5 - 100 ºC	1	30 ºC
Oil exponent	Oil Exp	SPTR1.ColTmpGra (ASG) SP	0.5 - 1.5	0.01	0.8
Top oil layer temp gradient for ambient at nominal load	Oil-Ambient Grad	SPTR1.OilFact (ASG) SP	10 - 100 ºC	0.1	60 ºC
Loss ratio at nominal load and no load	Losses ratio	SPTR1.OilTmpGra (ASG) SP	1 - 20	0.1	6
Paper thermal treatment	Upgraded paper	SPTR1.LodLod0LosRat (ASG) SP	YES / NO		NO
Initial loss of life	Initial Life	SPTR1.ThmPap (SPG) SP	0-131400 h	1	0 hours

4.6.6 Analog Inputs to the Hot Spot Thermal Image Unit

Table 4.6-1: Analog Inputs to the Hot Spot Thermal Image Unit

Name	Description	IEC 61850
IAx (Note1)	Phase Ax Current	MMXU1.AWdgx.phsA
IBx (Note1)	Phase Bx Current	MMXU1.AWdgx.phsB
ICx (Note1)	Phase Cx Current	MMXU1.AWdgx.phsC
TRANS.IN1 (Note2)	Input transducer 1	
TRANS.IN2 (Note2)	Input transducer 2	

Note 1: Selectable according to "Current Channel" setting.
Note 2: Selectable according to "Sensor input selection" setting.
X= It could be 1, 2 or 3.

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4.6.7 Digital Inputs to the Hot Spot Thermal Image Unit

Table 4.6-2: Digital Inputs to the Hot Spot Thermal Image Unit

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_HotSpot			Hot Spot Thermal Unit Enabling Input		Activating this input places the unit in service. Digital inputs can be assigned by level or to commands from the communications protocol or from the HMI. The default value for the logic inputs is "1".
HotSpot_BL			Hot Spot Trip Block Input		Activating the input before the trip is generated impedes activation of the unit. If activated after the trip, it resets.
TopOil_BL			Oil Temperature Trip Block Input		
RST_Acc_L			Accumulated Loss of Life Initialization Order		Initializes loss of life using the setting value. This command must be configured in the programmable logic.
RST_HS			Hot Spot Initiate Order		Initializes the Hot Spot calculation.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.6.8 Auxiliary Outputs and Events of the Hot Spot Thermal Image Unit

Table 4.6-3: Auxiliary Outputs and Events of the Hot Spot Thermal Image Unit

Name	Group	IEC 61850	Description	Vis.	Function
HS_ALR			Hot Spot temperature alarm		Unit high temperature alarms.
L1_Oil			Oil temperature alarm		
HS_TRIP			Hot Spot temperature trip		Unit high temperature trips.
L2_ Oil_TRIP			Oil temperature trip		
HS_TRIPM			Hot Spot temperature masked trip		Unit trips conditioned by masked trips.
L2_ Oil_TRIPM			Oil temperature masked trip		
Cool_Ef_ALR			Cooling system alarm		Indicates a cooling problem due to the difference between the measured and calculated oil temperature.
HotSpot_ ENBLD			Enabled Hot Spot thermal unit		Indicates the status of the unit, enabled or disabled.
ENBL_HotSpot			Hot Spot thermal unit input enabling		The same as for the digital inputs.
HotSpot_BL			Hot Spot trip block input		
TopOil_BL			Oil temperature trip block input		
RST_Acc_L			Accumulated loss of life initialization order		
RST_HS			Hot Spot initiate order		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.6.9 IEC 61850 Logical Node

CLASS IDFSPTRsg		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Op	ACTnotr	Trip
AlmThm	ACTg	Thermal Alarm
Settings		
StrVal	ASGsg	Start value
ConsTms1	INGsg	Time constant of the thermal model (heating)
ConsTms2	INGsg	Time constant of the thermal model (cooling)
AlmVal	ASGsg	Alarm Value
Measured Values		
TmpRl	MVro	Relation between temperature and max. temperature
Extended Data		
LNInSvc	EXT_SPGsg	In service
LNEna	EXT_SPC	Unit enable command
LNBlk	EXT_SPC	Unit blocking command
MagTyp	EXT_ING_ENUMsg	Magnitude type
ProTyp	EXT_ING_ENUMsg	Device type
CrvTyp	EXT_ING_ENUMsg	Curve Type
RsLev	EXT_ASGsg	Reset Threshold
SetMot	EXT_INGsg	Motor Scaling Factor
ThmMem	EXT_SPGsg	Thermal Memory Enable setting
ChgSet	EXT_SPCtr	Constant change command
ThmRs	EXT_SPCtr	Thermal Image value reposition command

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4.6.10 Hot Spot Thermal Image Unit Test

As a recommendation, disable the units that are not being tested when testing the unit.

Set the converter inputs as 0 to 5 mA converters.

Set the Hot Spot thermal image unit according to the following table:

Current Channel	IA1
Enabling the Unit (Permission)	YES
Sensor Input Selection	0
Minimum Oil Sensor Temperature	-20 ºC
Maximum Oil Sensor Temperature	140ºC
Transformer Nominal Current (I_nomXF)	5 A
Transformer Thermal Model k11 Constant	0.5
Transformer Thermal Model k21 Constant	2
Transformer Thermal Model k22 Constant	2
Oil heating Time Constant	150 min
Winding Heating Time Constant	7 min
Winding Exponent	1.3
Winding Temperature Gradient for Oil at Nominal Load	35 ºC
Hot Spot Start Threshold Current	0.1 A
Fault Detection Current	25 A
Hot Spot Temperature Alarm Level	110 ºC
Hot Spot Temperature Trip Level	130 ºC
Winding temp trip reset level	96 **%**
Oil Layer Temp Alarm Level	100 ºC
Oil Layer Temp Trip Level	120 ºC
Oil Layer Temp Trip Reset Level	95 **%**

The ratio between the sensor temperature and the equivalent in the mA converter is:

$$\frac{T - Tmin}{Tmax - Tmin} := \frac{mA - Cmin}{Cmax - Cmin}$$

For this case (settings from the table above):

Cmin = 0 mA. Cmax = 5 mA. Tmin = -20ºC Tmax = 140ºC

The ratio between the phase A current and the load is as follows:

K = IA / I_nomXF

In our case, according to the settings in the table above, the transformer nominal current is:

I_nomXF = 5 A

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4.6.10.a Top Oil Layer Temperature Alarm and Trip

Injected by converter 1 (TR-IN1), a DC current increase from 3 mA to 4.5 mA, and from 4.5 mA to 3 mA (*):

- The top oil layer temperature alarm activates at 3.75 mA ± 0.2% and resets at 3.594 mA ± 0.2%.
- The top oil layer temperature trip activates at 4.375 mA ± 0.2% and resets at 4.188 mA ± 0.2%.

(*) Note that the unit performs the calculations every minute.

4.6.10.b Hot Spot Temperature Alarm and Trip

Disable the unit and inject 2.82 mA (dc) by TR-IN1 and 5 A (ac) by channel IA1. Enable the unit (at the moment when the initial conditions are calculated) and vary the values injected according to the following table at a rate of 1 minute:

TR-IN1	2.82 mA cc	2.82 mA cc	2.82 mA cc	2.82 mA cc	2.82 mA cc	2.34 mA cc
IA1	5 A ac	7.5 A ac	7.5 A ac	18.5 A ac	0 A	0 A
Hot Spot	105.24 ºC	108.39 ºC	111.29 ºC	131.12 ºC	124.58 ºC	103.3 ºC

Verify the activation and reset of the Hot Spot alarm and trip according to the value settings.

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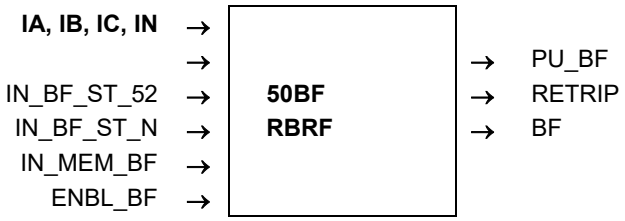
4.7 Breaker Failure Unit with Retrip Function

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4.7.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Breaker Failure Unit	RBRF1	3I>/Io>BF	50BF

4.7.2 General Block



4.7.3 Operation Principles

The Breaker Failure protection works with two phase overcurrent elements and a neutral current element. The two phase metering units and the neutral metering unit have independent pickup levels, with the following settings: ***Single-Phase Pickup*** (**Phase 1 Pickup**), ***Three Phase Pickup*** (phase 2 pickup) and ***Neutral Pickup***. The pickup of overcurrent elements on breaker failure takes place at 1.05 times the setting value, and resets at the setting value. The Breaker Failure Element includes a Retrip Function with the purpose of sending a new trip command to the failed breaker before the Breaker Failure signal is activated, according to the applicable setting.

The main feature of pickup detectors is their fast reset time (about 5ms), based on instantaneous current, rather than RMS. Although, in case of exponential drop of the current when the breaker opens, RMS is also considered for element reset.

Once the reset condition has been complied with in terms of actual values (5 samples in a row within the range), the pickup based on RMS values is blocked until a sample exceeds the threshold. The reason for RMS pickup blocking is to avoid the generation of multiple pickups (in terms of RMS values) and reset (in terms of actual values) the signals issued under the pickup threshold.

As stated above, together with the fast reset time, a reset based on RMS current values is also produced, which will be used in cases when the fault current has a dc component at the moment when it is cut off when the breaker opens. An RMS value reset will generate a faster reset than the actual value reset.

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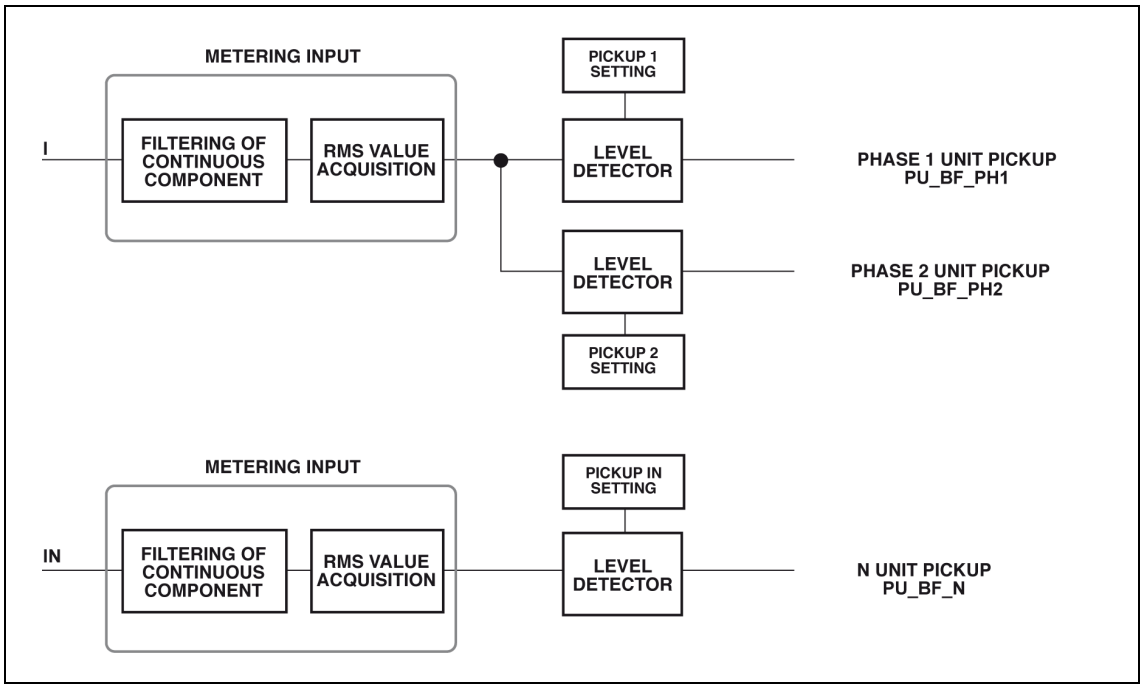


Figure 4.7.1 Block Diagrams of BF Element Phase and Neutral Measuring Elements.

4.7.3.a Single Phase Breaker Failure

The single-phase breaker failure pickup is produced by the activation of a single-phase trip signal generated by the IED itself —**Pole A Trip** (**TRIP_A**), **Pole B Trip** (**TRIP_B**) and **Pole C Trip** (**TRIP_C**) signals— or by an external IED through the activation of the **External Pole A Trip** (**IN_EXT_A**), **External Pole B Trip** (**IN_EXT_B**) and **External Pole C Trip** (**IN_EXT_C**) logic inputs.

Depending on the status of the ***Pickup Supervision*** (**PU_BF_SUP_EN**) setting, the unit has two different behaviors:

Overcurrent Pickup Supervision = YES

In addition to the single-phase breaker failure pickup (**IN_EXT_A**, **IN_EXT_B**, **IN_EXT_C**, **TRIP_A**, **TRIP_B**, **TRIP_C**), there must be a current flow in the same phase exceeding the value of the corresponding setting (***Single Phase PU***), in order to start the ***Single-Phase Breaker Failure Time T1*** (***1 Pole BF Delay***) and the corresponding ***Single-Phase Retrip Time T2*** (***1 Pole Retrip Delay***). If **T2** ends while the breaker failure pickup and the phase current detector output are active, the **Retrip** output corresponding to that phase will be activated: **A Pole Retrip** (**RETRIP_A**), **B Pole Retrip** (**RETRIP_B**), **C Pole Retrip** (**RETRIP_C**). If **T1** reaches its end while the breaker failure pickup and the phase current detector output are active, the breaker failure output corresponding to that phase will be activated: **Phase A Single-Phase Breaker Failure** (**BF_PHA**), **Phase B Single-Phase Breaker Failure** (**BF_PHB**), **Phase C Single-Phase Breaker Failure** (**BF_PHC**).

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Overcurrent Pickup Supervision = NO

The pickup of the single-phase breaker failure (**IN_EXT_A**, **IN_EXT_B**, **IN_EXT_C**, **TRIP_A**, **TRIP_B**, **TRIP_C**) triggers the start of the ***Single-Phase Breaker Failure Time T1*** (***1 Pole BF Delay***) and the corresponding ***Single-Phase Retrip Time T2*** (***1 Pole Retrip Delay***). If **T2** ends while the breaker failure pickup is active and the current detector output of the same phase is active (there must be a current flow exceeding the value of the ***Single-Phase PU*** setting), the **Retrip** output corresponding to that phase will be activated: **RETRIP_A**, **RETRIP_B**, **RETRIP_C**. If **T1** reaches its end while the breaker failure pickup is active and the current detector output of the same phase is active (there must be a current flow exceeding the value of the ***Single Phase PU*** setting), the **Breaker Failure** output corresponding to that phase will be activated: **BF_PHA**, **BF_PHB**, **BF_PHC**.

4.7.3.b Three Phase Breaker Failure

The three phase breaker failure pickup is produced by the activation of the **External Three Phase Trip Input** signal associated to this function, **IN_EXT_3PH,** with the activation of the three single-phase failure pickup by external trip signals associated with the logic inputs (**IN_EXT_A**, **IN_EXT_B**, **IN_EXT_C**) or with the activation of any internal three phase trip signal, **TRIP**.
Depending on the status of the ***Pickup Supervision*** (**PU_BF_SUP_EN**) setting, the unit has two different behaviors:

Overcurrent Pickup Supervision = YES

In addition to the breaker failure pickup (**IN_EXT_3PH** or **TRIP3PH**), there must be a current flow exceeding the value of the corresponding setting (***Three Phase PU***), in order to start the ***Three-Phase Breaker Failure Time T3*** (***3 Pole BF Delay***) and the corresponding ***Three-Phase Retrip Time T4*** (***3 Pole Retrip Delay***). If both times reach their end while the breaker failure pickup and the phase current detector output are active, the **Three Phase Retrip** (**RETRIP_3PH**) and **Breaker Failure Activation** (**BF**) outputs will be activated.

Overcurrent Pickup Supervision = NO

The pickup of the breaker failure (**IN_EXT_3PH** or **TRIP3PH**) triggers the start of the ***Three-Phase Breaker Failure Time T3*** (***3 Pole BF Delay***) and the corresponding ***Three-Phase Retrip Time T4*** (***3 Pole Retrip Delay***). If both times reach their end while the breaker failure pickup is active and the current detector output is active (there must be a current flow exceeding the value of the ***Three Phase PU*** setting), the **Three Phase Retrip** (**RETRIP_3PH**) and **Breaker Failure Activation** (**BF**) outputs will be activated.

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4.7.3.c No Load Three Phase Breaker Failure

There are two alternate ways to detect a breaker failure without overcurrent:

- **Detection Based on Breaker Contact Status**

The no load breaker failure initiate conditions are complied with the activation of **52b Contacts Breaker Failure Initiation Input** (**IN_BF_ST_52**) and any breaker pole remaining closed. In order to know the breaker status, the element supervises that the AND of the three open breaker status inputs (**IN_52bA**, **IN_52bB** and **IN_52bC**) is deactivated or else, that the three open pole input (**IN_3POL_AND**) is zero.

When the no load three phase breaker failure picks up, the timers ***No Load Three Phase Breaker Failure Time T5*** (***3 Pole No OC Delay***) and ***No Load Three Phase Retrip Time T6*** (***3 Pole Retrip No OC Delay***) will be activated. If both times time out while the input signal and any breaker closed pole are active, the **Three Phase Retrip**, (**RETRIP_3PH**) and **Breaker Failure Activation** (**BF**) outputs will be activated.

52b Contacts Breaker Failure Initiation Input can be configured with the frequency, overvoltage, weak infeed logic element trip outputs, through a user logic, etc. If this signal (**IN_BF_ST_52**) is not configured in the user logic (no signal is assigned to activate it), then the **No Load Three Phase Breaker Failure Trip** (supervised by the position of the breaker contacts) will never be activated.

- **Detection based on a Ground Current Measuring Element**

Breaker failure initiate is produced by the activation of signal **Ground Unit Breaker Failure Initiation Input** (**IN_BF_ST_N**).

Depending on the status of the ***Pickup Supervision*** (**PU_BF_SUP_EN**) setting, the unit has two different behaviors:

Overcurrent Pickup Supervision = YES

In addition to the breaker failure pickup (**IN_BF_ST_N**), there must be a neutral current flow exceeding the value of the corresponding setting (***BF Neutral Pickup***), in order to start the countdown of the corresponding timers to the ***No Load Three Phase Breaker Failure Time T5*** (***3 Pole No OC Delay***) and the corresponding ***No Load Three Phase Retrip Time T6*** (***3 Pole Retrip No OC Delay***). If both timers time out while the input signal and the neutral current detector output are active, the **Three Phase Retrip** (**RETRIP_3PH**) and **Breaker Failure Activation** (**BF**) outputs will be activated.

Overcurrent Pickup Supervision = NO

The pickup of the breaker failure (**IN_BF_ST_N**) triggers the start of the timers corresponding to ***No Load Three Phase Breaker Failure Time T5*** (***3 Pole No OC Delay***) and the corresponding ***No Load Three Phase Retrip Time T6*** (***3 Pole Retrip No OC Delay***). If both timers time out while the input signal and the neutral current detector output are active (there must be a neutral current flow that exceeds the value of the ***BF Neutral Pickup*** setting), the **Three Phase Retrip** (**RETRIP_3PH**) and **Breaker Failure Activation** (**BF**) outputs will be activated.

The **Ground Unit Breaker Failure Initiation Input** can be configured with the relay general trip output (**TRIP**), with an external trip input, with internal protection element signals, through user logic, etc. If this signal (**IN_BF_ST_N**) is not configured in the user logic (no signal is assigned to activate it), then the **No Load Three Phase Breaker Failure Trip** (supervised by neutral overcurrent).

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4.7.3.d Retrip

The **Retrip** function maybe used to open the faulted line breaker before the retrip command is sent to the whole protection zone via activation of the corresponding breaker failure. To this end, the breaker failure timer must be set higher than the Retrip function timer.

The Single Phase Braker Failure, the Three Phase Breaker Failure and No Load Three Phase Breaker Failure can be retripped, each with a separate time setting.

The retrip function is always enabled.

4.7.3.e Configurable Pickup Mode

This setting allows the user to disable the Breaker Failure Pickup Conditions (single trip, three phase trip, external trips, etc.) and enable the activation of the Breaker Failure Pickup through the configurable signals **Single phase A Breaker Failure input**, **Single phase B Breaker Failure input**, **Single phase C Breaker Failure input** and **Three phase Breaker Failure input**. This way, the user can select every unit to activate the Breaker Failure Pickup.

4.7.3.f Internal Arc Detector

As a complement to the above-mentioned Breaker Failure unit, the equipment incorporates a logic which allows to detect the existence of an unextinguished internal arc.

The presence of an unextinguished electric arc in a phase can be detected if the pole position contacts associated with that phase indicate that this is open and notwithstanding the current in this phase exceeds a determined threshold (***Arc Detector Pick Up*** setting).

4.7.3.g Latched Breaker Failure Output

The breaker failure element has two outputs, **Breaker Failure Activation** and **Latched Breaker Failure Activation**. While the signal **Breaker Failure Activation** resets with the element reset, the signal **Latched Breaker Failure Activation** remains active until the element receives the activation of **Reset Latched Breaker Failure** input.

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4.7.4 Block Diagram

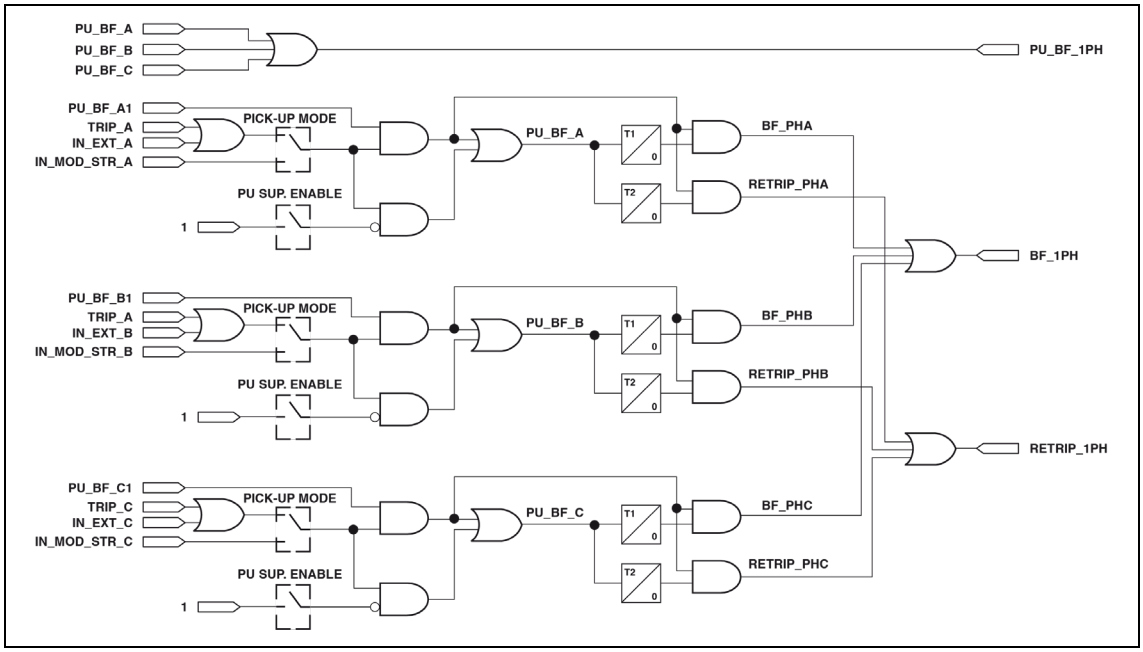


Figure 4.7.2 Block Diagram of Breaker Failure and Single Phase Retrip Function.

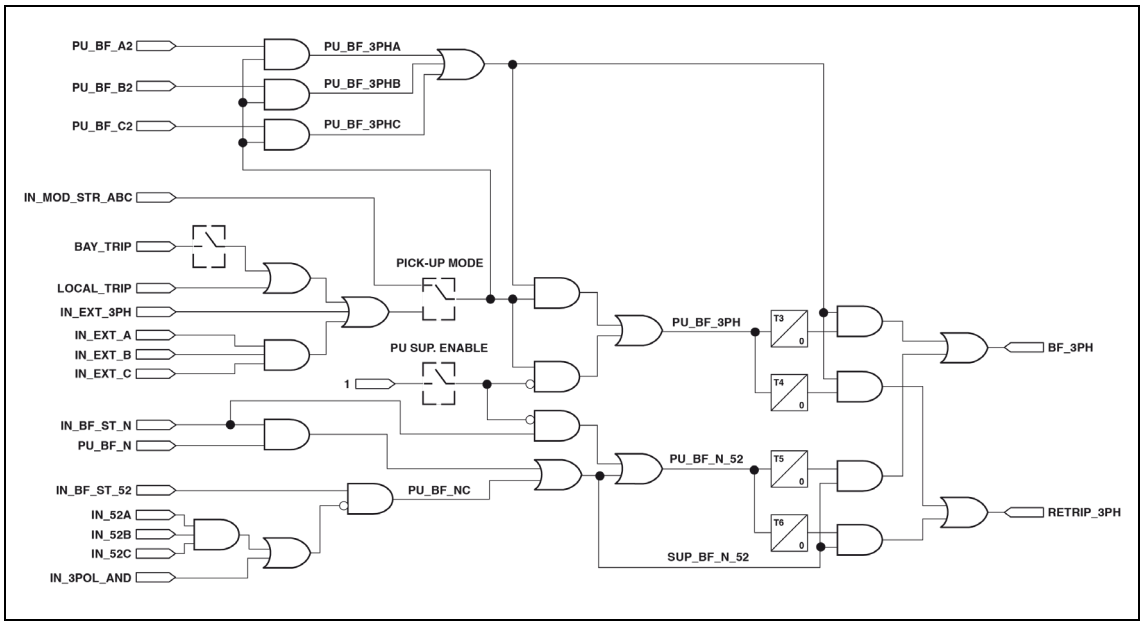


Figure 4.7.3 Block Diagram of Breaker Failure and Three Phase Retrip Function.

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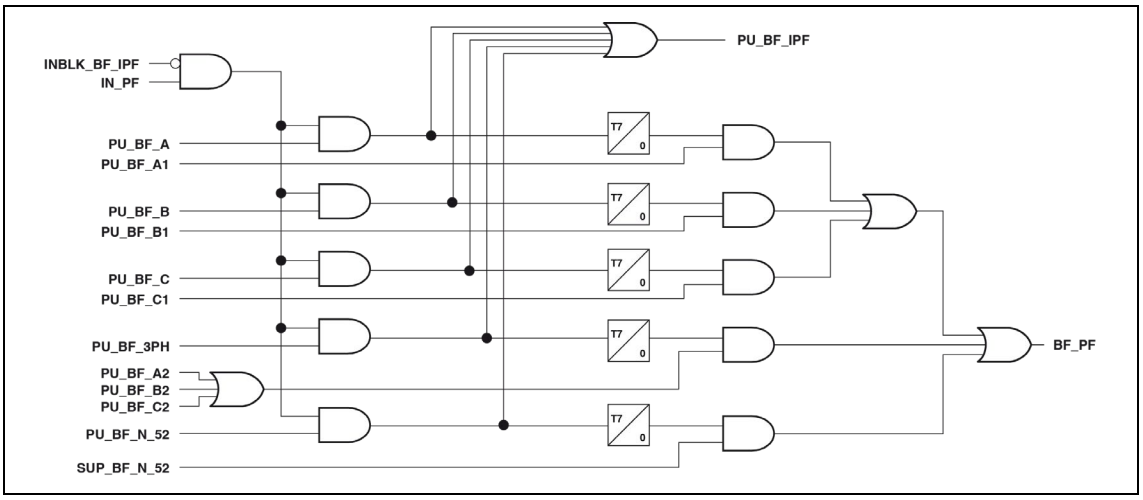


Figure 4.7.4 Block Diagram of Breaker Failure Previously Failed

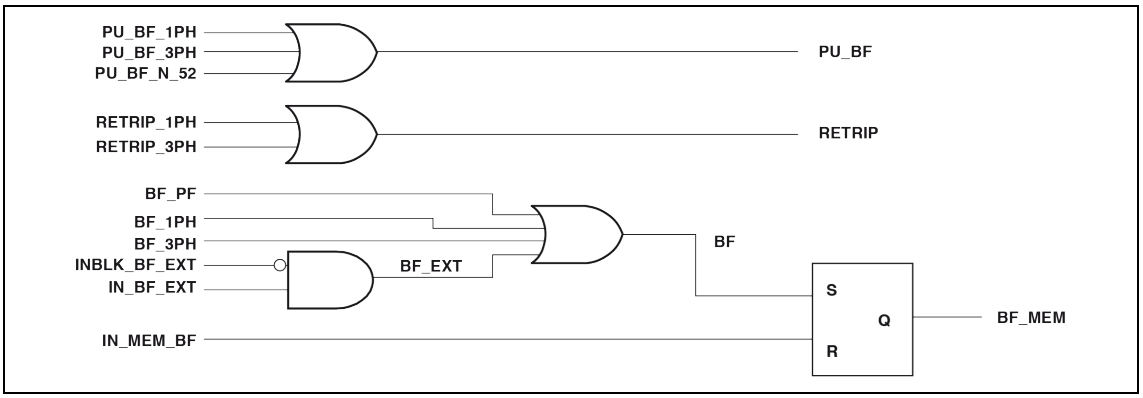


Figure 4.7.5 Block Diagram of Breaker Failure and Retrip Function.

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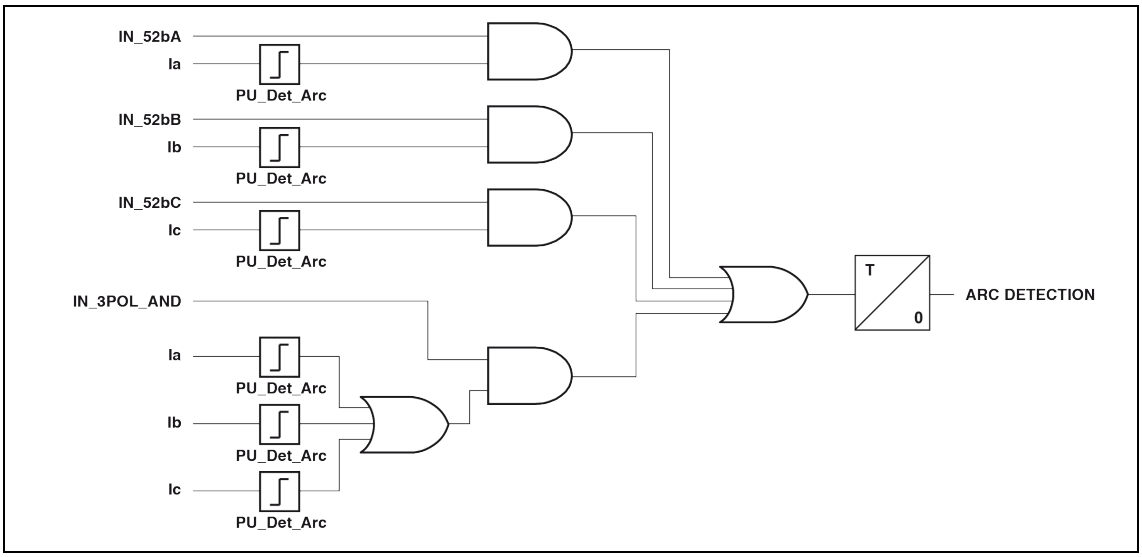


Figure 4.7.6 Internal Arc Detector.

4.7.5 Setting Ranges

Protection / Breaker Failure					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
BF Enable	BF Enable	RBRF1.LNInSvc	YES / NO		NO
Configurable Pickup Mode	Pickup Mode	RBRF.StrMod	YES / NO		NO
PU Supervision	PU Supervision	RBRF1.StrSup	YES / NO		YES
Single Phase PU	Single Phase PU	RBRF1.SP1DetValA	0.02-12 A	0.01	0.2A
Three Phase PU	Three phase PU	RBRF1.DetValA	0.02-12 A	0.01	0.2A
BF Ground Pickup	BF Ground Pickup	RBRF1.DetValA2	0.02-6 A	0.01	0.1A
1 Pole BF Delay	1 Pole BF Delay		0.05-2 s	0.01	0.5s
3 Pole BF Delay	3 Pole BF Delay	RBRF1.FailTmms1	0.05-2 s	0.01	0.5s
3 Pole No OC Delay	3Pole NoOC BF Dly	RBRF1.FailTmms2	0.05-2 s	0.01	0.5s
1 Pole Retrip Delay	1 Pole Retrip Delay		0.05-2 s	0.01	0.5s
3 Pole Retrip Delay	3 Pole Retrip Delay	RBRF1.TPTrTmms1	0.05-2 s	0.01	0.5s
3 Pole Retrip No OC Delay	3Pole Retrp NoOC Dly	RBRF1.TPTrTmms2	0.05-2 s	0.01	0.5s
Enable Arc Detector	Arc Det Enable	ADPTOC1.LNInSvc	NO / YES		NO
Arc Detector Pick Up	Arc Detec pick up	ADPTOC1.StrVal	0.01-1 A	0.01	0.01A
Arc Detector Time	Arc detector time	ADPTOC1.OpDlTmms	0.01-2 s	0.01	0.1s

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4.7.6 Analog Inputs to BF Unit

Table 4.7-1: Analog Inputs to BF Unit		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
IN	Neutral Calculated Current	MMXU1.A.res

4.7.7 Digital Inputs to the BF Unit

Table 4.7-2: Digital Inputs to the BF Unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_BF	Enabling Commands	RBRF1.Mod	Enable Breaker Failure Unit	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
ENBL_ARC		ADPTOC1.Mod	Arc Detector Enable Input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”
IN_EXT_3PH	Logic Inputs to Protection	RBRF1.TPStrIn	External Three Phase Trip Input	I	Activation of this input indicates the existence of a three-phase trip of the breaker generated by an external protection.
IN_EXT_A		RBRF1.ExP1StrIn	External Pole A Trip Input	I	Activation of this input indicates the existence of a phase A single-phase trip of the breaker generated by an external protection.
IN_EXT_B		RBRF1.ExP2StrIn	External Pole B Trip Input	I	Activation of this input indicates the existence of a phase B single-phase trip of the breaker generated by an external protection.
IN_EXT_C		RBRF1.ExP3StrIn	External Pole C Trip Input	I	Activation of this input indicates the existence of a phase C single-phase trip of the breaker generated by an external protection.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 4.7-2: Digital Inputs to the BF Unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_MEM_BF		RBRF1.RsMem	Reset Latched Breaker Failure	I	Activation of this input resets the memorized output of the breaker failure.
IN_BF_ST_52		RBRF1.CBPosStrIn	52b Contacts Breaker Failure Initiation Input	I	Activation of this input produces the start of the breaker failure without overcurrent, whenever there is a breaker pole closed.
IN_BF_ST_N		RBRF1.GndStrIn	Ground Unit Breaker Failure Initiation Input	I	Activation of this input produces the start of the breaker failure without overcurrent, provided that the neutral current detection unit is picked up.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.7.8 Auxiliary Outputs and Events of the BF Unit

Table 4.7-3: Auxiliary Outputs and Events of the BF unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_BF_A1	Pickup Protection Outputs	RBRF1.StrSP1	Single Pole Trip Breaker Failure Phase A Supervision Pick Up	I	Pick up of the current metering unit for single-phase breaker failure detection in the corresponding phase.
PU_BF_B1		RBRF1.StrSP1	Single Pole Trip Breaker Failure Phase B Supervision Pick Up	I	
PU_BF_C1		RBRF1.StrSP1	Single Pole Trip Breaker Failure Phase C Supervision Pick Up	I	
PU_BF_A2		RBRF1.StrTP	Three Pole Trip Breaker Failure Phase A Supervision Pick Up	I	Pick up of the current metering unit for three-phase breaker failure detection in the corresponding phase.
PU_BF_B2		RBRF1.StrTP	Three Pole Trip Breaker Failure Phase B Supervision Pick Up	I	
PU_BF_C2		RBRF1.StrTP	Three Pole Trip Breaker Failure Phase C Supervision Pick Up	I	
PU_BF_3PH			Breaker Failure Three-Phase Supervision Pick Up		
PU_BF_N		RBRF1.StrGnd	Breaker Failure Neutral Supervision Pick Up	I	Pick up of the Neutral current metering unit for breaker failure detection without phase overcurrent.
PU_BF		RBRF1.Str	Breaker Failure Pick Up	I	Pick up of the Breaker Failure.

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Table 4.7-3: Auxiliary Outputs and Events of the BF unit					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
RETRIP_A	Trip Protection Outputs	RBRF1.OpIn	Pole A Retrip	I	
RETRIP_B		RBRF1.OpIn	Pole B Retrip	I	
RETRIP_C		RBRF1.OpIn	Pole C Retrip	I	
RETRIP_3PH		RBRF1.OpIn	Three Phase Retrip	I	Three-phase retrip output.
BF		RBRF1.OpEx	Breaker Failure Activation	I	Activation of breaker failure.
BF_MEM		RBRF1.OpExMem	Latched Breaker Failure Activation	I	
ACT_ARC_DET	Generic Outputs of Protection	ADPTOC1.Op	Arc Detector Activation	I	Activation of the Arc Detector Unit.
BF_ENBLD	Enabled Units Protection Outputs	RBRF1.Mod	Breaker Failure Unit Enabled	I	Indication of enabled or disabled status of the unit.
ARC_ENBLD		ADPTOC1.Mod	Arc Detector Enabled	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.7.9 IEC 61850 Logical Nodes

CLASS RBRF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Start
OpEx	ACT	Trip
OpIn	ACT	Retrip
Settings		
SP1F1Tmms	ING	Delay time single-phase
FailTmms	ING	Delay time three-phase
NLodFlTmms	ING	Delay time three-phase no load
SP1TrTmms	ING	Sigle pole retrip time delay
TPTrTmms	ING	Three pole retrip time delay
NLodTrTmms	ING	Three pole no load retrip time delay
SP1DetValA	ASG	Current detector value for single-phase
DetValA	ASG	Current detector value for three-phase
DetValAGnd	ASG	Current detector value for ground
Extended Data		
LNInSvc	EXT_SPG	In service
StrMod	EXT_SPG	Configurable Pickup Mode
StrSup	EXT_SPG	Pickup Supervision
StrSP1	EXT_ACD	Pickup of the single phase BF unit
StrTP	EXT_ACD	Pickup of the three phase BF unit
StrGnd	EXT_ACD	Pickup of the ground BF unit
ExTPStrIn	EXT_SPS	Three-phase external Protection trip
ExP1StrIn	EXT_SPS	Single-phase A external Protection trip
ExP2StrIn	EXT_SPS	Single-phase B external Protection trip
ExP3StrIn	EXT_SPS	Single-phase C external Protection trip
RsMem	EXT_SPC	Memorized breaker failure reset
CBPosStrIn	EXT_SPS	No Load Breaker failure contact position start
GndStrIn	EXT_SPS	No Load Breaker failure ground unit start
OpExMem	EXT_ACT	Memorized breaker failure

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CLASS IRLADPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service

4.7.10 Breaker Failure Unit Test

To check this element, configure one of the auxiliary outputs for the breaker failure function. Then disable all elements except phase and neutral instantaneous and the breaker failure elements.

Set phase and neutral instantaneous elements to **0.5 A** and trip time to zero. Set breaker failure element reset levels to the desired reset values for overcurrent and activation time. Cause a trip applying a **1 A** current by phases and neutral and maintain the current after tripping. The breaker failure element will activate in period of time between ±1% or ±20 ms of the setting value. To check this element an auxiliary output must be configured as latched breaker failure, and one ED as latched breaker failure reset.

Reduce the current gradually until the breaker failure element resets, in a stable fashion. Check that this occurs for a value between ±1% the setting.

Configure the previously failed breaker failure initiate signal, and previously failed breaker failure blocking, in two ED. Cause a phase overcurrent element trip. Check latched breaker failure signal activation and reset. Activate the previously failed breaker failure blocking ED, repeat the test, and check the breaker failure is not activated.

Configure the **52b Contacts Breaker Failure Initiation Input** (**IN_BF_ST_52**), and open breaker status, in two ED. Activate the **IN_BF_ST_52** input with closed breaker, and check latched breaker failure signal activation and reset. Open the breaker, repeat the test, and check the breaker failure is not activated.

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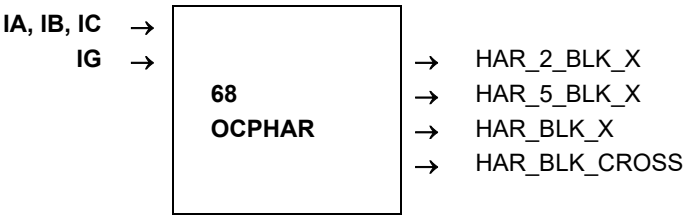
4.8 Harmonic Blocking

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4.8.2 General Block 4.8-2
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4.8.5 Auxiliary Outputs and Events of the Harmonic Blocking 4.8-5
4.8.6 IEC 61850 Logical Node 4.8-6

4.8.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Harmonic Blocking	OCPHAR1	3I2f5f>	68

4.8.2 General Block



4.8.3 Operation Principles

The energizing of a transformer causes transient saturation as a consequence of the DC component generated in the magnetic flux. This results in high magnetizing currents (*inrush*), which can be several times the machine rated current.

Under overexcitation conditions of the transformer, as a result of overvoltage and under frequency, important magnetizing currents can also be produced.

In order to avoid the operation of overcurrent and/or distance elements under the mentioned magnetizing currents, the Harmonic Blocking function is included. In order to differentiate between a fault current and an *inrush* current, both with high fundamental component, the 2nd and 5th harmonic components are analyzed.

Energizing currents have a high 2nd harmonic content and over excitation currents a high 5th harmonic content. Blocking by 2nd and 5th harmonics is enabled through the settings ***2nd Blocking Enable*** and ***5th Blocking Enable***. The 2nd and 5th harmonic content is calculated for the three phase currents, ground current and residual ground current. When the ratio between the 2nd harmonic current and the fundamental current exceeds, in percentage, the setting ***2nd Blocking Pickup***, the signals **Phase A Blocking by 2nd Harmonic**, **Phase B Blocking by 2nd Harmonic**, **Phase C Blocking by 2nd Harmonic**, **Ground Blocking by 2nd Harmonic** and **Harmonic** will activate, as a function of the type of current analyzed. Likewise, when the ration between the 5th harmonic current and the fundamental current exceeds the setting ***5th Blocking Pickup***, the signals **Phase A Blocking by 5th Harmonic**, **Phase B Blocking by 5th Harmonic**, **Phase C Blocking by 5th Harmonic**, **Ground Blocking by 5th Harmonic** and. The signals **Phase A Blocking by Harmonics**, **Phase B Blocking by Harmonics**, **Phase C Blocking by Harmonics**, **Ground Blocking by Harmonics** are OR functions of the corresponding blocking signals by 2nd and 5th harmonic.

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All overcurrent and distance elements include the setting ***Harmonic Blocking***. When this setting is set to **YES**, the applicable element will be blocked by the corresponding blocking by harmonics signal. The Phase A overcurrent element and the distance unit for AG, AB and CA faults will be blocked by signal **Phase A Blocking by Harmonics**; the ground overcurrent element will be blocked by signal **Ground Blocking by Harmonics**, etc.

The calculation of the ratio *harmonic current / fundamental current* will only be carried out when the fundamental current exceeds the setting ***Minimum Current*** (phase, ground or). This setting must equal the minimum pickup level setting of the applicable overcurrent element (phase, ground or).

For phase overcurrent and distance elements, there is the possibility to enable a Cross-Blocking logic. This logic allows for extending the blocking by harmonics to the rest of phases when at least in one phase (**OR** option) or in two phases (**2 out of 3** option) the harmonic level is high. The cross-blocking logic keeps the safety under *inrush* situations when phase harmonic content is too low. The **2 out of 3** option has a better response than the **OR** option. When the energized transformer winding has the neutral connected to ground and another winding is delta connected, the logic **2 out of 3** will never be met if the transformer is closed onto fault (internal fault at the same time than the *inrush* current). If it is a single phase fault, the zero sequence current from the ground connection will substantially reduce the harmonic content of the healthy phases. If it is a polyphase fault the **2 out of 3** option will not be met either.

The **AND** option of the setting ***Harmonic Blocking Logic*** disables the Cross-Blocking logic.

The setting ***Cross Blocking Time*** limits the duration of the Cross-Blocking logic, i.e., although the **Cross Blocking by Harmonics** signal remains active, at the end of the cross blocking time only the blocking signals of the phases whose harmonic percentage exceeds the setting will remain active.

In new transformers, the *inrush* current has a smaller percentage of second harmonic than in old transformers. As a result of the difference in current phase angle between the three phases when switching on (voltage phase difference is 120º to each other), generating different DC level in the flux associated to each phase, one phase could exist in which the *inrush* current harmonic content is very small. In this case, cross-blocking logic must be used to keep the safety. However, this logic will only be necessary during the first 4 or 5 energizing cycles, since after this, as a result of the reduction of the *inrush* current, the 2nd harmonic content will have increased. Hence, a recommended cross-blocking time is 100 ms. However, as mentioned above, if the transformer is grounded star / delta and it is energized from the star side, the **2 out of 3** logic will always be met. In this case the Cross-Blocking time could be extended to several seconds.

The signal **Cross Blocking by Harmonics** indicates the Cross-Blocking logic setting: **OR** or **2 out of 3** is met. This signal will be used to block the negative sequence overcurrent elements, provided the setting ***Harmonic Blocking*** is enabled. The **Cross Blocking by Harmonics** signal does not depend on the cross blocking time, this is, while the signal is active, the negative sequence overcurrent units will remain blocked. When the cross blocking signal is reset, the negative sequence units will be unblocked.

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4.8.4 Setting Ranges

Protection / Overcurrent / Harmonic Blocking					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
2nd Block. Enab.	2nd Block. Enab.	OCPHAR1.BlkEna1	YES / NO		NO
2nd Blocking PU	2nd Blocking PU	OCPHAR1.BlkValPct1	5%-100%	0.01%	20%
5th Block. Enab.	5th Block. Enab.	OCPHAR1.BlkEna2	NO / YES		NO
5th Blocking PU	5th Blocking PU	OCPHAR1.BlkValPct1	5%-100%	0.01%	20%
H Blocking Logic	H Blocking Logic	OCPHAR1.HBlkTyp	OR AND 2 OUT OF 3		OR
Cross Blocking Time	Cross Bloq Time	OCPHAR1.BlkOrTmms	0.05-300s	0.01s	0.1s
Phase Minimum Current	Phase Min Current	OCPHAR1.BlkValA1	0.01-120 A	0.01 A	0.2 A
Neutral Minimum Current	Neutral Min Curr	OCPHAR1.BlkValA2	0.01-90 A	0.01 A	0.2 A
Ground Minimum Current	Ground Min Current	OCPHAR1.BlkValA4	0.01-90 A	0.01 A	0.2 A

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4.8.5 Auxiliary Outputs and Events of the Harmonic Blocking

Table 4.8-1: Auxiliary Outputs and Events of the Harmonic Blocking

Name	Group	IEC 61850	Description	Vis.	Function
HAR_2_BLK_A	Harmonic Lock and Saturation Detector	OCPHAR1.Str1	Phase A Blocking by 2nd Harmonic	I	Phase, Neutral, Ground and Harmonic Blocking.
HAR_2_BLK_B		OCPHAR1.Str1	Phase B Blocking by 2nd Harmonic	I	
HAR_2_BLK_C		OCPHAR1.Str1	Phase C Blocking by 2nd Harmonic	I	
HAR_2_BLK_N		OCPHAR1.Str2	Neutral Blocking by 2nd Harmonic	I	
HAR_2_BLK_G		OCPHAR1.Str3	Ground Blocking by 2nd Harmonic	I	
HAR_5_BLK_A		OCPHAR1.Str4	Phase A Blocking by 5th Harmonic	I	
HAR_5_BLK_B		OCPHAR1.Str4	Phase B Blocking by 5th Harmonic	I	
HAR_5_BLK_C		OCPHAR1.Str4	Phase C Blocking by 5th Harmonic	I	
HAR_5_BLK_N		OCPHAR1.Str5	Neutral Blocking by 5th Harmonic	I	
HAR_5_BLK_G		OCPHAR1.Str6	Ground Blocking by 5th Harmonic	I	
HAR_BLK_A		OCPHAR1.Str8	Phase A Blocking by Harmonics	I	
HAR_BLK_B		OCPHAR1.Str8	Phase B Blocking by Harmonics	I	
HAR_BLK_C		OCPHAR1.Str8	Phase C Blocking by Harmonics	I	
HAR_BLK_N		OCPHAR1.Str9	Neutral Blocking by Harmonics	I	
HAR_BLK_G		OCPHAR1.Str10	Ground Blocking by Harmonics	I	
HAR_BLK_CROSS		OCPHAR1.Str7	Cross Blocking by Harmonics	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.8.6 IEC 61850 Logical Node

CLASS IRLPHAR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str1	ACD	Second harmonic blocking phase pickup
Str2	ACD	Second harmonic blocking neutral pickup
Str4	ACD	Fifth harmonic blocking phase pickup
Str5	ACD	Fifth harmonic blocking neutral pickup
Str7	ACD	Harmonic cross blocking pickup
Str8	ACD	Harmonic blocking phase pickup
Str9	ACD	Harmonic blocking neutral pickup
Extended Data		
HBlkTyp	EXT_ENG	Harmonic blocking logic type
BlkOrTmms	EXT_ING	Cross blocking time
BlkEna1	EXT_SPG	Second harmonic blocking enable
BlkEna2	EXT_SPG	Fifth harmonic blocking enable
BlkValPct1	EXT_ASG	Second harmonic blocking pickup
BlkValPct2	EXT_ASG	Fifth harmonic blocking pickup
BlkValA1	EXT_ASG	Phase minimum current
BlkValA2	EXT_ASG	Neutral minimum current

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4.9 Saturation Detector

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4.9.2 General Block 4.9-2
4.9.3 Operation Principles 4.9-2
4.9.4 Setting Ranges 4.9-3
4.9.5 Auxiliary Outputs and Events of the Saturation Detector 4.9-3
4.9.6 IEC 61850 Logical Node 4.9-4

4.9.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Saturation Detector	PHSTCTR1		

4.9.2 General Block



4.9.3 Operation Principles

The Saturation Detector is based on the calculation of the derivative of the measured current. Just as CT saturation occurs the derivative suffers a sharp increase. Taking into account that the maximum value of the current derivative is

$$A \cdot \frac{2\pi}{N}$$

where ***A*** is the maximum value of the current and ***N*** the number of samples per cycle, when

$$It' > k \cdot A \cdot \frac{2\pi}{N}$$

k being constant, saturation will be detected. ***A*** will be calculated as the largest of two consecutive maximums. The Saturation Detector will only operate when ***A*** is greater than the peak value of the local phase nominal current and when the Fault Detector is active. It will include one cycle reset time.

Additionally, the **DLF** can receive saturation detection signals from the connected remote far-end units thorough 87L communications system.

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4.9.4 Setting Ranges

Protection / Saturation Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Saturation Detector Enable	Enable		YES / NO		NO
Minimum Current	Minimun Current	PHSTCTR1.SatMimA	0.1-100 A	0.1	2 A

4.9.5 Auxiliary Outputs and Events of the Saturation Detector

Tabla 4.9-1 Auxiliary Outputs and Events of the Saturation Detector

Name	Group	IEC 61850	Description	Vis.	Function
SAT_A	Harmonic Lock and Saturation Detector	PHSTCTR1.Sat	Phase A CT Saturation	I	The CT associated to the corresponding phase is in saturation conditions.
SAT_B		PHSTCTR1.Sat	Phase B CT Saturation	I	
SAT_C		PHSTCTR1.Sat	Phase C CT Saturation	I	
SAT_A2		PHSTCTR2.Sat	Phase A CT Saturation from Remote E2	I	The CT associated to the corresponding phase in Remote far-end E2 is in saturation conditions.
SAT_B2		PHSTCTR2.Sat	Phase B CT Saturation from Remote E2	I	
SAT_C2		PHSTCTR2.Sat	Phase C CT Saturation from Remote E2	I	
SAT_A3		PHSTCTR3.Sat	Phase A CT Saturation from Remote E3	I	The CT associated to the corresponding phase in Remote far-end E3 is in saturation conditions.
SAT_B3		PHSTCTR3.Sat	Phase B CT Saturation from Remote E3	I	
SAT_C3		PHSTCTR3.Sat	Phase C CT Saturation from Remote E3	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.9.6 IEC 61850 Logical Node

CLASS IDFPHSTCTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured Values		
Amp	SAV	Current. (Optional data as Tissue 80)
Settings		
ARtg	ASG	Rated current
Rat	ASG	CT Ratio
Measured Values		
Amp	SAV	Current
Extended Data		
Sat	EXT_ACT	CT saturated
SatMinA	EXT_ASG	Minimum Current for Saturation Detector
SupSvc	EXT_SPG	CT supervision in service setting
SupEna	EXT_SPC	CT supervision enable command
SupBlk	EXT_SPC	CT supervision block command
SupFail	EXT_ACT	CT supervision failure
SupTmms	EXT_ING	CT supervision delay
SupFailIn	EXT_SPS	CT supervision failure input

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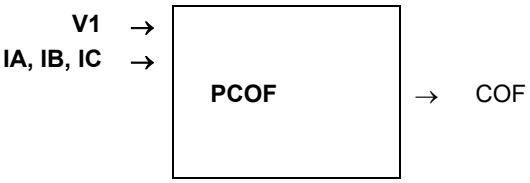
4.10 Close-on-Fault Detector

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4.10.2 General Block 4.10-2
4.10.3 Operation Principles 4.10-2
4.10.4 Setting Ranges 4.10-6
4.10.5 Analog Inputs to the Unit 4.10-7
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4.10.7 Auxiliary Outputs and Events of the Close-on-Fault Module 4.10-8
4.10.8 IEC 61850 Logical Node 4.10-8
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4.10.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Close-on-fault detector	PCOF		

4.10.2 General Block



4.10.3 Operation Principles

The IEDs are provided with a Close-on-Fault Detector, which generates instantaneous tripping when a fault is detected at the time a breaker close command is generated.

The unit will enter into operation with orders for manual closing as well as for reclose, since these are internal (activation of the **Manual Closing Order** (**IN_CLOSE_MAN**) output, of the control logic, or activation of the **Reclose Command** (**RCLS_CMD**) output, from the recloser) or external (activation of the **External Manual Closing** (**IN_CLOSE_EXT**) input or activation of the **External Reclose** (**IN_EXT_RCLS**) input). The generation of any of the above-mentioned commands keep the element in operation during one adjustable duration pulse, based on ***COF Time*** setting.

No matter whether the breaker manual reset or reclose commands are external, the switch onto fault detector can be put into operation with no need for supervising the state of any digital input. To this end, the output generated by the dead line detector can be used. In order for the switch onto fault detector to activate when the breaker closes, namely, when the line is energized, the deactivation of the signal **Any Phase Dead** (switching from 1 to 0, obtained applying the leading edge function, incorporated into the programmable logic, to the negation of said signal) can be assigned to both **External Manual reset** and **External Reclosing** inputs. To discern between manual reset and reclose (the switch onto fault detector operation may differ whether manual reset or reclose: zone 1 extension, etc.), the time during which the line has remained deenergized can be taken into account. To this end, the logic input **External Manual reset** must be activated only if the signal **Any Phase Dead** has remained active for a time sufficiently greater than that of any reclose cycle. A time of 50 s may be advisable.

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The signals to activate the operation of the relay can be selected. This can be done through the ***Close-on-Fault Detector Initiate Mask*** setting. The relay can operate both with manual close commands and reclose commands, whether:

Internal
Activation of control logic's **Manual Close Command** output (**IN_CLOSE_MAN**).
Activation of **Manual Close by Dead Line Deactivation** output (**CLOSE_DL**).
Activation of **Manual Close by Open Pole Deactivation** output (**CLOSE_OP**).
Activation of recloser **Reclose Command** output (**RCLS_CMD**).
Activation of **Reclose by Dead Line Deactivation** output (**RCLS_DL**).
Activation of **Reclose by Open Pole Deactivation** output (**RCLS_OP**).
External
Activation of **External Manual Close** input (**IN_CLOSE_EXT**).
Activation of **External Reclose** input (**IN_EXT_RCLS**).

Manual Close by Dead Line Deactivation (**CLOSE_DL**) activates when **Any Dead Line** (**DL_OR**) signal deactivates, after having been active for at least the ***Manual Close Delay*** setting value.

Manual Close by Open Pole Deactivation (**CLOSE_OP**) activates when **Any Open Pole** (**OR_P_OP**) signal deactivates, after having been active for at least the ***Manual Close Delay*** setting value.

Reclose by Dead Line Deactivation (**RCLS_DL**) activates when **Any Dead Line** (**DL_OR**) signal deactivates, after having been active for at least the ***Reclose Delay*** setting value.

Reclose by Open Pole Deactivation (**RCLS_OP**) activates when **Any Pole Open** (**OR_P_OP**) signal deactivates, after having been active for at least the ***Reclose Delay*** setting value.

When the Close-on-Fault unit is activated with a manual closing order, it will always produce non-resetting three-phase tripping. However, if the unit begins to operate with a reclose command, its activation will also permit three-phase tripping but will generate a new reclose sequence (which will result in a new reclose command or a definite trip according to the decisions made by the recloser).

The Close-on-Fault unit presents non-directional phase overcurrent units with adjustable pickup levels (**COF Current Pickup** setting). These units are for the purpose of clearing faults with voltage less than the minimum to polarize the distance units, when there is no voltage memory. They can only operate when the positive sequence voltage has dropped below ***COF Voltage Pickup*** setting.

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The operation of the Close-on-Fault Detector is shown in Figure 4.10.1.

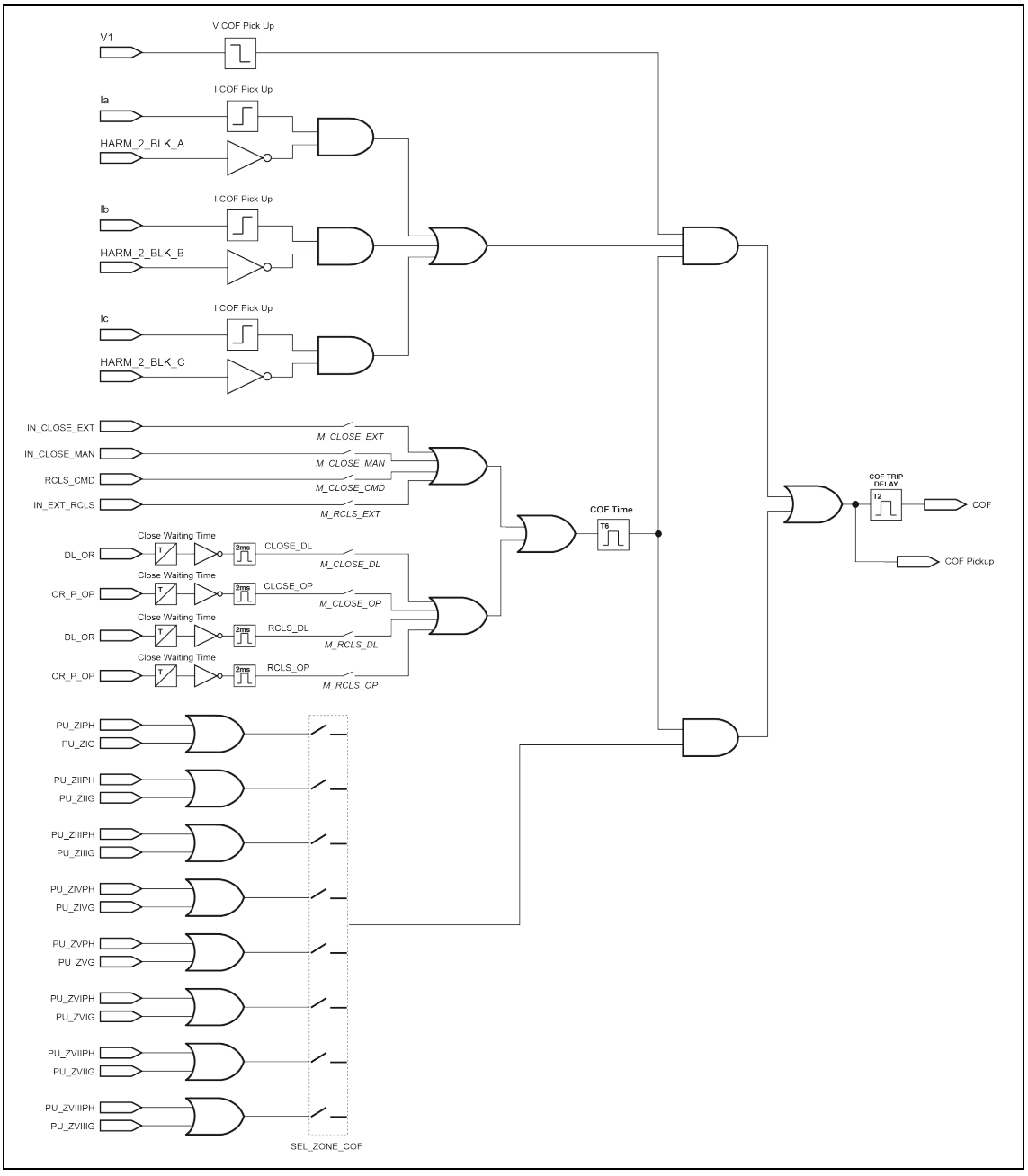


Figure 4.10.1 Close-on-Fault Detector Block Diagram

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Legend	
V COF Pickup: close-on-fault voltage pickup level	I COF Pickup: close-on-fault current pickup level
V1: positive sequence voltage	CLOSE_DL: manual close by dead line.
Ix: phase X current	CLOSE_OP: manual close by pole open.
HARM_2_BLK_X: 2nd harmonic blocking of phase X.	RCLS_DL: reclose by dead line.
IN_CLOSE_EXT: external manual close input.	RCLS_OP: reclose by open pole.
IN_CLOSE_MAN: manual close command.	M_CLOSE_EXT: close-on-fault external close permission
RCLS_CMD: reclose command.	M_CLOSE_MAN: close-on-fault manual close permission
IN_EXT_RCLS: external reclose input.	M_RCLS_CMD: close-on-fault reclose command permission
DL_OR: any dead phase.	M_RCLS_EXT: close-on-fault external reclose permission
OR_P_OP: any pole open.	COF_TIME: close-on-fault time
PU_ZnX: pcik-up phase/ground zone n units	COF_TRIP_DELAY: close-on-fault trip delay
SEL_ZONE_COF: close-on-fault supervision zone (setting)	COF: close-on-fault trip

Sometimes closing the line breaker supposes the energization of a transformer. There is usually a sudden increase in current during transformer energizing, and in devices where the voltage is supplied from the line side, the low voltage and the increase in current could cause the equipment to trip without fault conditions present. To avoid this type of phenomena, current harmonic blocking is used, since energizing a transformer, besides the current increase, it also generates 2nd harmonic content. For cases in which there are transformers near the line, it is necessary to consider the presence of 2nd harmonics to differentiate current increases due to a fault from those due to the transformer energizing.

On the other hand, the Close-on-Fault unit permits the area selected through the ***COF Supervision Zone*** setting to generate an instantaneous tripping. Consequently, it permits to make an extension of zone 1. This will always occur in the case of manual closings.

In dual breaker bays, whether the switch onto fault element activates with the closing of the first breaker or both breakers can be selected through the ***COF Breaker*** setting. It is worth mentioning that in breaker and a half or ring bays the current circulating through each CT may vary greatly. If the closing of the first breaker connects the line to a very weak source, the above-mentioned phase overcurrent elements might not pickup upon a switch onto fault condition.

Additionally, a trip delay for the unit can be configured using the setting ***Trip Delay for Unit Activation (COF Trip Delay)***, represented as T2 in the unit's logic diagram. The start of this timer is triggered by the **COF_Pickup** signal. In this way, while this timer is counting, it can be identified that fault conditions are active. On the other hand, this start signal is also used for latching the Fault Detector.

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4.10.4 Setting Ranges

Protection / Close-on-Fault Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
COF Enable	COF Enable	PCOF1.LnInSvc	YES / NO		NO
COF Supervision Zone	COF Sup. Zone	PCOF1.SOFZn	Zone 2 Zone 3 Zone 4 Zone 5 Zone 6 Zone 7 Zone 8		Zone 2
I COF Pickup	I COF Pick up	PCOF1.StrVal	0.2 - 30 A	0.05 A	10A
V COF Pickup	V COF Pick up	PCOF1.PSVLev	5 - 100 V	0.01 V	50 V
COF Trip Delay	COF Trip Delay	PCOF1.OpTmms	0 - 300 s	0.01 s	0 s
COF Time	COF Time	PCOF1.EnaTmms	0 - 300 s	0,01 s	0,3 s
COF Breaker*	COF Breaker	PCOF1.CBClsTyp (ENG)	0: First Closing. 1: Both.		0
Close Waiting Time	Close Waiting Time	PCOF1.ClsTmms	0.05 s - 300 s	0.01 s	50 s
Reclosing Wait Time	Reclo Waiting Time	PCOF1.RecTmms	0.05 s - 300 s	0.01 s	0.2 s
COF Initiation Mask	COF Init Mask				
DL Deactiv Manual Close	DL Manual Close	PCOF1.DELCls	YES / NO		YES
OP Deactiv Manual Close	OP Manual Close	PCOF1.OpnPCls	YES / NO		YES
External Manual Close	Ext Manual Close	PCOF1.ExtCls	YES / NO		YES
Manual Close Command	Manual Close CMD	PCOF1.ClsCmd	YES / NO		YES
DL Deactiv Reclose	DL Reclose	PCOF1.DELRec	YES / NO		YES
OP Deactiv Reclose	OP Reclose	PCOF1.OpnPRec	YES / NO		YES
External Reclose	Ext Reclose	PCOF1.ExtRec	YES / NO		YES
Reclose Command	Reclose CMD	PCOF1.RecCmd	YES / NO		YES

(*) Setting included for relays with Double Breaker or Breaker and a Half capability.

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4.10.5 Analog Inputs to the Unit

Table 4.10-1: Analog Inputs of the Close-on-Fault Detector		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
V1	Positive Sequence Calculated Voltage	MSQI1.SeqV.c1

$$|V_1| = \left| \frac{V_A + V_B \cdot 1\angle 120° + V_C \cdot 1\angle 240°}{3} \right|$$

4.10.6 Digital Inputs to the Close-on-Fault Module

Table 4.10-2: Digital Inputs to the Close-on-Fault Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_COF	Inputs		Close-on-fault detector enable input		Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
IN_CLOSE_EXT			External manual closing input		The activation of this input indicates that an external manual closing has been carried out; this input puts into operation the close-on-fault detector.
IN_EXT_RCLS			External reclose input		The activation of this input indicates that a reclose has been carried out through an external unit; this input puts into operation the close-on-fault detector.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.10.7 Auxiliary Outputs and Events of the Close-on-Fault Module

Table 4.10-3: Auxiliary Outputs and Events of the Close-on-Fault Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
COF	Outputs	PCOF1.Op	Close-on-fault detector trip		Trip of the unit
COF_ENBLD			Close-on-fault detector enabled		Indication of enabled or disabled status of the unit.
COF_PU			Close-on-fault detector Pickup		Indication of the Pickup status of the unit

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.10.8 IEC 61850 Logical Node

CLASS PCOF		
Data Object Name	**Common Data Class**	**Explanation**
PCOF		
Data Objects		
Status information		
Op	ACT	Tripping due to close-on-fault detector
Settings		
LnInSvc	SPG	COF Enable
SOFZn	ENG	COF Supervision Zone
StrVal	ASG	I COF Pickup
PSVLev	ASG	V COF Pickup
OpTmms	ING	COF Trip Delay
EnaTmms	ING	COF Time
ClsTmms	ASG	Close Waiting Time
RecTmms	ASG	Reclosing Wait Time
DELCls	SPG	DL Deactiv Manual Close
OpnPCls	SPG	OP Deactiv Manual Close
ExtCls	SPG	External Manual Close
ClsCmd	SPG	Manual Close Command
DELRec	SPG	DL Deactiv Reclose
OpnPRec	SPG	OP Deactiv Reclose
ExtRec	SPG	External Reclose
RecCmd	SPG	Reclose Command

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4.10.9 Close-on-Fault Detector Test

During the test, consult the following indicators:

Display In the **Information** - **Status** - **Measuring Elements** - **Close-on-Fault**.
ZIVercomPlus® In the status screen (**Status** - **Elements** - **Close-on-Fault**).

Introduce an undervoltage and overcurrent condition, as high as would be seen on a balanced three-phase system of 25 Vac with inductive angles of 0º, 120º and 240º in the A, B and C phases, respectively for the voltages; and of 15 A ac with identical angles for the currents.

The input **External Manual Closing** (**IN_CLOSE_EXT**) should be activated. The state of each metering element indicator should activate for the switch onto fault time (setting) and the equipment should trip. The last trip indicator in the display, as well as in the ***ZIVercomPlus***® program, should show a three-phase fault with a close-on-fault detector trip (**COF**).

It will be verified that the performance of the relay is the same if instead of activating the **External Manual Closing** (**IN_CLOSE_EXT**) input we carry out a close command under the same conditions.

It will be verified that the close-on-fault detector also operates after a reclosing (close-on-fault reclosing) that is, a trip due to close-on-fault reclosing will be obtained in case that under the same conditions mentioned previously the reclosing is carried out or the **External Reclosing (IN_EXT_RCLS)** input is activated. In case of close-on-fault reclosing, in addition, it is possible to disable the extension of zone 1.

All the zones will be adjusted in reverse (in order that the close/reclose onto-on-fault does not act by the extension of zone 1) and fault conditions with second harmonic content will be applied to the relay. It will be verified that the close/reclose-on-fault acts (in case of any of the signals mentioned previously are activated) or not according to the settings ***CSF Current Pickup*** and ***2nd Harmonic Restraint*** (provided that the positive sequence voltage is below 50 V).

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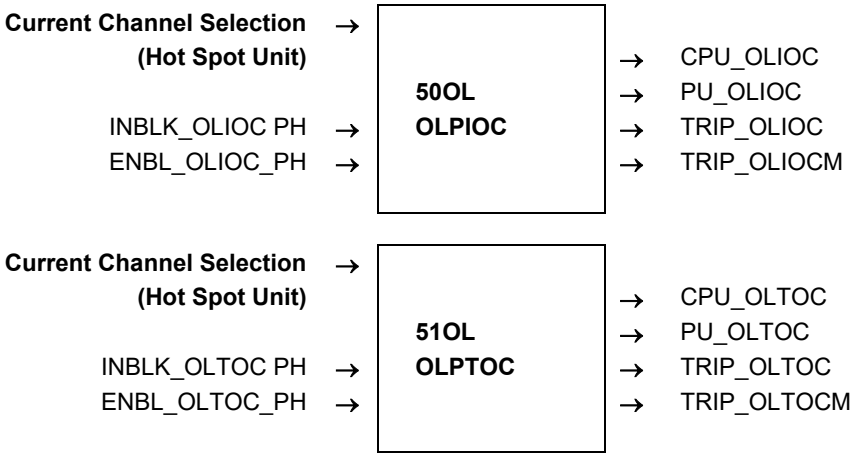
4.11 Overload Units

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4.11.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Overload Instantaneous Overcurrent	OLPIOC	50OL>>	50OL
Overload Time Overcurrent	OLPTOC	51OL>	51OL

4.11.2 General Block



4.11.3 Operation Principles

IEDs are equipped with two overload units (one instantaneous and one timer). The main application of these units is to protect the transformer during short term emergency load conditions, as described in the IEC 60076-7 loading guide.

Power transformer operations can be classified into three operating conditions (normal, long term emergency and short term emergency) according to the loading and heat conditions.

- The normal condition assumes transformer operations under the nominal conditions for which it was designed.
- The long term emergency condition assumes transformer accelerated aging (this situation can be prolonged for days, weeks or months) and is covered by the hot spot thermal image unit that trips the transformer if the risk values for the machine are reached.
- The short term emergency load condition assumes overload and heat values that cause a loss of dielectric strength that can cause the transformer to fail. However, it is preferable to assume the risk of a fault for a short period of time (30 minutes) before a supply fault occurs. The overload unit applies to this case.

These units are independent of the hot spot thermal image unit and can be used for other applications. The operating principles of overload elements are the same as for instantaneous and time phase overcurrent elements (operating only by the phase selected in setting ***Current Channel*** located in the **Hot Spot** element), with the distinction that it includes a ***Fixed Time*** setting up to 2 hours.

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4.11.4 Setting Ranges

Protection / Overload / Time Overload					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	TOL Enable		YES / NO		NO
Unit Pickup	TOL Pickup		(0.02-25) In	0.01 A	6.50 A
Time Curve	Overload Curve		See list of curves		Fixed T.
Negative Curve Time Dial	Overload Dial		0.05-10	0.01	1
Effective range for the IEC curves			0.05-1	0.01	1
Effective range for the IEEE/US/RI curves			0.1-10	0.01	1
Fixed Time	TOL Delay		0.05-7200 s	0.01 s	1800 s

Protection / Overload / Instantaneous					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	IOL Enable	OLPIOC1.LNInSvc (SPG)	YES / NO		NO
Unit Pickup	IOL Pickup	OLPIOC1.StrVal (ASG)	(0.02-25) In	0.01 A	7.50 A
Unit Time	IOL Delay	OLPIOC1.OpDlTmms (ING)	0.05-7200 s	0.01 s	5 s

4.11.5 Digital Inputs of the Overload Module

Table 4.11-1: Auxiliary Outputs and Events of the Overload Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_TOL		OLPTOC1.Mod (ENC)	Overload Timer Unit Block Input		Activating the input before the trip is generated impedes activation of the unit. If activated after the trip, it resets.
IN_BLK_IOL		OLPIOC1.OpDlInh (SPC)	Overload Instantaneous Unit Block Input		
IN_BPT_TOL		OLPTOC1.OpDlInh (SPC)	Overload Timing Cancellation Input		Converts the timer setting in the unit to instantaneous. Only affects the timer unit.
ENBL_TOL		OLPTOC1.Mod (ENC)	Overload Timer Unit Enable Input		Activating this input places the unit in service. Digital inputs can be assigned by level or to commands from the communications protocol or from the HMI. The default value for the logic inputs is "1".
ENBL_IOL		OLPIOC1.Mod (ENC)	Overload Instantaneous Unit Enable Input		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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4.11.6 Auxiliary Outputs and Events of the Overload Module

Table 4.11-2: Auxiliary Outputs and Events of the Overload Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_TOL			Overload Timer Unit Startup		Overload unit start-up logic.
PU_IOL			Overload Instantaneous Unit Startup		
TRIP_TOL			Overload Timer Unit Trip		Overload unit trip.
TRIP_IOL			Overload Instantaneous Unit Trip		
TRIP_TOL_M			Overload Timer Unit Masked Trip		Unit trip conditioned by corresponding masked trips.
TRIP_IOL_M			Overload Instantaneous Unit Masked Trip		
IN_BLK_TOL			Overload Timer Unit Block Input		Identical to digital inputs.
IN_BLK_IOL			Overload Instantaneous Unit Block Input		
ENBL_OL			Overload Unit Enable Input		Identical to digital inputs.
ENBL_IOL			Overload Instantaneous Unit Enable Input		
OL_ENBLD			Overload Unit Enabled		Indicates the status of the current units, enabled or disabled.
IOL_ENBLD			Overload Instantaneous Unit Enabled		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

4.11.7 Overload Unit Test

As a recommendation, disable the units that are not being tested when testing each unit.

- **Startup and Reset**

Set the startup values desired for the unit. Check unit activation by actuating an output configured for this purpose. The unit can also be checked by checking the startup flags from the **Information - Status - Units** menu, or by ensuring the trip flag on the menu mentioned above activates if the unit trips.

Table 4.11-3: Overload Unit Startup and Reset				
Unit Setting	Pickup		Reset	
	maximum	minimum	maximum	minimum
X	1.08 **x** X	1.02 **x** X	1.03 **x** X	0.97 **x** X

The ranges below the startup and reset interval can be extended up to X ± (5% x In) mA.

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- **Activation Times**

For testing, at least one relay output must be configured with the trip signals of the element under test. The output configuration will be carried out with the ***ZIV e-NET tool***® changing the protection settings of the output to be used as shown in the Inputs, Outputs and LEDs Configuration section.

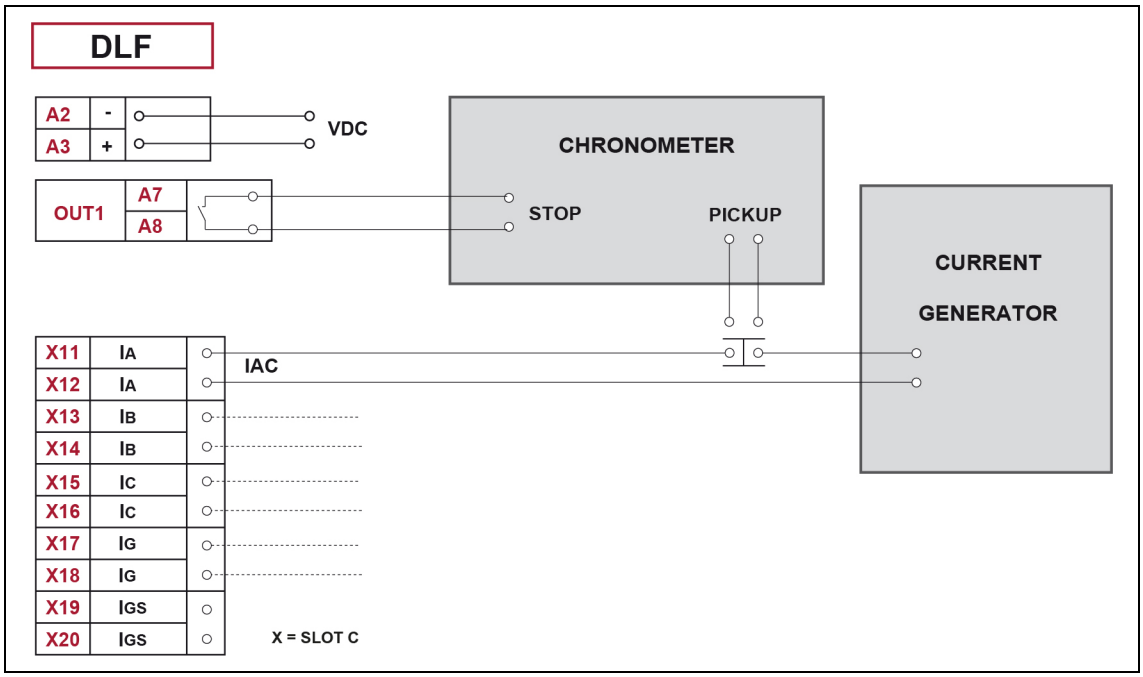


Figure 4.11.1 Operating Time Test Setup.

Fixed time

20% over the setpoint value selected for startup will be applied. The activation time will correspond to ±1% or ±30ms (whichever is greater) of the value setting for the selected time.

Inverse time

For a determined curve, the activation time is given by the dial selected and by the applied current (number of times for the start value setting). The tolerance is given by the result of applying a margin of error of ±1% to the current measurement. This translates into an error of ±2% or ±35ms (whichever is greater) for the time measurements.

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Chapter 5.

Voltage and Frequency Protection Units

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Voltage Protection Elements		
4	Phase Overvoltage Elements	**59-1 / 59-2 / 59-3 / 59-4**
4	Neutral Overvoltage Elements	**59N1 / 59N2 / 59N3 / 59N4**
4	Ground Overvoltage Elements	**64-1 / 64-2 / 64-3 / 64-4**
1	Negative Sequence Overvoltage Element	**47**
4	Phase Undervoltage Elements	**27-1 / 27-2 / 27-3 / 27-4**

***- Depending on model. See the corresponding model selection table.**

5.1.1 Common Principles

5.1.1.a Operation and Reset

For a given voltage unit, pickup occurs when the measured value is equal to or greater / less than the set value, and the resets with a selectable percentage value (lower / upper) on the setting.

The Phase Voltage elements have a setting to select between working with ***Line Voltage*** or ***Phase Voltage*** voltages. They operate when the RMS values of the voltages measured reach a given value. It is set as either ***Line Voltage*** or ***Phase Voltage*** voltage.

The Phase Voltage elements have an **associated logic** which can be controlled with a setting in which you select between the following two possible types of operation (see Figure 5.1.1):

- **AND**: the element trips when the three associated overvoltage elements comply with the trip condition.
- **OR**: the element trips when one or more of the three associated overvoltage elements comply with the trip condition.

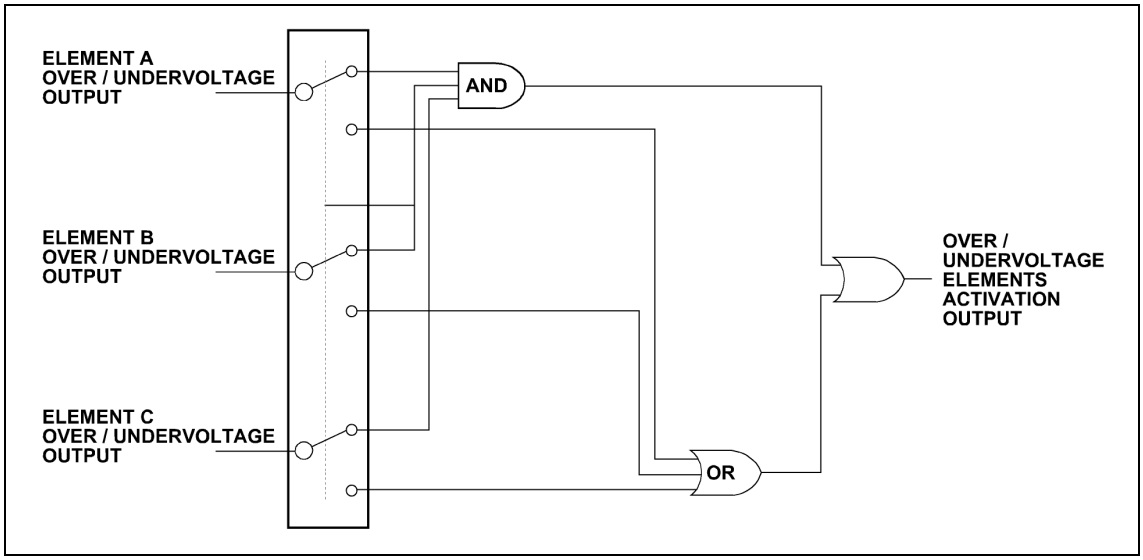


Figure 5.1.1 Block Diagram of the AND/OR Operation for the Voltage Elements.

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5.1.1.b Trip Blocking

Voltage Elements can program block trip inputs, which prevents the operation of the element if this input is activated before the trip is generated. If activated after the trip, it resets. Even if the element is blocked it remains operative so that if the relay is under trip conditions at the moment when the blocking input deactivates, the relay will issued a trip command instantaneously.

To be able to use these logic input signals, it is necessary to program the status contact inputs defined as **Block Trip**.

5.1.1.c Enabling and Disabling the Unit

All elements include an enable and disable input in such a way that, the element being enabled by protection settings, it may be disabled through logic upon given circumstances. In this way, when the enable input is disabled, the element is not operative and the element starts operation from zero the moment the enable input is activated.

5.1.1.d Restoration Settings

The reset value of each set of voltage elements (phase overvoltage, phase undervoltage, ground or neutral overvoltage and negative sequence overvoltage) is settable and one setting per set is provided to this end.

Protection / Voltage / Voltage Restoration					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase UV reset	Ph. UV Reset	PVCF1.PhUnVRs	101-150%	1	105%
Phase OV reset	Ph OV Reset	PVCF1.PhOvVRs	50-99%	1	95%
Ground OV reset	Neut OV Reset	PVCF1.GndOvVRs	50-99%	1	95%
N.S. OV reset	NegSeq OV Reset	PVCF1.NgSeqOvVRs	50-99%	1	95%

5.1.1.e Logical Node: Common Characteristics (Voltage Elements Reset Settings)

CLASS PVCF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Settings		
PhUnVRs	ASG	Phase undervoltage reset
PhOvVRs	ASG	Phase overvoltage reset
GndOvVRs	ASG	Ground overvoltage reset
NgSeqOvVRs	ASG	Negative sequence overvoltage reset

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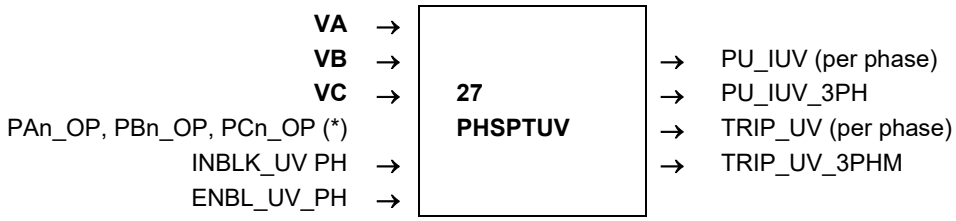
5.1.2 Phase Undervoltage Elements

5.1.2.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Phase Undervoltage Unit *n*	PHSPTUV*n*	3U<	27-*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.1.2.b General Block



5.1.2.c Operation Principles and Block Diagram

IEDs have three phase undervoltage elements (4 units for models with digits X27+X28 = 30 or higher). Each element is associated with the three voltage analog inputs and has a setting to select between working with ***Line Voltage*** or ***Phase Voltage*** voltages. They operate when the RMS values of the voltages measured reach a given value, the one set in the corresponding unit. This value is set simultaneously for the three voltages in each IED. It is set as either ***Line Voltage*** or ***Phase Voltage***.

Pickup occurs for a given undervoltage element when the value measured is equal to or less than one times the set value, and resets at a selectable percentage (greater) above the setting.

The undervoltage element pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out. The time setting included allows selecting a ***Fixed Time***, ***Inverse Curve*** or ***IEC60255-127 Inverse Curve*** timing sequence.

Inverse Curve option calculates operate time according to the following formula:

$$t = \frac{0.482 * Tp}{\left(1 - \frac{V}{Vp}\right)^{2.145}}$$

IEC60255-127 Inverse Curve option calculates operate time according to the following formula:

$$t = \frac{Tp}{\left(1 - \left(\frac{V}{Vp}\right)\right)}$$

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Where:

t	Operation time.	***V***	Measured voltage.
Tp	Dial.	***Vp***	Pick-up voltage setting.

When the RMS exceeds the set pickup, a rapid reset of the integrator occurs. The activation of the output requires the pickup to continue operating throughout the integration. Any reset leads the integrator to its initial conditions so that a new operation initiates the time count from zero.

If the ***Block by 52 Open*** setting is enabled, the tripping of the unit is conditioned to the position of the breaker, so that with the breaker open the start of the undervoltage unit is blocked (working with Phase-Earth voltages the blocking is applied for each phase according to the state of the pole of said phase and, working with Phase-Phase voltages, the blocking occurs when all 3 open breaker poles are detected).

Also, phase undervoltage elements include an associated logic that can be controlled through the setting ***Phase UV Logic*** where the type of operation OR/AND is selected (refer to Figure 5.1.1).

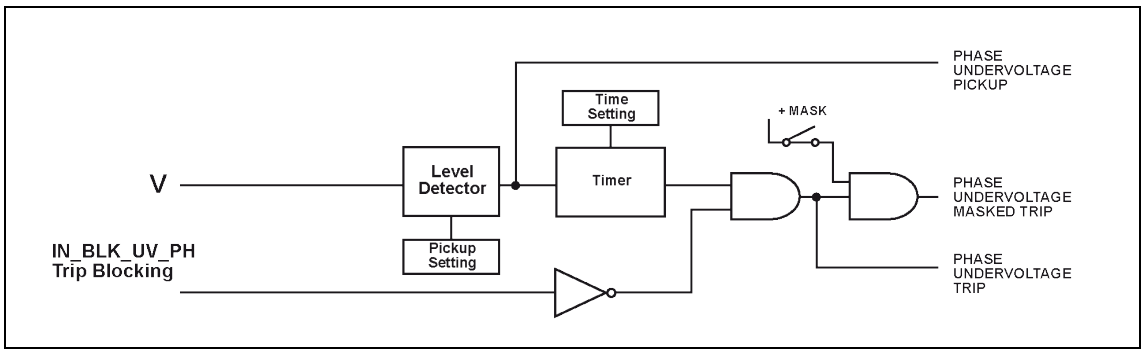


Figure 5.1.2 Block Diagram of the Phase Undervoltage Element.

5.1.2.d Application

The Phase Undervoltage element detects undervoltage in power systems such as generators, transformers, transmission and distribution lines, motors, etc. These low voltage conditions can be caused by different factors:

- Malfunction of voltage regulation equipments.
- Power system overloads that imply a voltage supply drop, which cannot be compensated by the voltage regulation equipments.
- Trips causing phase voltage drop under fault conditions.
- Total absence of a busbar voltage caused by operation of the transformer or busbar protection scheme.

In this way, the phase undervoltage element can be used to disconnect from the network any equipment that could be damaged when working under low voltage conditions or under conditions that could produce overheating.

By having several undervoltage units, it is possible to determine different low voltage conditions (different steps), adjusting the operation time according to the voltage step, or even blocking one or more voltage units with the activation of another unit, providing greater selectivity to the units that must operate.

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An example of this type of selectivity would be the configuration of the timed undervoltage units 1 and 2 for the detection of overloads (with trip settings at 80% and 70% of the nominal voltage) together with the instantaneous undervoltage unit 3 (with the pickup setting at 5% of the nominal voltage), so that the pickup of the instantaneous undervoltage unit 3 (upon detection of total loss of voltage in one or more phases) blocks the activation of the timed undervoltage units 1 and 2 (in this example, these should only act in the event of overloads that imply a gradual drop in voltage in the phases).

The blocking of timed units 1 and 2 must be done in the user logic, by assigning the pickup or trip signal of undervoltage unit 3 to the blocking input signals (**IN_BLK_UV_PH**) of units 1 and 2.

On the other hand, this element is of common use in the control functions implemented locally or remotely in protection relays that operate on the power system.

5.1.2.e Setting Ranges

Protection / Voltage / Phase Undervoltage (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase UV Enable	Ph. UV Enable	PHSPTUV.LNInSvc	YES / NO		NO
Voltage Type	Voltage Type	PHSPTUV.VTyp	Line Voltage Phase Voltage		Line Voltage
Phase UV Pickup	Ph. UV Pickup	PHSPTUV.StrVal	2-300 V	0.01 V	40 V
Phase UV Curve	Phase UV Curve	PHSPTUV.TmVCrv	Definite Time. Inverse.		Definite Time
Phase UV Dial	Phase UV Dial	PHSPTUV.TmMult	0.05-1	0.01	1
Phase UV Delay	Ph. UV Delay	PHSPTUV.OpDITmms	0-300 s	0.01 s	0 s
Phase UV logic	Output Logic Ph UV	PHSPTUV.EvTyp	OR AND		OR

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

- **Settings Ranges for Models with Digits X27+X28 = 30 or Higher**

Protection / Voltage / Phase Undervoltage (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase UV Enable	Ph. UV Enable	PHSPTUV.LNInSvc	YES / NO		NO
Voltage Type	Voltage Type	PHSPTUV.VTyp	Line Voltage Phase Voltage		Line Voltage
Phase UV Pickup	Ph. UV Pickup	PHSPTUV.StrVal	2-300 V	0.01 V	40 V
Phase UV Curve	Phase UV Curve	PHSPTUV.TmVCrv	Definite Time. Inverse. IEC60255-127 Inverse.		Definite Time
Phase UV Dial	Phase UV Dial	PHSPTUV.TmMult	0.05-1	0.01	1
Phase UV Delay	Ph. UV Delay	PHSPTUV.OpDITmms	0-300 s	0.01 s	0 s
Phase UV logic	Output Logic Ph UV	PHSPTUV.EvTyp	OR AND		OR
Block by 52 Open	Block by 52 Open	PHSPTUV.CBopEna	YES / NO		YES

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.1.2.f Analog Inputs to the Unit

The operating magnitude of the Phase Undervoltage Elements will be VA, VB and VC voltage. It is true that the element will take into account the ***Line Voltage*** or ***Phase Voltage*** voltage as a function of the setting ***Voltage Type***.

Table 5.1-1: Analog Inputs to the Phase Undervoltage Modules		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

5.1.2.g Digital Inputs to the Phase Undervoltage Modules

Table 5.1-2: Digital Inputs to the Phase Undervoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_UV*n*_PH	Logic Inputs to Protection	PHSPTUV*n*.Mod	Block Phase Undervoltage Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_UV_PH*n*	Enabling Commands	PHSPTUV*n*.Mod	Enable Phase Undervoltage Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.1.2.h Auxiliary Outputs and Events of the Phase Undervoltage Modules

Table 5.1-3: Auxiliary Outputs and Events of the Phase Undervoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IUV*n*_A	Pickup Protection Outputs	PHSPTUV*n*.Str	Phase A Undervoltage Unit *n* Pick Up	I,F	Pickup of the undervoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
PU_IUV*n*_B		PHSPTUV*n*.Str	Phase B Undervoltage Unit *n* Pick Up	I,F	
PU_IUV*n*_C		PHSPTUV*n*.Str	Phase C Undervoltage Unit *n* Pick Up	I,F	
PU_IUV*n*_3PH		PHSPTUV*n*.Str	Three Phase Undervoltage Unit *n* Pick Up	I,F	
TRIP_UV*n*_A	Trip Protection Outputs	PHSPTUV*n*.Op	Phase A Undervoltage Unit *n* Trip	I,F	Trip of the undervoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_UV*n*_B		PHSPTUV*n*.Op	Phase B Undervoltage Unit *n* Trip	I,F	
TRIP_UV*n*_C		PHSPTUV*n*.Op	Phase C Undervoltage Unit *n* Trip	I,F	
TRIP_UV*n*_3PH		PHSPTUV*n*.Op	Three Phase Undervoltage Unit *n* Trip	I,F	Trip of the undervoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_UV*n*_3PHM	Masked Trips		Three Phase Undervoltage Unit *n* Masked Trip		Trip of the undervoltage and overvoltage elements affected by their corresponding mask. Three-phase trips are those that are generated after the chosen AND or OR algorithm and are the outputs that go to the trip contacts.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.1.2.i IEC 61850 Logical Node

CLASS IRLPHSPTUV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
TmVCrv	CURVE	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
VTyp	EXT_ENG	Type of voltage
EvTyp	EXT_ENG	Trip logic

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5.1.2.j Protection Element Test

Models several three phase undervoltage units (27F*n*) and it is possible to select between ***Line Voltage*** or ***Phase Voltage*** voltage to set the pickups of the units.

Before testing the undervoltage unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu, **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 5.1-4: Pickup and Reset of the Undervoltage Elements

Setting of the unit	Pickup		Reset	
X	Maximum	Minimum	Maximum	Minimum
	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” is the setting in per unit of the **Unit Reset** for the Undervoltage elements.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time or Instantaneous

The pickup setting is decreased 20%. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz) or 28ms (for 60Hz). A setting of 0 ms will have an operating time between 20 and 32 ms (for 50Hz) or between 15 and 28 ms (for 60Hz).

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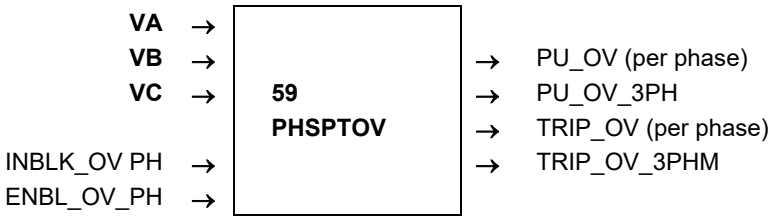
5.1.3 Phase Overvoltage Elements

5.1.3.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Phase Overvoltage Unit *n*	PHSPTOV*n*	3U>	59-*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.1.3.b General Block



5.1.3.c Operation Principles and Block Diagram

IEDs have three phase overvoltage elements (4 units for models with digits X27+X28 = 30 or higher). Each element is associated with the three voltage analog inputs and has a setting to select between working with ***Line Voltage*** or ***Phase Voltage*** voltages. They operate when the RMS values of the voltages measured reach a given value, the one set in the corresponding unit. This value is set simultaneously for the three voltages in each IED. It is set as either ***Line Voltage*** or ***Phase Voltage***.

Pickup occurs for a given overvoltage element when the value measured is equal to or greater than one times the set value, and resets at a selectable percentage (less) over the setting.

The overvoltage element pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out. The time setting included allows selecting a ***Fixed Time***, ***Inverse*** curve or ***IEC60255-127 Inverse*** curve timing sequence.

Inverse curve option calculates operate time according to the following formula:

$$t = \left[\frac{1.372 * 10^{13}}{\left(1.323 * 10^{3} \left(\left(\frac{V}{Vp} \right) - 1 \right) - 0.5\right)^{4.385}} + 0.099 \right] Tp$$

IEC60255-127 Inverse curve option calculates operate time according to the following formula:

$$t = \frac{Tp}{\left(\left(\frac{V}{Vp} \right) - 1 \right)}$$

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Where:

t Operation time.
Tp Dial.
V Measured voltage.
Vp Pick-up voltage setting.

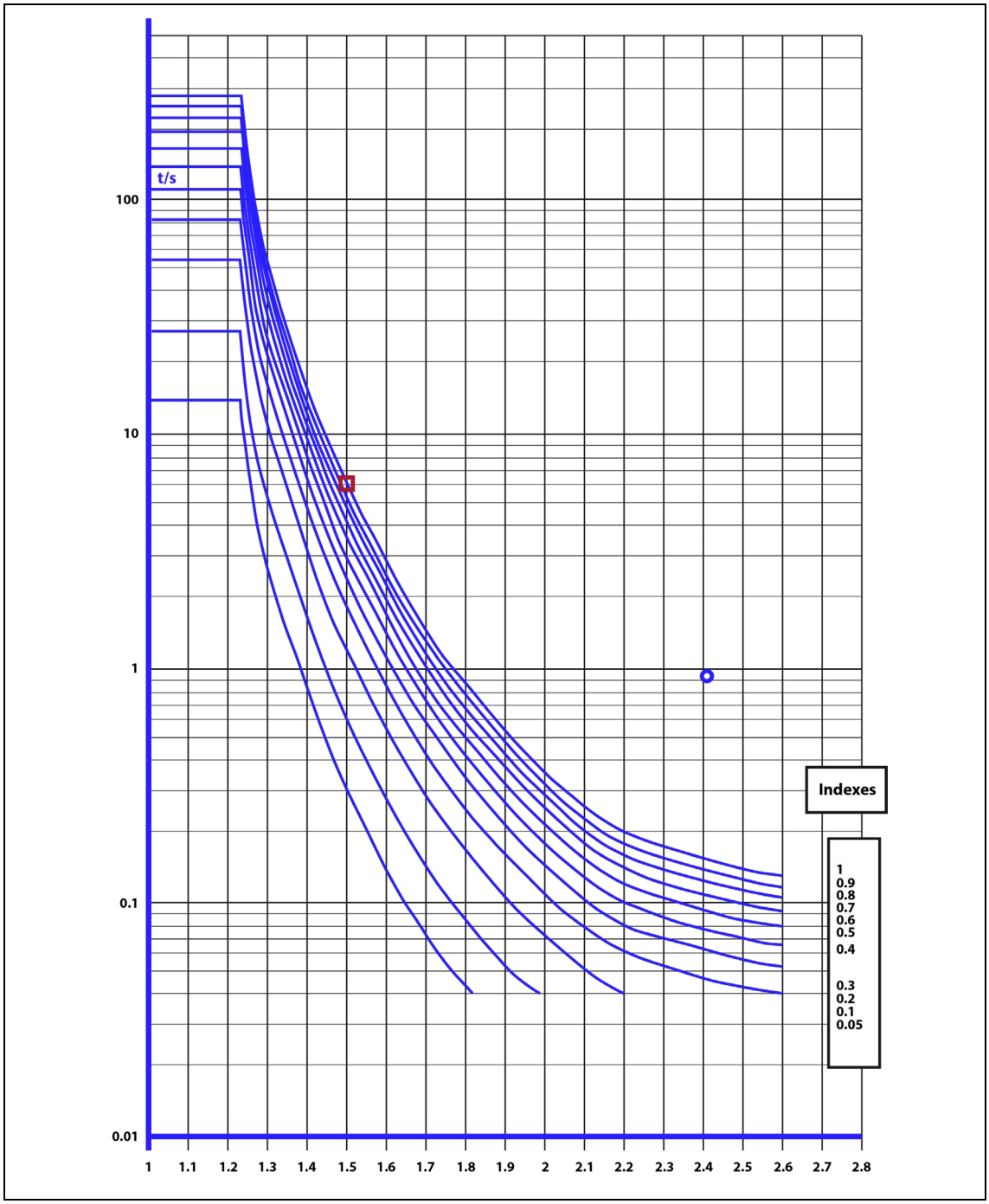


Figure 5.1.3 Inverse Curve.

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When the RMS falls below the pickup setting, a rapid reset of the integrator occurs. The activation of the output requires the pickup to continue operating throughout the integration. Any reset leads the integrator to its initial conditions so that a new operation initiates the time count from zero.

Also, phase overvoltage elements include an associated logic that can be controlled through the setting ***Phase OV Logic*** where the type of operation OR/AND is selected (refer to Figure 5.1.1).

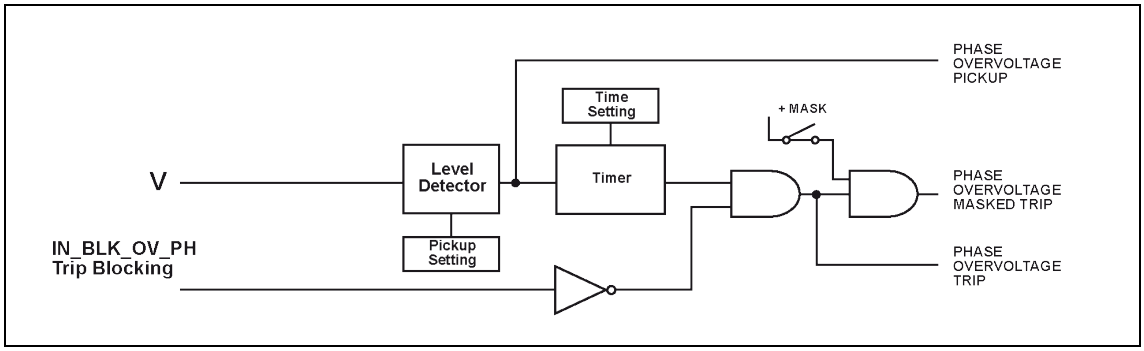


Figure 5.1.4 Block Diagram of the Phase Undervoltage Element.

5.1.3.d Application

The Phase Overvoltage Element detects overvoltage conditions in power equipment such as generators, transformers, transmission and distribution lines, motors, etc. that can cause insulation damage in the protected equipment. These overvoltage conditions can be caused by different factors such as:

- Voltage drop not compensated by regulators.
- Bad operation of voltage regulators.
- Phase overvoltage derived from ground faults, even through the system should be designed to support them.
- Sudden voltage drop due to line bay trips.

In this way, the phase overvoltage element can be used to disconnect from the network any equipment that could be damaged when working under high voltage conditions.

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5.1.3.e Setting Ranges

Protection / Voltage / Phase Overvoltage (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase OV Enable	Ph. OV Enable	PHSPTOV.LNInSvc	YES / NO		NO
Voltage Type	Voltage Type	PHSPTOV.VTyp	Line Voltage Phase Voltage		Line Voltage
Phase OV Pickup	Ph. OV Pickup	PHSPTOV.StrVal	2-300 V	0.01 V	70 V
Phase OV Curve	Ph. OV Curve	PHSPTOV.TmVCrv	Definite Time Inverse		Definite Time
Phase OV Dial	PH. OV Dial	PHSPTOV.TmMult	0.05-1	0.01	1
Phase OV Delay	Ph. OV Delay	PHSPTOV.OpDlTmms	0-300 s	0.01 s	0 s
Phase OV Logic	Output Logic Ph OV	PHSPTOV.EvTyp	OR AND		OR

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

- **Settings Ranges for Models with Digits X27+X28 = 30 or Higher**

Protection / Voltage / Phase Overvoltage (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Phase OV Enable	Ph. OV Enable	PHSPTOV.LNInSvc	YES / NO		NO
Voltage Type	Voltage Type	PHSPTOV.VTyp	Line Voltage Phase Voltage		Line Voltage
Phase OV Pickup	Ph. OV Pickup	PHSPTOV.StrVal	2-300 V	0.01 V	70 V
Phase OV Curve	Ph. OV Curve	PHSPTOV.TmVCrv	Definite Time Inverse IEC60255-127 Inverse		Definite Time
Phase OV Dial	PH. OV Dial	PHSPTOV.TmMult	0.05-1	0.01	1
Phase OV Delay	Ph. OV Delay	PHSPTOV.OpDlTmms	0-300 s	0.01 s	0 s
Phase OV Logic	Output Logic Ph OV	PHSPTOV.EvTyp	OR AND		OR

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.1.3.f Analog Inputs to the Unit

The operating magnitude of the Phase Overvoltage Elements will be VA, VB and VC voltage. It is true that the element will take into account the ***Line Voltage*** or ***Phase Voltage*** voltages as a function of the setting ***Voltage Type***.

Table 5.1-5: Analog Inputs of the Phase Overvoltage Modules		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

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5.1.3.g Digital Inputs to the Phase Overvoltage Unit

Table 5.1-6: Digital Inputs to the Phase Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_OV*n*_PH	Logic Inputs to Protection	PHSPTOV*n*.Mod	Block Phase Overvoltage Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OV_PH*n*	Enabling Commands	PHSPTOV*n*.Mod	Enable Phase Overvoltage Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.3.h Auxiliary Outputs and Events of the Phase Overvoltage Modules

Table 5.1-7: Auxiliary Outputs and Events of the Phase Overvoltage Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_OV*n*_A	Pickup Protection Outputs	PHSPTOV*n*.Str	Phase A Overvoltage Unit *n* Pick Up	I,F	Pickup of the overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
PU_OV*n*_B		PHSPTOV*n*.Str	Phase B Overvoltage Unit *n* Pick Up	I,F	
PU_OV*n*_C		PHSPTOV*n*.Str	Phase C Overvoltage Unit *n* Pick Up	I,F	
PU_OV*n*_3PH		PHSPTOV*n*.Str	Three Phase Overvoltage Unit *n* Pick Up	I,F	
TRIP_OV*n*_A	Trip Protection Outputs	PHSPTOV*n*.Op	Phase A Overvoltage Unit *n* Trip	I,F	Trip of the overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_OV*n*_B		PHSPTOV*n*.Op	Phase B Overvoltage Unit *n* Trip	I,F	
TRIP_OV*n*_C		PHSPTOV*n*.Op	Phase C Overvoltage Unit *n* Trip	I,F	
TRIP_OV*n*_3PH		PHSPTOV*n*.Op	Three Phase Overvoltage Unit *n* Trip	I,F	
TRIP_OV*n*_3PHM	Masked Trips		Three Phase Overvoltage Unit *n* Masked Trip	I,F	Trip of the overvoltage and overvoltage elements affected by their corresponding mask. Three-phase trips are those that are generated after the chosen AND or OR algorithm and are the outputs that go to the trip contacts.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.3.i IEC 61850 Logical Node

CLASS IRLPHSPTOV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
TmVCrv	CURVE	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
VTyp	EXT_ENG	Type of voltage
EvTyp	EXT_ENG	Trip logic

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5.1.3.j Protection Element Test

IEDs have several phase overvoltage units (59-*n*) and it is possible to select between ***Line Voltage*** or ***Phase Voltage*** to set the pickups of the phase units.

Before testing the overvoltage unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu, **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 5.1-8: Pickup and Reset of the Overvoltage Elements

Setting of the unit	Pickup		Reset	
X	Maximum	Minimum	Maximum	Minimum
	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” corresponds to the setting in per unit of the **Unit Reset** for the overvoltage elements.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz). A setting of 0 ms will have an operating time between 20 and 32 ms (for 50Hz) or between 15 and 28 ms (for 60Hz).

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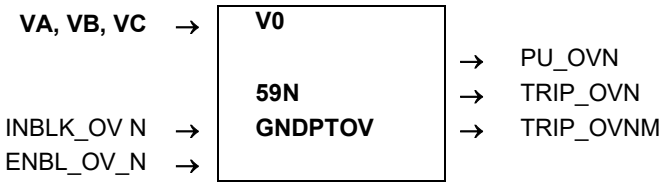
5.1.4 Neutral Overvoltage Elements

5.1.4.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Neutral Overvoltage Unit *n*	NPTOV*n*	Uo>	59N-*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.1.4.b General Block



5.1.4.c Operation Principles and Block Diagram

The relays are provided with three neutral overvoltage elements (4 units for models with digits X27+X28 = 30 or higher). These elements are associated to the calculated neutral voltage input. This neutral voltage is voltage is calculated from the three phase voltages as follows:

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

For a given overvoltage unit, pick up takes when the measured value is equal to or greater than 1 times the set pickup value and resets with a selectable value percentage (lower) of the setting.

The pickup of the overvoltage element enables the timing function. This is carried out by counter increments, the time element operating when the counter times out. The time setting included allows selecting a ***Definite Time***, ***Inverse*** curve or ***IEC60255-127 Inverse*** curve. When the measured value is below the set pickup value a fast reset of the integrator is produced. The output activation requires that the pickup remains active for all the integration time. Any reset sets the integrator to the initial condition, such that a new operation makes the counter start counting.

Inverse curve option calculates operate time according to the following formula:

$$t = \left[\frac{1.372 * 10^{13}}{\left(1.323 * 10^{3} \left(\left(\frac{V}{Vp}\right) - 1 \right) - 0.5\right)^{4.385}} + 0.099 \right] Tp$$

IEC60255-127 Inverse curve option calculates operate time according to the following formula:

$$t = \frac{Tp}{\left(\left(\frac{V}{Vp}\right) - 1 \right)}$$

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Where:

t Operation time.
Tp Dial.
V Measured voltage.
Vp Pick-up voltage setting.

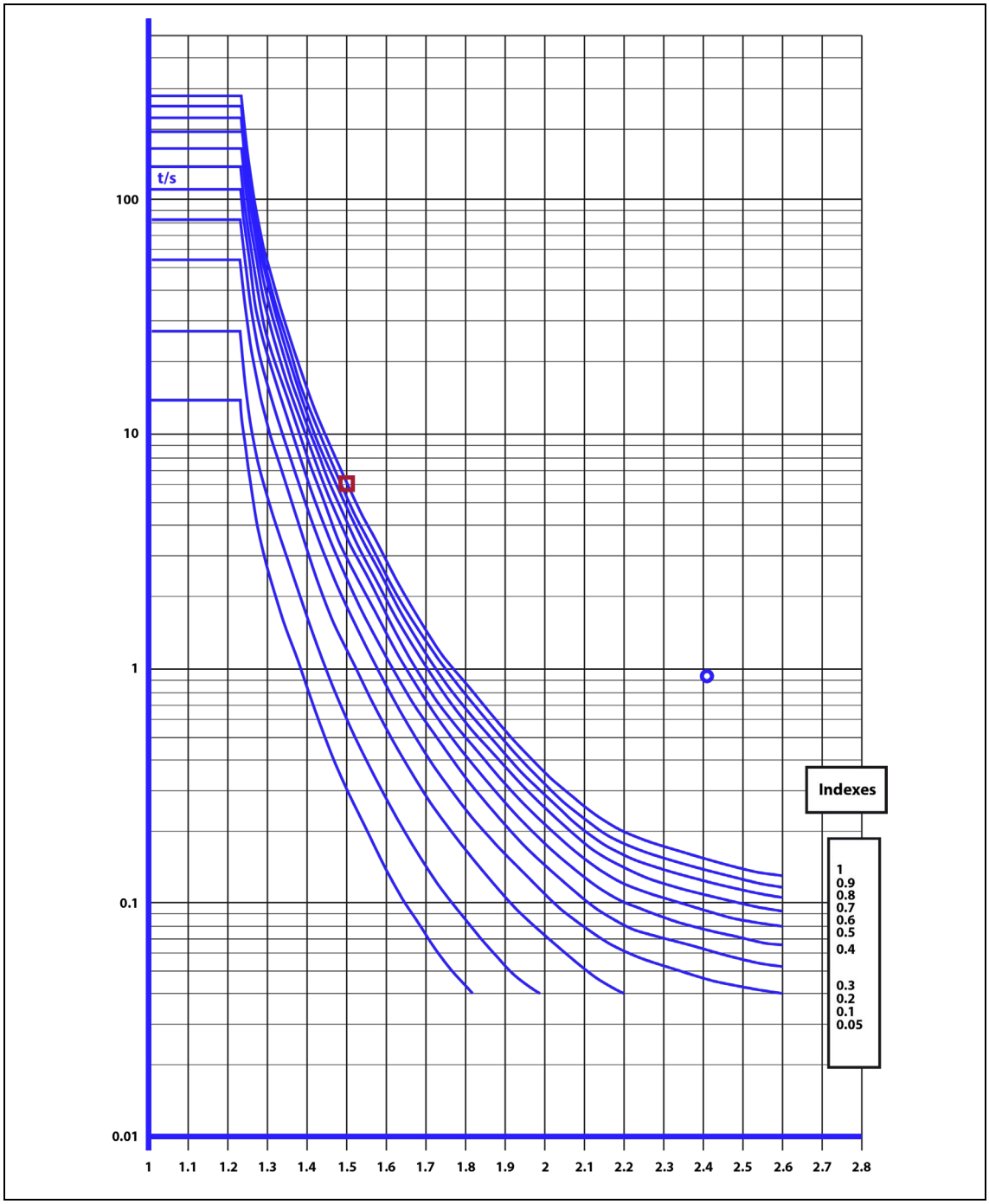


Figure 5.1.5 Inverse Curve.

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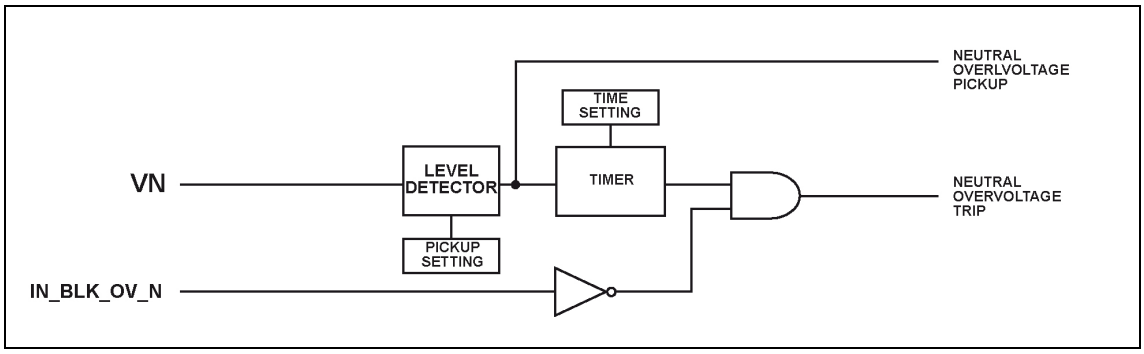


Figure 5.1.6 Block Diagram of the Neutral Overvoltage Element.

- **Models with Digits X27+X28 = 25 or Higher**

The neutral overvoltage unit includes the ***Reset Type*** setting, which allows you to select between three reset modes of the pickup signal:

- Instantaneous: The start signal is reset immediately as soon as the pickup conditions are no longer met.
- Trip-timer running: The start signal is reset after the time set in the ***Start Reset Timer*** setting. This timer is reset if successive starts are detected within the same time interval, extending the time the unit remains pickup. The trip signal will be activated after the pickup signal has remained active for a time equal to or greater than the value set for the trip.
- Trip timer stopped: The Pickup signal is reset instantly, but the time it has remained active is deducted from the configured trip time, provided that the intervals between starts are less than or equal to the value defined in the ***Pickup Reset Timer*** setting. The trip timer is restarted if the interval between pickups is greater than the ***Pickup Reset Timer*** setting.

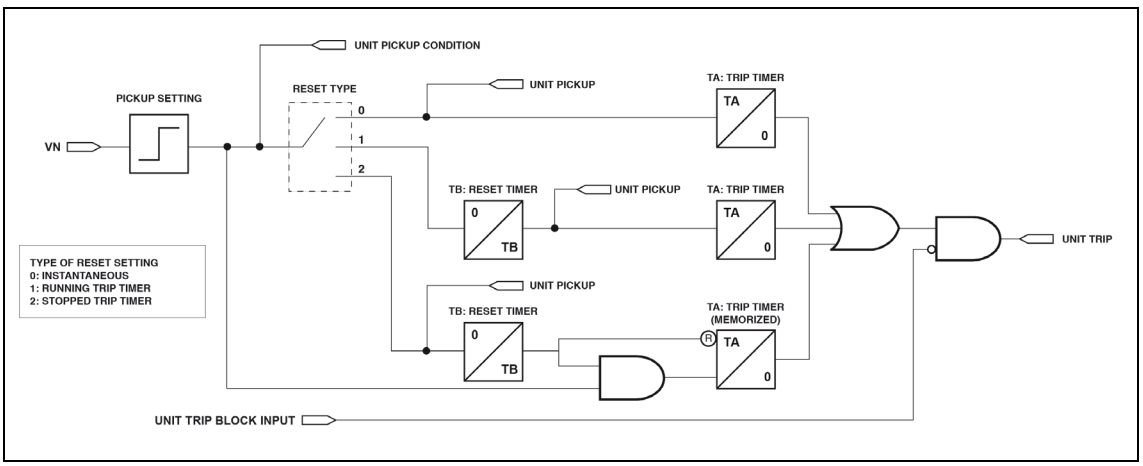


Figure 5.1.7 Block Diagram of the Neutral Overvoltage Element for Models with Digits X27+X28=25 or Higher.

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5.1.4.d Application

The Neutral Overvoltage Element is used as ground fault protection or line backup, for example in busbar protection schemes. It is also used for generator, motor protection and to measure capacitor bank unbalanced voltage.

In stable three phase power systems, the sum of the three phase currents, 120º out-of-phase, will be zero, so the unbalance caused by ground faults generates a residual voltage that can be measured through the calculation made internally by phase voltages.

5.1.4.e Setting Ranges

Protection / Voltage / Neutral Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutral OV Enable	Neut OV Enable	NPTOV1.LNInSvc	YES / NO		NO
Neutral OV Pickup	Neut OV Pickup	NPTOV1.StrVal	2-150 V	0.01 V	10 V
Neutral OV Curve	Neut OV Curve	NPTOV1.TmVCrv	Definite Time. Inverse.		Definite Time
Neutral OV Dial	Neut OV Dial	NPTOV1.TmMult	0.05-1	0.01	1
Neutral OV Delay	Neut OV Delay	NPTOV1.OpDlTmms	0-300 s	0.01 s	0 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

- **Settings Ranges for Models with Digits X27+X28 = 25 or Higher**

Protection / Voltage / Neutral Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutral OV Enable	Neut OV Enable	NPTOV1.LNInSvc	YES / NO		NO
Neutral OV Pickup	Neut OV Pickup	NPTOV1.StrVal	2-150 V	0.01 V	10 V
Neutral OV Curve	Neut OV Curve	NPTOV1.TmVCrv	Definite Time. Inverse.		Definite Time
Neutral OV Dial	Neut OV Dial	NPTOV1.TmMult	0.05-1	0.01	1
Neutral OV Delay	Neut OV Delay	NPTOV1.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	Reset Type	NPTOV1.RstMod	0: Instantaneous 1: Trip Timer running 2: Trip Timer stopped		0
Pickup Reset Timer	Pu reset timer	NPTOV1.RstTmms	0-10 s	0.001s	0 s

(n) The number of units depends on the specific model. See the corresponding Model Selection table

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- **Settings Ranges for Models with Digits X27+X28 = 28 or Higher**

Protection / Voltage / Neutral Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutral OV Enable	Neut OV Enable	NPTOV1.LNInSvc	YES / NO		NO
Neutral OV Pickup	Neut OV Pickup	NPTOV1.StrVal	0.5-150 V	0.01 V	10 V
Neutral OV Curve	Neut OV Curve	NPTOV1.TmVCrv	Definite Time. Inverse.		Definite Time
Neutral OV Dial	Neut OV Dial	NPTOV1.TmMult	0.05-1	0.01	1
Neutral OV Delay	Neut OV Delay	NPTOV1.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	Reset Type	NPTOV1.RstMod	0: Instantaneous 1: Trip Timer running 2: Trip Timer stopped		0
Pickup Reset Timer	Pu reset timer	NPTOV1.RstTmms	0-10 s	0.001s	0 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table

- **Settings Ranges for Models with Digits X27+X28 = 30 or Higher**

Protection / Voltage / Neutral Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutral OV Enable	Neut OV Enable	NPTOV1.LNInSvc	YES / NO		NO
Neutral OV Pickup	Neut OV Pickup	NPTOV1.StrVal	0.5-150 V	0.01 V	10 V
Neutral OV Curve	Neut OV Curve	NPTOV1.TmVCrv	Definite Time. Inverse. IEC60255-127 Inverse.		Definite Time
Neutral OV Dial	Neut OV Dial	NPTOV1.TmMult	0.05-1	0.01	1
Neutral OV Delay	Neut OV Delay	NPTOV1.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	Reset Type	NPTOV1.RstMod	0: Instantaneous 1: Trip Timer running 2: Trip Timer stopped		0
Pickup Reset Timer	Pu reset timer	NPTOV1.RstTmms	0-10 s	0.001s	0 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table

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- **Settings Ranges for Models with Digits X27+X28 = 31 or Higher**

Protection / Voltage / Neutral Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Neutral OV Enable	Neut OV Enable	NPTOV1.LNInSvc	YES / NO		NO
Neutral OV Pickup	Neut OV Pickup	NPTOV1.StrVal	0.5-200 V	0.01 V	10 V
Neutral OV Curve	Neut OV Curve	NPTOV1.TmVCrv	Definite Time. Inverse. IEC60255-127 Inverse.		Definite Time
Neutral OV Dial	Neut OV Dial	NPTOV1.TmMult	0.05-1	0.01	1
Neutral OV Delay	Neut OV Delay	NPTOV1.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	Reset Type	NPTOV1.RstMod	0: Instantaneous 1: Trip Timer running 2: Trip Timer stopped		0
Pickup Reset Timer	Pu reset timer	NPTOV1.RstTmms	0-10 s	0.001s	0 s

(n) The number of units depends on the specific model. See the corresponding Model Selection table

5.1.4.f Analog Inputs to the Unit

The operating magnitude of neutral overvoltage elements will be the calculated neutral voltage from the phase voltages VA, VB and VC.

Table 5.1-9: Analog Inputs to the Ground Overvoltage Modules		
Name	**Description**	**IEC 61850**
VG	Measured Voltage VAUX	MMXU1.PhV.neut
V0 / VN	Calculated Neutral Voltage or Measured Ground Voltage	MMXU1.PhV.res

VN calculated from the phase voltages:

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

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5.1.4.g Digital Inputs of the Neutral Overvoltage Modules

Table 5.1-10: Digital Inputs of the Neutral Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_OV_N*n*	Logic Inputs to Protection	NPTOV*n*.Mod	Block Neutral Overvoltage Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OV_N*n*	Enabling Commands	NPTOV*n*.Mod	Enable Neutral Overvoltage Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.4.h Auxiliary Outputs and Events of the Neutral Overvoltage Modules

Table 5.1-11:Auxiliary Outputs and Events of the Neutral Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_OV*n*_N	Pickup Protection Outputs	NPTOV*n*.Str	Neutral Overvoltage Unit *n* Pick Up	I,F	Pickup of the overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
TRIP_OV*n*_N	Trip Protection Outputs	NPTOV*n*.Op	Neutral Overvoltage Unit *n* Trip	I,F	Trip of the overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_OV*n*_NM	Masked Trips		Neutral Overvoltage Unit *n* Masked Trip		Trip of the overvoltage elements affected by their corresponding mask. Three-phase trips are those that are generated after the chosen AND or OR algorithm and are the outputs that go to the trip contacts.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.4.i IEC 61850 Logical Node

CLASS IRLGNDPTOV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
TmVCrv	CURVE	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service

5.1.4.j Protection Element Test

IEDs have several neutral overvoltage units. Before testing the neutral overvoltage units, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu, **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 5.1-12: Pickup and Reset of the Neutral Overvoltage Elements

Setting of the unit	Pickup		Reset	
X	Maximum	Minimum	Maximum	Minimum
	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” corresponds to the setting in per unit of the **Unit Reset** for the ground overvoltage elements.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz). A setting of 0 ms will have an operating time between 20 and 32 ms (for 50Hz) or between 15 and 28 ms (for 60Hz).

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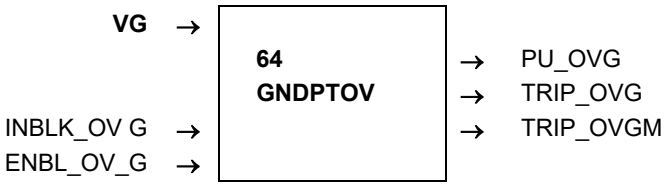
5.1.5 Ground Overvoltage Elements

5.1.5.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Ground Overvoltage Unit *n*	GNDPTOV*n*	Ug>	64-*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.1.5.b General Block



5.1.5.c Operation Principles and Block Diagram

The relays are provided with three ground overvoltage elements (4 units for models with digits X27+X28 = 30 or higher). These elements are associated to the ground voltage input. The relay will use the measured ground voltage directly obtained through an open delta transformer, connecting it to the terminals dedicated for that purpose (see 1.9, Schemes and Drawings).

For a given overvoltage unit, pick up takes when the measured value is equal to or greater than 1 times the set pickup value and resets with a selectable value percentage (lower) of the setting.

The pickup of the overvoltage element enables the timing function. This is carried out by counter increments, the time element operating when the counter times out. The time setting included allows selecting a ***Definite Time***, ***Inverse*** curve or ***IEC60255-127 Inverse*** curve. When the measured value is below the set pickup value a fast reset of the integrator is produced. The output activation requires that the pickup remains active for all the integration time. Any reset sets the integrator to the initial condition, such that a new operation makes the counter start counting.

Inverse curve option calculates operate time according to the following formula:

$$t = \left[\frac{1.372 * 10^{13}}{\left(1.323 * 10^{3} \left(\left(\frac{V}{Vp} \right) - 1 \right) - 0.5\right)^{4.385}} + 0.099 \right] Tp$$

IEC60255-127 Inverse curve option calculates operate time according to the following formula:

$$t = \frac{Tp}{\left(\left(\frac{V}{Vp} \right) - 1 \right)}$$

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Where:

t Operation time.
Tp Dial.
V Measured voltage.
Vp Pick-up voltage setting.

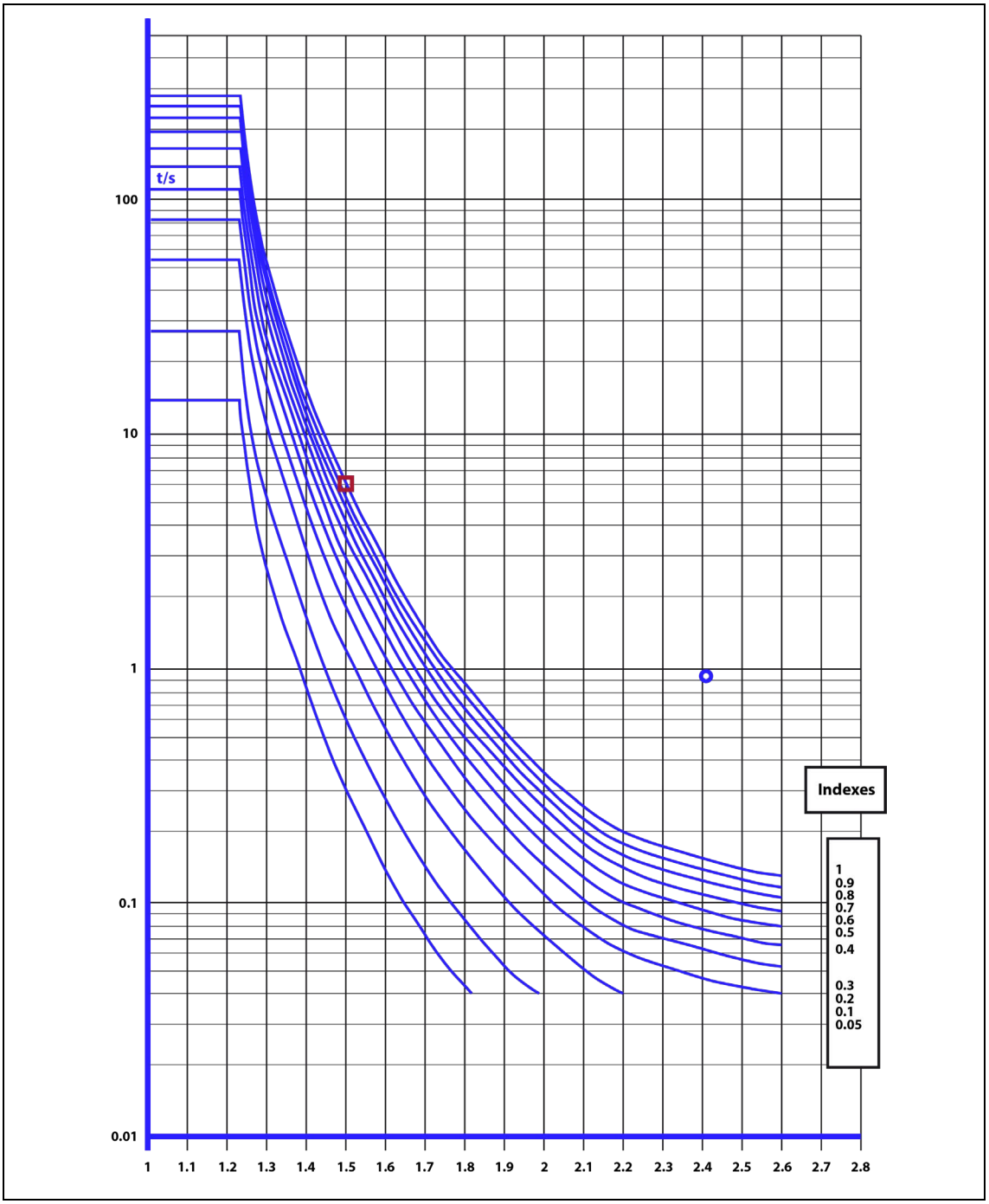


Figure 5.1.8 Inverse Curve.

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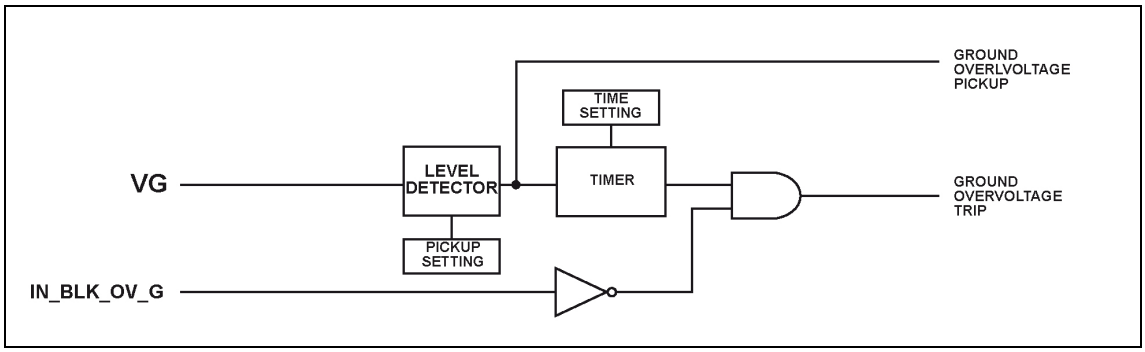


Figure 5.1.9 Block Diagram of the Ground Overvoltage Element.

5.1.5.d Application

The Ground Overvoltage Element is used as ground fault protection or line backup, for example in busbar protection schemes. It is also used for generator, motor protection and to measure capacitor bank unbalanced voltage.

In stable three phase power systems, the sum of the three phase currents, 120º out-of-phase, will be zero, so the unbalance caused by ground faults generates a residual voltage that can be measured both through an open delta voltage transformer or a single phase voltage transformer placed between the star winding of the transformer and ground.

5.1.5.e Setting Ranges

Protection / Voltage / Ground Overvoltage (*n* Units)					
Communication Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Gnd OV Enable	Gnd OV Enable	GNDPTOV1.LNInSvc	YES / NO		NO
Gnd OV Pickup	Gnd OV Pickup	GNDPTOV1.StrVal	2-150 V	0.01 V	10 V
Ground OV Curve	Gnd OV Curve	GNDPTOV1.TmVCrv	Definite Time. Inverse. IEC60255-127 Inverse.		Definite Time
Ground OV Curve	Gnd OV Curve	GNDPTOV1.TmVCrv	Definite Time Inverse		Definite Time
Ground OV Dial	Gnd OV Dial	GNDPTOV1.TmMult	0.05-1	0.01	1
Gnd OV Delay	Gnd OV Delay	GNDPTOV1.OpDlTmms	0-300 s	0.01 s	0 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.1.5.f Analog Inputs to the Unit

The operating magnitude of ground overvoltage elements will be the measured voltage VG.

Table 5.1-13: Analog Inputs to the Ground Overvoltage Modules		
Name	**Description**	**IEC 61850**
VG	Ground Neutral Voltage	MMXU1.PhV.neut

5.1.5.g Digital Inputs of the Ground Overvoltage Modules

Table 5.1-14: Digital Inputs of the Ground Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_OV_GND*n*	Logic Inputs to Protection	GNDPTOV*n*.Mod	Block Ground Overvoltage Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OV_ GND*n*	Enabling Commands	GNDPTOV*n*.Mod	Enable Ground Overvoltage Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.5.h Auxiliary Outputs and Events of the Neutral Overvoltage Modules

Table 5.1-15:Auxiliary Outputs and Events of the Neutral Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_OV*n*_GND	Pickup Protection Outputs	GNDPTOV*n*.Str	Ground Overvoltage Unit *n* Pick Up	I,F	Pickup of the overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
TRIP_OV*n*_GND	Trip Protection Outputs	GNDPTOV*n*.Op	Ground Overvoltage Unit *n* Trip	I,F	Trip of the overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_OV*n*_GNDM	Masked Trips		Ground Overvoltage Unit *n* Masked Trip		Trip of the overvoltage elements affected by their corresponding mask. Three-phase trips are those that are generated after the chosen AND or OR algorithm and are the outputs that go to the trip contacts.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.5.i IEC 61850 Logical Node

CLASS IRLGNDPTOV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
TmVCrv	CURVE	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service

5.1.5.j Protection Element Test

IEDs have several ground overvoltage units. Before testing the ground overvoltage unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu, **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 5.1-16: Pickup and Reset of the Ground Overvoltage Elements

Setting of the unit	Pickup		Reset	
X	Maximum	Minimum	Maximum	Minimum
	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” corresponds to the setting in per unit of the **Unit Reset** for the ground overvoltage elements.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz). A setting of 0 ms will have an operating time between 20 and 32 ms (for 50Hz) or between 15 and 28 ms (for 60Hz).

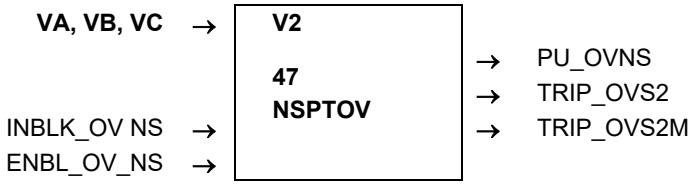
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5.1.6 Negative Sequence Overvoltage Elements

5.1.6.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Negative Sequence Overvoltage Unit	NSPTOV1	U2>	47

5.1.6.b General Block



5.1.6.c Operation Principles and Block Diagram

IEDs have a negative sequence overvoltage element. It operates with the negative sequence voltage calculated from the phase voltages. Pick up occurs when the measured value is equal to or greater than 1 times the pickup setting, and resets with a selectable (lower) percentage value over the setting.

The pickup of the overvoltage element enables the timing function. This is carried out by counter increments, the time element operating when the counter times out. The time setting included allows selecting a ***Definite Time***, ***Inverse*** curve or ***IEC60255-127 Inverse*** curve. When the measured value is below the set pickup value a fast reset of the integrator is produced. The output activation requires that the pickup remains active for all the integration time. Any reset sets the integrator to the initial condition, such that a new operation makes the counter start counting.

Inverse curve option calculates operate time according to the following formula:

$$t = \left[\frac{1.372 * 10^{13}}{\left(1.323 * 10^{3} \left(\left(\frac{V}{Vp} \right) - 1 \right) - 0.5\right)^{4.385}} + 0.099 \right] Tp$$

IEC60255-127 Inverse curve option calculates operate time according to the following formula:

$$t = \frac{Tp}{\left(\left(\frac{V}{Vp} \right) - 1 \right)}$$

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Where:

t Operation time.
Tp Dial.
V Measured voltage.
Vp Pick-up voltage setting.

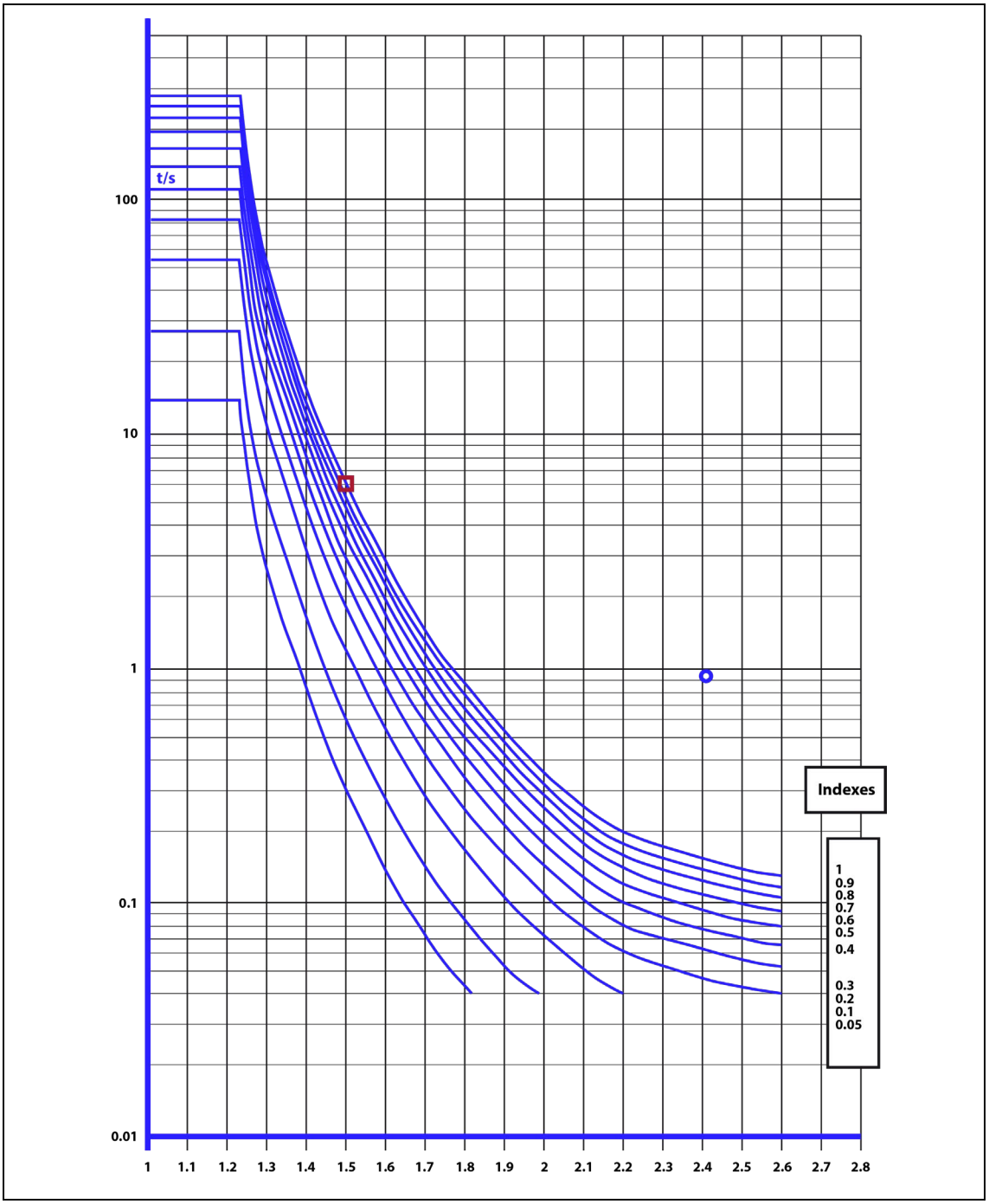


Figure 5.1.10 Inverse Curve.

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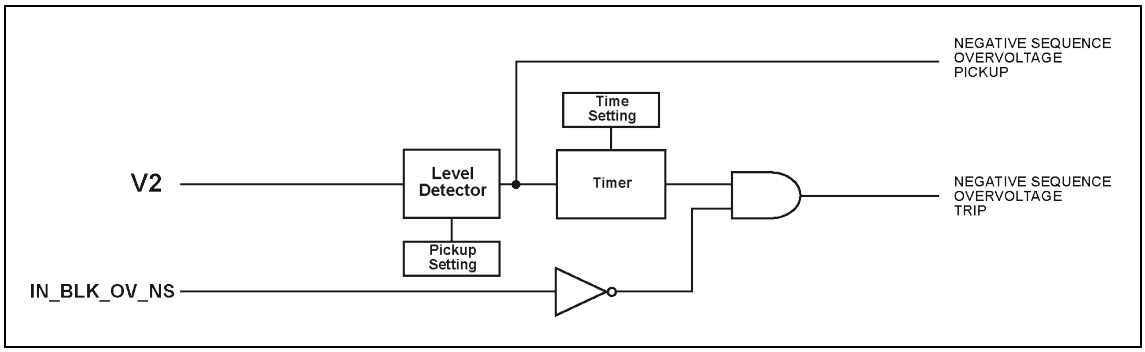


Figure 5.1.11 Block Diagram of the Negative Sequence Overvoltage Element.

5.1.6.d Application

The Negative Sequence Overvoltage Element is used as protection against system unbalances that can arise due to broken conductors, load change or asymmetric loads and other various reasons. The element can also be used to detect incorrect phase rotations.

5.1.6.e Setting Ranges

Protection / Voltage / Negative Sequence Overvoltage					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
N.S. OV Enable	NegSeq OV Enbl	NSPTOV1.LNInSvc	YES / NO		NO
N.S. OV Pickup	NegSeq OV Pickup	NSPTOV1.StrVal	2-100 V	0.01 V	10 V
N.S. OV Curve	NegSec OV Curve	NSPTOV1.TmVCrv	Definite Time. Inverse. IEC60255-127 Inverse.		Definite Time
N.S. OV Dial	NegSeq OV Dial	NSPTOV1.TmMult	0.05-1	0.01	1
N.S. OV Delay	NegSeq OV Timer	NSPTOV1.OpDlTmms	0-300 s	0.01 s	0 s

5.1.6.f Analog Inputs to the Unit

The operating magnitude of the Negative Sequence Overvoltage Element will be the negative sequence voltage calculated from VA, VB and VC phase voltages.

Table 5.1-17: Analog Inputs to the Negative Sequence Overcurrent Modules		
Name	**Description**	**IEC 61850**
V2	Negative Sequence Calculated Voltage	MSQI1.SeqV.c2

$$|V_2| = \left| \frac{V_A + V_B \cdot 1\angle 240° + V_C \cdot 1\angle 120°}{3} \right|$$

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5.1.6.g Digital Inputs to the Negative Sequence Overvoltage Modules

Table 5.1-18: Digital Inputs to the Negative Sequence Overvoltage Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_OV_NS	Logic Inputs to Protection	NSPTOV1.Mod	Block Negative Sequence Overvoltage Unit	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OV_NS	Enabling Commands	NSPTOV1.Mod	Enable Negative Sequence Overvoltage Unit	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.6.h Auxiliary Outputs and Events of the Negative Sequence Overvoltage Modules

Table 5.1-19: Auxiliary Outputs and Events of the Negative Sequence Overvoltage Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_OV_NS	Pickup Protection Outputs	NSPTOV1.Str	Negative Sequence Overvoltage Unit Pick Up	I,F	Pickup of the overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
TRIP_OV_S2	Trip Protection Outputs	NSPTOV1.Op	Negative Sequence Overvoltage Unit Trip	I,F	Trip of the overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_OV1_S2M	Masked Trips		Negative Sequence Overvoltage Unit Masked Trip		Trip of the overvoltage elements affected by their corresponding mask. Three-phase trips are those that are generated after the chosen AND or OR algorithm and are the outputs that go to the trip contacts.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.1.6.i IEC 61850 Logical Node

CLASS IRLNSPTOV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
TmVCrv	CURVE	Operating Curve characteristic
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service

5.1.6.j Protection Element Test

IEDs have a negative sequence overvoltage unit. Before testing the overvoltage unit, all the voltage units that are not being tested must be disabled.

- **Pickup and Reset**

The desired pickup values for the relevant unit are set and their activation is checked by operating any output configured for this purpose. This can also be verified by checking the pickup flags of the menu, **Information** - **Status** - **Units**. This verification can also be made by checking that the trip flag of this menu is activated if the unit trips.

Table 5.1-20: Pickup and Reset of the Negative Sequence Overvoltage Elements				
Setting of the unit	Pickup		Reset	
X	Maximum	Minimum	Maximum	Minimum
	1.03 x X	0.97 x X	(RST setting + 0.03) x X	(RST setting - 0.03) x X

Where the value “RST setting” corresponds to the setting in per unit of the **Unit Reset** for the ground overvoltage elements.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz). A setting of 0 ms will have an operating time between 20 and 32 ms (for 50Hz) or between 15 and 28 ms (for 60Hz).

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5.2.1 Common Principles

5.2.1.a Frequency Measurement

Relays include a frequency measurement module that detects voltage wave zero crossing and computes the time between crossings. This module uses the instantaneous voltage values obtained with a frequency of **4800 Hz**. In order to maintain the frequency measurement even when any phase voltage is lost (for example during a single phase reclose cycle), the frequency module operates with the Clark alfa component of the three phase input to the module:

$$V_\alpha = \frac{2 \cdot Va - Vb - Vc}{3}$$

In order to prevent the zero crossing detection from being distorted by harmonics the Clark alfa component is processed by a digital band pass filter before computing the time between zero crossings.

In order to validate the frequency measurement, the instantaneous value of the Clark alfa voltage must be above the setting ***Inhibit Voltage*** during 6 consecutive zero crossings or the RMS value of the positive sequence voltage must be above this setting also during 6 zero crossings if the setting ***RMS Supervision*** is set to ***Yes***. Similarly, the calculated frequency must be within the range 15 - 80 Hz and the difference between a frequency measurement and the immediately preceding measurement must not exceed a maximum threshold.

When the frequency module changes from measuring a valid frequency value to measuring an invalid value, the module keeps the last valid frequency measured during a period of 2 s. When this time lapses, if the frequency measurement is still valid, the module will consider the rated frequency.

5.2.1.b Adaptation of the Sampling Frequency to the Network Frequency

The equipment incorporates a PLL (Phase Locked Loop) module that automatically adapts the sampling frequency of the analogue channels to the network frequency, varying the time between samples, in order to ensure that the DFT (Discrete Fourier Transform) calculation window covers exactly one network cycle at all times. If there were no such adaptation, in the event of a variation in the frequency network, the said window would not cover a periodic wave, which would produce measurement errors in the DFT (algorithm for calculating the measurement of current and voltage, in RMS value, of the analogue channels). These errors will be greater the greater the deviation between the time of the window and the period of the sampled wave.

The PLL module controls the speed (samples/second) at which the analog signals are sampled at the output of the A/D converter. In short, the analog signals digitized by the A/D converter at 4800 Hz, are sampled again so that at all times the DFT works with 80 samples / cycle, regardless of frequency variations that may occur in the network.

The operating range of the PLL is 15 to 80 Hz.

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To ensure a correct adaptation of the sampling frequency in the different situations of the network, the PLL includes an algorithm that distinguishes network frequency changes (imply variation in the sampling frequency) from phase changes (do not imply variation in the sampling frequency) produced by faults or abrupt load variations.

The PLL module includes an ***Enable*** setting that is **YES** by default.

5.2.1.c Operation and Reset

All the elements have a time module that can be set to instantaneous. It has the following settings: ***Pickup*** and ***Time Delay***.

Associated with the level detection block, there is a setting for the pickup value: if the element is the Overfrequency element, and the value measured exceeds the setting value a given quantity, the element picks up; if it is the Underfrequency element, it picks up whether or not the value measured is less than the setting value a given quantity.

Activation of the pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out.

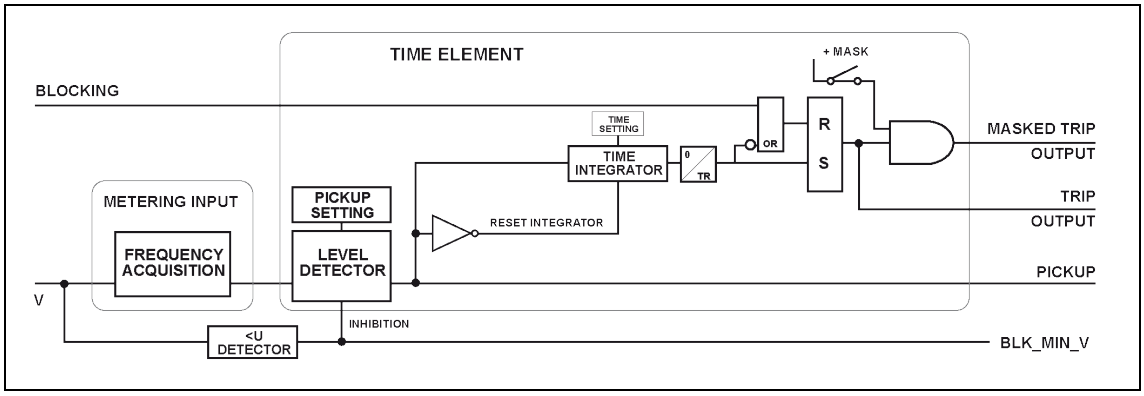


Figure 5.2.1 Block Diagram of a Frequency Element.

5.2.1.d Elements Blocking Logic

Each of the Frequency elements has a **Blocking Logic Input**. Activating this input prevents the activation of the output of the corresponding Frequency element, as shown in Figure 5.2.1.

These logic input signals can be associated to the relay's status contact inputs by configuring the input settings.

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5.2.1.e Enabling and Disabling the Element

All the elements have a disabling counter. This counter, of approximately 50 milliseconds, operates when the function is deactivated either by the inhibition voltage or by setting.

5.2.1.f Undervoltage Element for Blocking

This element supervises the functioning of the Frequency elements, impeding their operation for measured voltage below the set value.

Voltages compared to the setting ***Inhibit Voltage*** are:

- Instantaneous value of the voltage Clark alfa component.
- RMS value of the voltage positive sequence component if the setting ***RMS Supervision*** is set to ***YES***.

Disabling the frequency element operation when the voltage is below a given threshold prevents it from operating in fault situations (as a result of phase changes and frequency measurement errors); also in motor feedback situations when, with absence of network voltage, motors provide voltage because of inertia. This latter voltage will have a decreasing frequency, which could cause the operation of underfrequency elements. As the voltage provided by motors is small, the minimum voltage element will block the operation of frequency elements.

The element picks up when the measured voltage value coincides with or is less than the pickup value (100% of the setting), and resets with a value greater than or equal to 105% of the setting, provided this condition is maintained for at least 6 consecutive half-cycles. These 6 verification half-cycles provide assurance that the voltage is stable.

In any case, the relay cannot measure frequency for voltage less than 4 volts. Therefore, in these conditions, the Frequency and Out-of-Step elements do not work.

- **Auxiliary Outputs of the Undervoltage Element for Blocking**

Table 5.2-1: Auxiliary Outputs and Events of the Undervoltage Element for Blocking

Name	Group	IEC 61850	Description	Vis.	Function
BLK_MIN_V	Generic Outputs of Protection	PFCF1.BlkV	Frequency Disabled by Lack of Voltage.	I	Frequency and Out-of-Step elements blocking.

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5.2.1.g Load Shedding Algorithm

As described in previous units, the frequency measurement is obtained from the input voltage Va, Vb and Vc. The voltage is obtained from the side still having voltage after load shedding (generally the busbar side). This way, after load shedding the device continues to measure frequency in order to reconnect the load.

The IED provides a control function for performing 1 load shedding and reset step. Frequency elements 1 can be set to operate in pairs, with Underfrequency 1 or Rate of Change 1 element paired with the Overfrequency 1 element, to perform a load shedding and reset control function.

For more steps, it is necessary to use the programmable logic and configure it using the signals generated by the rest of the Frequency elements. The reason for this is that the designed control function takes into account the position of the breaker, which is unique for the IED. If more steps are configured, the user can choose to follow a similar operating scheme by requiring information about the position of other breakers, or choose a completely different logic. The control function logic for frequency elements 1 is described below:

Closure Command (**CLOSE**) and **Open Command** (**OPEN**) can be given as long as switching permission (**MsIr**) are set to **YES** and the Frequency elements are not blocked (**INBLK**). The operation of the Overfrequency element is conditioned by the prior operation of the Underfrequency or Rate of Change element (**TRIP_U**) and the Open Breaker (**IN_BKR**) status, as indicated in the logic diagram of Figure 5.2.2. The Overfrequency unit will be reset either when the frequency level complies with the unit reset conditions or when the **TRIP_U** signal is reset.

The **TRIP_U** signal is not a logic output of the Load Shedding module nor does it generate an event. To make it available, it must be generated in the programmable logic.

After the equipment generates the Close Command, either because underfrequency has existed or the rate of change has acted and the breaker has opened, it restores the condition of another possible close.

If the Trip Circuit supervision Failure (**FAIL_SUPR**) signal is activated having complied with all the conditions that allow after an overfrequency the closure by load shedding element (**IN_BKR** = 1 and **TRIP_U** = 1) is activated, when the close by load shedding element is activated its close command will not be generated and the Close Command annulled (**CCR**) signal will be activated.

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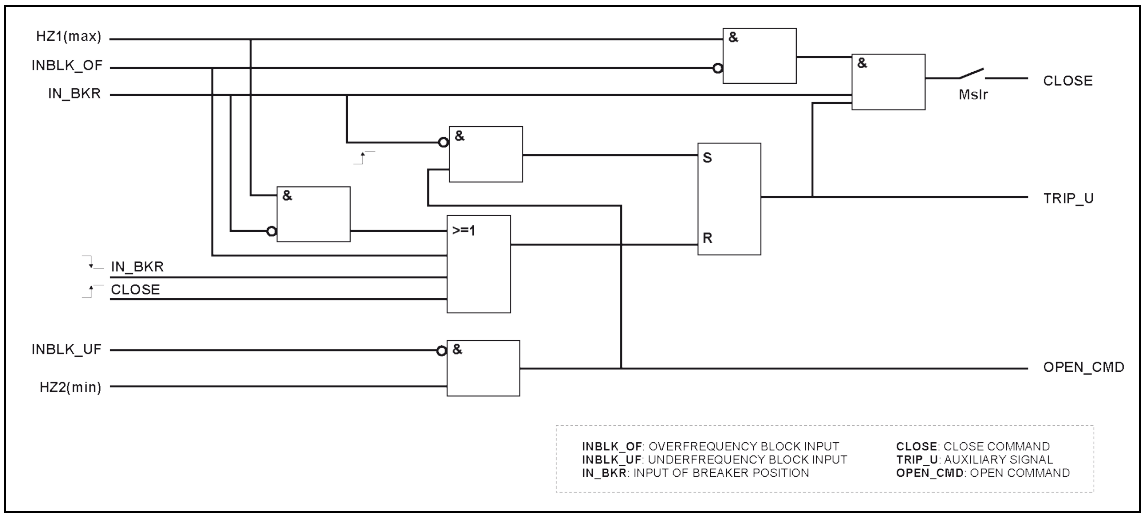


Figure 5.2.2 Under/Overfrequency Load Shedding Algorithm Logic Diagram.

- **Auxiliary Outputs of the Load Shedding Algorithm**

Table 5.2-2: Auxiliary Outputs and Events of the Load Shedding Algorithm

Name	Group	IEC 61850	Description	Vis.	Function
CLS_LS1	Generic Outputs of Protection	PFCF1.LodShedOp	Load Restoration after Load Shedding 1	I	Close of the overfrequency element 1 when it is configured for load shedding.

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5.2.1.h Common Settings

The Underfrequency, Overfrequency and Rate of Change elements have their own settings for each function and a set of settings common to all of them. The shared settings are:

- ***Inhibition Voltage***. This setting checks that the voltage is above a set value. If so, it allows the frequency elements to meter and to operate. Otherwise, it gives a frequency value of zero and the frequency elements are inhibited.
- ***Pickup Activation Timer***. This is the number of half-waves that must meet the fault conditions for the frequency elements to pick up This time allows filtering transients in frequency measurement, as are produced by phase changes resulting from load changes, faults, etc.
- ***Reset Time***. This is the number of cycles during which there may not exist fault conditions so that the frequency elements already picked up will reset. When the frequency elements have been picked up and have not yet operated, the fault conditions may disappear during a brief instant. This setting indicates how long these conditions may disappear without resetting the element. For example, if the rate of change should be falling below -0.5 Hz/s and during an instant it only goes down to -0.45 Hz/s; it may not be desirable that the protection function reset if the time the fault condition disappears is very short.
- ***Load Shedding Enable***. There is an option to have the frequency elements 1 operate in pairs, an Underfrequency or Rate of Change element with an Overfrequency element, to perform a load shedding scheme. This operation mode permits 1 load shedding level. For more than one level, programmable logic should be configured using the signals from the rest of frequency units.
- ***Load Shedding Type***. Either the Underfrequency or the Rate of Change element can be selected to initiate the load shedding.
- ***RMS Supervision***: allows disabling the frequency elements if the positive sequence voltage RMS value is below the setting ***Inhibit Voltage***.
- ***Time of Differentiation (half-cycles):*** gives the time lapse between the frequency values selected for computing the frequency rate of change. It allows reducing the rate of change value when frequency changes are produced that have an oscillatory component.
- ***Frequency Filter Time (half-cycles):*** enables computing a mean value of the measured frequency values, filtering frequency measurement oscillations, so avoiding computing excessive rate of changes. No filtering is performed if set to 1.

When the Load Shading type is defined as "Rate of Change", this always has to be with "Negative" rate of change. If it is set to positive, the Load Shading element does not operate.

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5.2.1.i Application of the Units

The frequency variations are caused by an incorrect balance between generation and load, which is generally due to the following reasons:

- Division of the system into parts.
- Imbalance between load and generation due to lack of foresight or deficient programming.
- Loss of generation, trip of busses or important interconnection lines.

Frequency is a reliable indicator of an overload condition. Any decrease in frequency is caused by an excess load. With this condition, minimum frequency relays must be used to shed load and thus balance generation with consumption and avoid a major collapse of the system. When frequency recovers its rated value and the electricity system stabilizes, the loads that have been shed are restored. This restoration operation is performed by the maximum frequency relay.

A decrease in frequency produces instability in the electricity system and can damage the generators. The greatest danger, however, lies in steam turbines. Variations in the rotational speed of the turbine produce vibrations and consequently the blades suffer mechanical fatigue. Since this is cumulative deterioration, the problem will increase whenever the turbine is in an underfrequency condition.

When the variation in the frequency is small, the imbalance can be corrected by regulating the generators. With large frequency variations, however, the generator cannot correct it. As a result, the frequency starts decreasing, risking a trip of the generation sets. If this frequency drop is not corrected, an irreversible process begins and leads to a general blackout.

In situations of strong generation deficit, the only way to restore balance is to selectively disconnect loads. The loads are usually disconnected when the frequency has fallen below fixed values to give the generation sets time to react to frequency drops with speed regulators. When the frequency drop is very quick, this action is not effective enough. Loads have to be disconnected according to the variation in the frequency in respect of time, that is, by basing calculations and operation on the rate of change in respect of time.

Underfrequency relays are usually installed in substations and industrial plants that require a load shedding system, where the loads are fed exclusively by local generation or by a combination of its own generators and a transmission line derivation. In this second case [part (A) of Figure 5.2.3], if a fault occurs in the transmission line, the system's own generators will be overloaded, and the frequency will drop quickly. This plant needs a fast load shedding system controlled by frequency relays.

If the transmission line supplies more than one plant and is disconnected at a remote end [part (B) of Figure 5.2.3], the plant, with its own generation, is in a situation to supply power to the line while its own frequency is decreasing. This power flow output can be avoided with protection relays against power inversion but, unless the whole overload is eliminated, the frequency relay must disconnect the lower priority local loads.

Independently of generation, frequency protections are also used in distribution substations that require a load shedding system with a disconnection priority scale. Priorities are also taken into account as frequency is recovered while restoring the loads.

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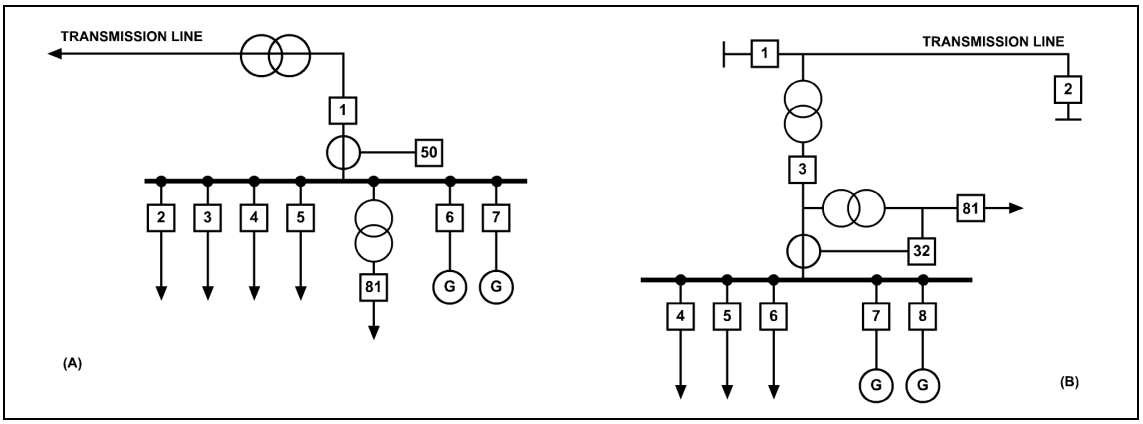


Figure 5.2.3 Load Shedding System in an Industrial Plant.

5.2.1.j Setting Ranges

Protection / Frequency					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Inhibit Voltage	Inhibit Voltage	PFCF1.InhValV	4-150 V	0.01 V	4 V
Pickup Activation Timer	Pick Up Time	PFCF1.StrDlHfCyc	3-30 hc	1	6 hc
Reset Time	Dropout Time	PFCF1.RsDlCyc	0-10 cycles	1	0 cycles
Load Shedding Enable	Load Shedd 1 Enbl	PFCF1.LodShedEna	NO / YES		NO
Load Shedding Type	Load Sheddng Type	PFCF1.LodShedTyp	Underfrequency ROC Frequency		Underfreq.
RMS Supervision	RMS supervision	PFCF1.RmsSupEna	NO / YES		NO
Time of Differentiation	Differentiation T.	PFCF1.ROCHfCyc	7-25 hc	1	7 hc
Frequency Filter Time	Freq. filter time	PFCF1.HzFilHfCyc	1-25 hc		1 hc

General					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
PLL Enable	PLL Enable	GENTVTR1.PLLEna	NO / YES		NO

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5.2.1.k IEC 61850 Logical Node

CLASS PFCF1		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
LodShedOp	ACT	Load Shedding Operation
BlkV	SPS	Frequency Disabled by Lack of Voltage
Settings		
InhValV	ASG	Inhibit Voltage
StrDlHfCyc	ING	Pickup Activation Timer
RsDlCyc	ING	Reset Time
LodShedEna	SPG	Load Shedding Enable
LodShedTyp	ENG	Load Shedding Type
RmsSupEna	SPG	RMS supervision
ROCHfCyc	ING	Time of differentiation
HzFilHfCyc	ING	Frequency filter time

5.2.1.l Protection Element Test

- **Voltage Reset**

The Frequency elements must reset within the margin indicated in Table 5.2-3 for set voltage value X.

Table 5.2-3: Voltage Reset				
Setting	Pickup		Reset	
X	MAX	MIN	MAX	MIN
	1.03 x X	0.97 x X	1.08 x X	1.02 x X

- **Operating Times**

To measure times, the voltage generator must be able to generate an up or down frequency ramp depending on the element to be tested as well as to provide an output to initiate a chronometer when it gets to the pickup frequency.

Operating times must comply with 1.5 cycles + ***Activation Half Cycles*** setting, provided that the frequency variation is not abrupt; in these cases, 2 half cycles should be added to the commented time. If the setting value is 0, the operating time will also be close to 1.5 cycles + ***Activation Half Cycles*** setting.

In operating times, it is important how the frequency ramp is generated and when the chronometer starts. The frequency value of the signal generated should be very close to the threshold to test and generate the broadest step possible.

Without a frequency ramp generator, only the Overfrequency element can be tested. Going from no voltage applied to applying voltage above the disable and the Overfrequency settings will yield a time value somewhat greater than with a frequency ramp.

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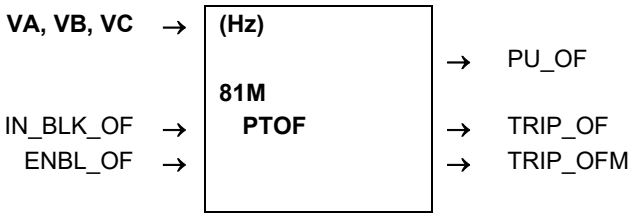
5.2.2 Overfrequency Elements

5.2.2.a Identification

Description of the Protection Elements	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Overfrequency Element *n*	PTOF*n*	f>	81M*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.2.2.b General Block



5.2.2.c Operation Principles

Pickup occurs when the value measured coincides with or surpasses the pickup value (100% of the setting) during a number of half-cycles equal to or greater than the ***Pickup Activation Timer*** setting, and resets when the frequency falls below 10mHz of this setting for a time equal to or greater than the ***Reset Time*** setting. This ***Reset Time*** setting indicates how long the fault conditions must disappear after a fault for the trip to reset.

5.2.2.d Setting Ranges

Protection / Frequency / Overfrequency (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Overfrequency Enable	`Overfreq. Enable`	PTOF.LNInSvc	NO / YES		NO
Overfrequency Pickup	`Overfreq. Pickup`	PTOF.StrVal	40 - 70 Hz	0.01 Hz	70 Hz
Overfrequency Delay	`Overfreq. Delay`	PTOF.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	`Dropout Time`	PTOF.RsDlTmms	0-300 s	0.01 s	2 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.2.2.e Analog Inputs to the Unit

The overfrequency value will be calculated from the phase voltage (Va, Vb, Vc) or phase-to-phase voltages.

Table 5.2-4: Analog Inputs to the Overfrequency Modules		
Name	**Description**	**IEC 61850**
FREC	Frequency	MMXU1.Hz (MV)

5.2.2.f Digital Inputs to the Overfrequency Modules

Table 5.2-5: Digital Inputs to the Overfrequency Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_OF*n*	Logic Inputs to Protection	PTOF*n*.Mod	Block Overfrequency Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OF*n*	Enabling Commands	PTOF*n*.Mod	Enable Overfrequency Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.2.g Auxiliary Outputs and Events of the Overfrequency Modules

Table 5.2-6: Auxiliary Outputs and Events of the Overfrequency Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_OF*n*	Pickup Protection Outputs	PTOF*n*.Str	Overfrequency Unit *n* Pick Up	I,F	Pickup of the overfrequency elements and start of the time count.
TRIP_OF*n*	Trip Protection Outputs	PTOF*n*.Op	Overfrequency Unit *n* Trip	I,F	Trip of the overfrequency elements.
TRIP_OF*n*M	Masked Trips		Overfrequency Unit *n* Masked Trip		Trip of the overfrequency elements affected by their corresponding trip masks.
OF*n*_ENBLD	Enabled Units Protection Outputs	PTOF*n*.Mod	Overfrequency Unit *n* Enabled.	I	Enable or disable status indication of the overfrequency elements.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.2.h IEC 61850 Logical Node

CLASS PTOF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Operate Delay time
RsDlTmms	ING	Reset Delay Time
Extended Data		
LNInSvc	EXT_SPG	In service

5.2.2.i Protection Element Test

Before testing these elements, the voltage elements that are not being tested must be disabled.

- **Pickup and Reset of the Overfrequency Elements**

The pickups and resets must be within the margins indicated in Table 5.2-7 for their rated voltage.

Table 5.2-7: Pickup and Reset of the Overfrequency Elements

Setting	Pickup		Reset	
XHz	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
	X - 0.005Hz	X + 0.005Hz	(X - 0.01Hz) + 0.005Hz	(X – 0.01Hz) - 0.005Hz

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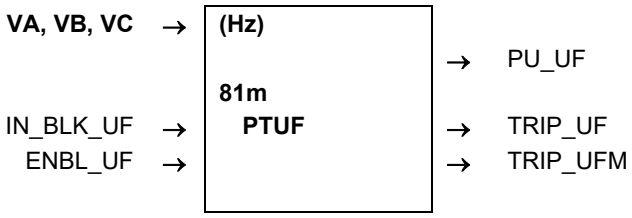
5.2.3 Underfrequency Elements

5.2.3.a Identification

Description of the Protection Elements	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Underfrequency Unit *n*	PTUF*n*	f<	81m*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.2.3.b General Block



5.2.3.c Operation Principles

Pickup occurs when the value measured coincides with or is below the pickup value (100% of the setting) during a number of half-waves equal to or greater than the setting ***Pickup Activation Timer***, and resets when the frequency goes up above 10mHz of this setting for a time equal to or greater than the ***Reset Time*** setting. The same as in the Overfrequency element, this ***Reset Time*** setting indicates how long the fault conditions must disappear after a fault for the trip to reset.

5.2.3.d Setting Ranges

Protection / Frequency / Underfrequency (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Underfrequency Enable	`Underfreq. Enable`	PTUF.LNInSvc	NO / YES		NO
Underfrequency Pickup	`Underfreq. Pickup`	PTUF.StrVal	40 - 70 Hz	0.01 Hz	70 Hz
Underfrequency Delay	`Underfreq. Delay`	PTUF.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	`Dropout Time`	PTUF.RsDlTmms	0-300 s	0.01 s	2 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

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5.2.3.e Analog Inputs to the Unit

The underfrequency value will be calculated from the phase voltage (Va, Vb, Vc) or phase-to-phase voltages

Table 5.2-8: Analog Inputs to the Underfrequency Modules		
Name	**Description**	**IEC 61850**
FREC	Frequency	MMXU1.Hz (MV)

5.2.3.f Digital Inputs to the Underfrequency Modules

Table 5.2-9: Digital Inputs to the Underfrequency Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_UF*n*	Logic Inputs to Protection	PTUF*n*.Mod	Block Underfrequency Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_UF*n*	Enabling Commands	PTUF*n*.Mod	Enable Underfrequency Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.3.g Auxiliary Outputs and Events of the Underfrequency Modules

Table 5.2-10: Auxiliary Outputs and Events of the Underfrequency Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_UF*n*	Pickup Protection Outputs	PTUF*n*.Str	Underfrequency Unit *n* Pick Up	I,F	Pickup of the underfrequency elements and start of the time count.
TRIP_UF*n*	Trip Protection Outputs	PTUF*n*.Op	Underfrequency Unit *n* Trip	I,F	Trip of the underfrequency elements.
TRIP_UF*n*M	Masked Trips		Underfrequency Unit *n* Masked Trip		Trip of the underfrequency elements affected by their corresponding trip masks.
UF*n*_ENBLD	Enabled Units Protection Outputs	PTUF*n*.Mod	Underfrequency Unit *n* Enabled	I	Enable or disable status indication of the underfrequency elements.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.3.h IEC 61850 Logical Node

CLASS PTUF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Operate Delay time
RsDlTmms	ING	Reset Delay Time
Extended Data		
LNInSvc	EXT_SPG	In service

5.2.3.i Protection Element Test

Before testing these elements, the voltage elements that are not being tested must be disabled.

- **Pickup and Reset of the Underfrequency Elements**

The pickups and resets must be within the margins indicated in Table 5.2-11 for their rated voltage.

Table 5.2-11:Pickup and Reset of the Underfrequency Elements

Setting	Pickup		Reset	
XHz	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
	X - 0.005Hz	X + 0.005Hz	(X - 0.01Hz) + 0.005Hz	(X - 0.01Hz) - 0.005Hz

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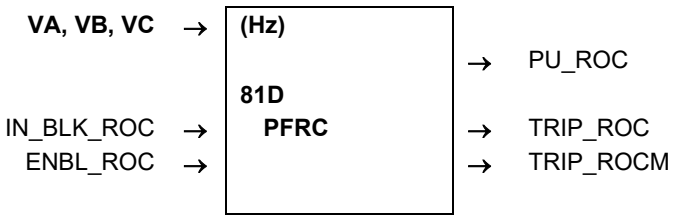
5.2.4 Frequency Rate of Change Elements

5.2.4.a Identification

Description of the Protection Elements	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Frequency ROC Element *n*	PFRC*n*	df/dt>	81D*n*

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.2.4.b General Block



5.2.4.c Operation Principles and Block Diagram

The algorithm of these elements uses the following specific settings for the Rate of Change function (in addition to the enabling setting of each of them):

- ***Underfrequency Pickup***. Frequency value below which this magnitude must be to consider the rate of its change.
- ***Rate of Change Pickup***. Instantaneous value of the rate of change in respect of the time for which the element is to pick up.
- ***ROC Frequency Delay***. Time during which the fault condition must remain for the element to activate.
- ***Reset Time***. Time during which the fault conditions must disappear after a fault for the element to reset.

In the algorithm, the Rate of Change must be below a given adjustable value for a time equal to or greater than the ***Pickup Activation Timer*** setting before the rate of change is taken into account. It is activated when the frequency is the same as or below the pickup setting, and resets when the frequency goes above 100.1% of this setting. This algorithm checks the frequency and the rate of change of the frequency separately. For the element to operate, the fault conditions must exist for both. See Figure 5.2.1.

The unit will pick-up only when the value of dF/dT is higher than the one set as ***Rate of Change Pickup*** (setting value + 0,05Hz/s in absolute value) for a selected period of time. This time begins to run when the fault is detected and will correspond to the one set as ***Pickup Activation Timer*** minus 7 half-waves (measurement window used by the device for the calculation of Hz/s).

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If the value of the ***Pickup Activation Timer*** setting is less than ten half-waves, then the Frequency Rate of Change unit will always consider a value equal to 10.

The figure below depicts the operation mode for the Rate of Change function:

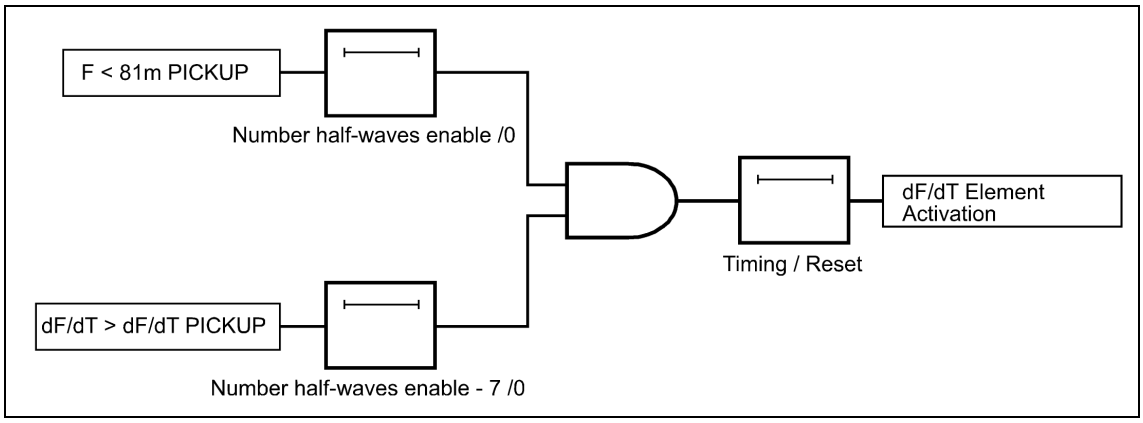


Figure 5.2.4 Logic Diagram of a Rate of Change Element.

- **Example of Element Pick Up Operation**

Activation half-cycles = 6.
Frequency Pickup = 49.8 Hz.
ROC Pickup = -1 Hz/s.
Time Delay = 0.1 s.

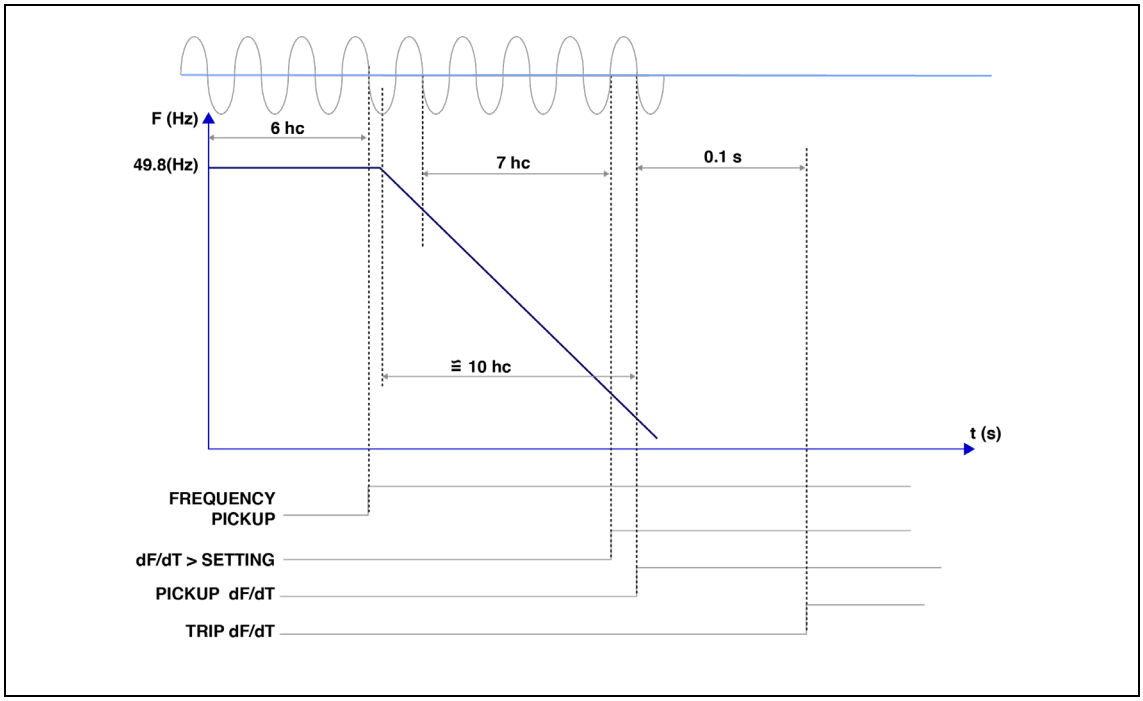


Figure 5.2.5 Example of Element Pick Up Operation.

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5.2.4.d Setting Ranges

Protection / Frequency / Frequency Rate of Change (*n* Units)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
ROC Frequency Enable	ROC Freq. Enable	PFRC.LNInSvc	NO / YES		NO
ROC Type	ROC Type	PFRC.ROCTyp	Negative Positive		Negative
Underfrequency Pickup	Underfreq. Pickup	PFRC.StrVal1	40-70 Hz	0.01 Hz	40 Hz
ROC Frequency Pickup	ROCOF Pickup	PFRC.StrVal2	0.1-10 Hz/s	0.01 Hz/s	1 Hz/s
ROC Frequency Delay	ROC Freq. Delay	PFRC.OpDlTmms	0-300 s	0.01 s	0 s
Reset Time	Dropout Time	PFRC.RsDlTmms	0-300 s	0.01 s	0 s

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.2.4.e Analog Inputs to the Unit

Table 5.2-12: Analog Inputs of the Frequency Rate of Change Modules		
Name	**Description**	**IEC 61850**
DERFREC	Frequency Rate of Change	MMXU1.HzRteChg (MV)

5.2.4.f Digital Inputs to the Frequency Rate of Change Modules

Table 5.2-13: Digital Inputs to the Frequency Rate of Change Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_ROC*n*	Logic Inputs to Protection	PFRC*n*.Mod	Block Frequency Rate of Change Unit *n*	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_ROC*n*	Enabling Commands	PFRC*n*.Mod	Enable Frequency Rate of Change Unit *n*	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.4.g Auxiliary Outputs and Events of the Frequency Rate of Change Modules

Table 5.2-14: Auxiliary Outputs and Events of the Frequency Rate of Change Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_ROC*n*	Pickup Protection Outputs	PFRC*n*.Str	Frequency Rate of Change Unit *n* Pick Up	I,F	Pickup of the Frequency Rate of Change elements and start of the time count.
TRIP_ROC*n*	Trip Protection Outputs	PFRC*n*.Op	Frequency Rate of Change Unit *n* Trip	I,F	Trip of the Frequency Rate of Change elements.
TRIP_ROC*n*M	Masked Trips		Frequency Rate of Change Unit *n* Masked Trip		Trip of the Frequency Rate of Change elements affected by their corresponding trip masks.
ROC*n*_ENBLD	Enabled Units Protection Outputs	PFRC*n*.Mod	Frequency Rate of Change Unit *n* Enabled	I	Enable or disable status indication of the Frequency Rate of Change elements.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.2.4.h IEC 61850 Logical Node

CLASS PFRC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal1	ASG	Underfrequency Pickup
StrVal2	ING	ROC Frequency Pickup
OpDlTmms	ING	Operate Delay time
RsDlTmms	ING	Reset Delay Time
Extended Data		
LNInSvc	EXT_SPG	In service
ROCTyp	EXT_ENG	ROC Type

5.2.4.i Protection Element Test

- **Pickup and Reset of the Rate of Change Elements**

The Rate of Change elements are configured with the following operation values:

81D1 Element	**0.5 Hz/s**
81D2 Element	**0.7 Hz/s**
81D3 Element	**0.9 Hz/s**
81D4 Element	**1 Hz/s**

They are all set to the same frequency value.

Frequency ramps are generated below the set frequency value and each ramp must operate with a margin of error not greater than 0.05 Hz/s.

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5.3 Overexcitation Protection Unit

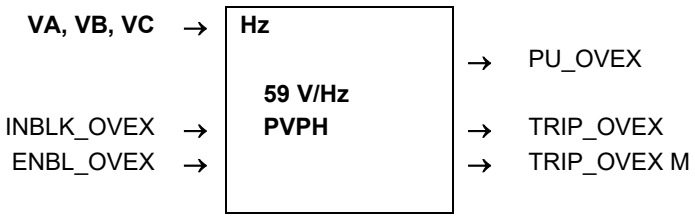
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5.3.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Overexcitation Protection Unit *n*	PVPH*n*	59V/Hz>	59V/Hz

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

5.3.2 General Block



5.3.3 Operation Principles and Block Diagram

The Overexcitation unit uses a voltage / frequency comparison curve to determine whether the measured values exceed the ratio setting value.

The ratio between the adjusted nominal voltage and adjusted nominal frequency is taken as the unit value (V/Hz=1). The function's pickup setting depends on this unit value.

The measured voltage used is a phase voltage whereas the ***Nominal Voltage*** setting is phase-to-phase voltage, thus, when using this phase voltage, the ratio V/Hz must be multiplied by $\sqrt{3}$.

Depending on the relay model, the pickup(Note) of the unit takes place when the measured value of the voltage/frequency ratio (V/Hz) exceeds the pickup setting value (100% of the setting), resetting when the measurement drops below the 98% of the pickup setting value. In the models which implement the reposition setting, the reset is an adjustable percentage between the 95% and the 99% of the pickup setting.

Note.

For the following firmware versions (version < 0.8.9-0A06, and 0.9.1-B06 = version < 0.9.1-0B12-44, and 0.10.0-0C03 = version < 0.10.0-0C17, and version = 0.10.0-0D00), the pickup of the unit takes place when the measured value of the voltage/frequency ratio exceeds the set V/Hz value by 1.05 times, resetting when the measurement drops below the set pickup value.

The same setting used for Frequency Units (***Inhibit Voltage***) is used to disable trips in this unit when the measured voltage is below a certain value.

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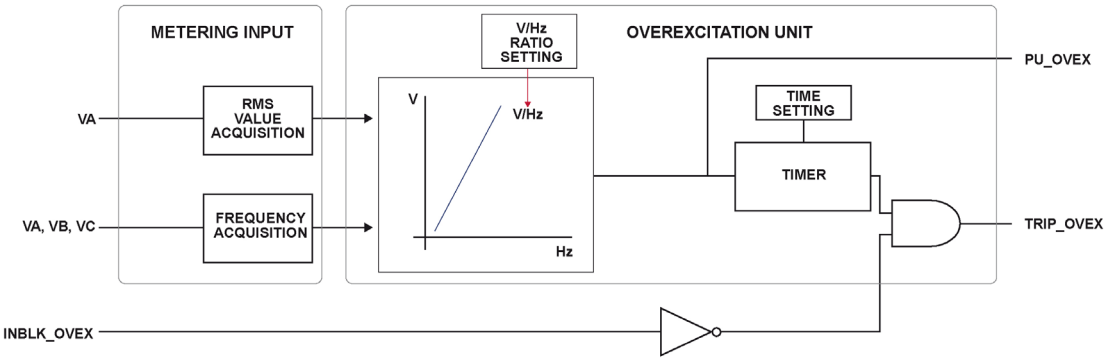


Figure 5.3.1 Overexcitation Unit Block Diagram.

VA, **VB**, **VC**: Analog Phase Voltage Inputs.	**PU_OVEX**: Overexcitation Unit Pick Up.
INBLK_OVEX: Block Overexcitation Unit.	**TRIP_OVEX**: Overexcitation Unit Trip.

Pickup activation enables the timing function to determine the performance of the time element. The activation of the output requires the pickup to remain activated throughout the entire time elapse set in the timer. The resetting of the pickup signal means that the output timer will start counting from zero when pickup conditions are present once again.

The user can choose between ***Fixed Time*** and ***Inverse Curve*** timing types. The equation for the ***Inverse Curve*** is as follows:

$$t = 0.8 + \frac{2 \cdot Overex.Dial}{\left(\frac{V/f}{(V_N/f_N)\,setting} - 1 \right)^2}$$

where V and f are the voltage between phases and the measured frequency.

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5.3.4 Application

The purpose of an Overexcitation protection is to protect the machine against overvoltage and underfrequency situations. Based on the equation that defines the voltage induced in a coil: $E = 4.44 \cdot f \cdot A \cdot N \cdot B_{MAX}$; the "maximum flow" (B_{MAX}) fulfills the following expression:

$$B_{MAX} = K \cdot \frac{E}{f}$$

and, therefore, the magnetic flow in the machine's core is directly proportional to the voltage and inversely proportional to the frequency.

The measurement of the V/Hz ratio is an indicator of the existing excitation. The magnetic core is saturated when this V/Hz ratio exceeds a permissible value, which gives rise to increased voltage between the strips that form the core, causing damage to the iron. When this happens, the magnetic path for which the machine was designed cannot accommodate the increased flow, thus generating "leakage currents" that cause thermal damage.

Under normal conditions, the voltage regulators of generators and other power system control elements maintain voltage within proper margins. However, anomalous conditions like those described below can occur:

- **Overvoltages**: When starting or stopping generators, with load losses in "island" configurations or load shedding. In addition, if the control system is not functioning properly, overvoltage situations can extend themselves over time.
- **Underfrequency**: For isolated or poorly meshed systems under overload conditions and for malfunction operations in load shedding schemes.

5.3.5 Setting Ranges

Protection / Overexcitation					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Overex. Enable	Overex. Enable	PVPH1.LnInSvc	NO / YES		NO
Overex. Pickup	Overex. Pickup	PVPH1.StrVal	1-3 V/Hz	0.01 V/Hz	1.1 V/Hz
Overex Reposition	Overex. Reposition	PVPH1.OpRs	95-99 %	1%	98%
Overex. Curve	Overex. Curve	PVPH1.VHzCrv	Definite Time Inverse		Definite Time
Overex. Dial	Overex. Dial	PVPH1.TmMult	0.01-10	0.01	1
Overex. Delay	Overex. Delay	PVPH1.OpDlTmms	0-600 s	0.01 s	1s

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5.3.6 Analog Inputs to the Unit

Table 5.3-1: Analog Inputs to the Overexcitation Module		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
FREQ	Frequency	MMXU1.Hz (MV)

5.3.7 Digital Inputs to the Overexcitation Module

Table 5.3-2: Digital Inputs to the Overexcitation Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INBLK_OVEX*n*	Logic Inputs to Protection	PVPH*n*.Mod	Block Overexcitation Unit *n*	I	Activation of input before trip generation blocks unit operation. If activated after tripping, trip resets.
ENBL_OVEX*n*	Enabling Commands	PVPH*n*.Mod	Enable Overexcitation Unit *n*	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.3.8 Auxiliary Outputs and Events of the Overexcitation Module

Table 5.3-3: Auxiliary Outputs and Events of the Overexcitation Module

Name	Group	IEC 61850	Description	Vis.	Function
PU_OVEX*n*	Pickup Protection Outputs	PVPH*n*.Str	Overexcitation Unit *n* Pick Up	I,F	Unit pickup and timing start.
TRIP_OVEX*n*	Trip Protection Outputs	PVPH*n*.Op	Overexcitation Unit *n* Trip	I,F	Trip of the Overexcitation Unit (not affected by its trip mask).
TRIP_OVEX M*n*	Masked Trips		Overexcitation Unit *n* Masked Trip		Trip of the Overexcitation Unit (affected by its trip mask).
OVEX_ENBLD*n*	Enabled Units Protection Outputs	PVPH*n*.Mod	Overexcitation Unit *n* Enabled	I	Indication of enabled or disabled status of the unit.

(*n*) The number of units depends on the specific model. See the corresponding Model Selection table.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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5.3.9 IEC 61850 Logical Node

CLASS PVPH		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Start
Op	ACT	Operate
Settings		
VHzCrv	CURVE	Operating curve type
StrVal	ASG	Volts per Hertz start value
OpDlTmms	ING	Operate delay time
TmMult	ASG	Time Dial Multiplier
Extended Data		
LnInSvc	EXT_SPG	In Service
VHz	EXT_MV	Volts per Hertz measurement
OpRs	EXT_ING	Protection unit reset

5.3.10 Protection Element Test

Set the transformer Overexcitation Unit (V/Hz) to 1.0 V/Hz, trip time to 5 seconds, the nominal values being 110Vac and 50Hz.

Apply 30V at 50Hz through the phase A voltage channel for 300ms (as 10 complete voltage cycles are initially needed for frequency calculation) being Inhibit Voltage value below 30V (for example 5V).

Apply a voltage higher than 66.7VAC at 50.00Hz through the phase A voltage channel and verify that the unit is activated at the end of the set time, checking that time recorder is within the range 4.85 - 5.25 s. Disconnect the test voltage.

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Chapter 6.

Power Elements

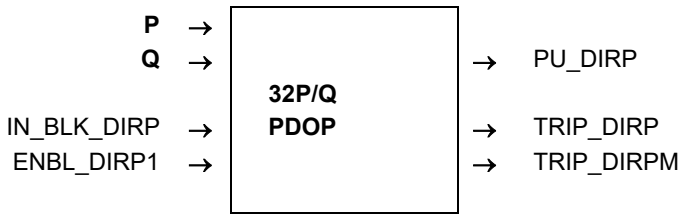
6.1 Directional Power Elements

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6.1.10 Protection Elements Test 6.1-8

6.1.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Directional Power Element 1	PDOP1	P/Q→	32P/Q-1
Directional Power Element 2	PDOP2	P/Q→	32P/Q-2

6.1.2 General Block



6.1.3 Operation Principles and Block Diagram

Relays are provided with two Directional Power elements the operation of which is based on the principle of finding three-phase power, which depends on the difference in phase angle between phase current and corresponding phase voltage.

Both elements are provided with settable characteristic angles and minimum operating power, and fit the following equation:

$$P * \cos\theta + Q * \text{sen}\theta > S_{MIN}$$

Where

- P is measured active three phase power.
- Q is measured reactive three phase power.
- θ is characteristic angle setting.
- S_{MIN} is pickup power setting (minimum operating power, ***Dir. Power PU*** setting).

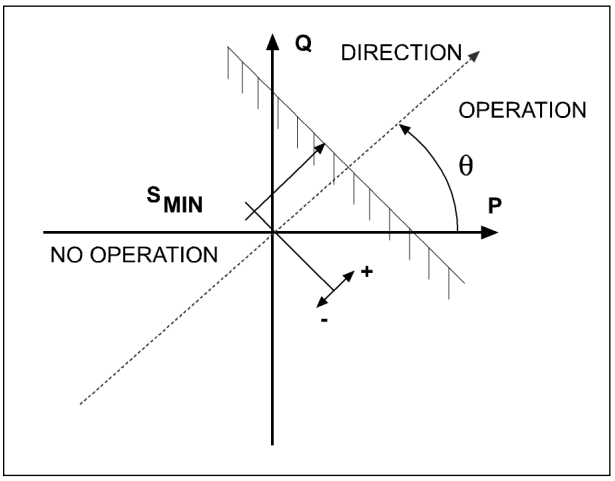


Figure 6.1.1 Directional Power Element Operation.

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A great variety of operate characteristics is obtained by changing the angle setting and introducing positive and negative operating power values. When the angle setting is neither 0º nor multiple of 90º, elements are being applied as “directional apparent power elements”.

Pickup takes place when the measured value exceeds 1.00 times the power setting, and resets at 0.95 times this value. When the measured RMS value goes down below the pickup setting a quick integrator reset takes place. For the output to activate the pickup must be activated during the entire integration time; any reset brings the integrator back to initial conditions, so that a new operation initiates timing from zero. Time characteristic is a Definite Time characteristic.

Operation of these elements is conditioned to breaker position; if breaker is open the element is disabled.

6.1.4 Application

Directional Power Elements are designed for synchronous machine applications or cogeneration interconnections, and can be used as protection against power reversal or power limiting.

For example, to check for negative active power (power reversal) angle must be set to 180º and pickup to a negative value.

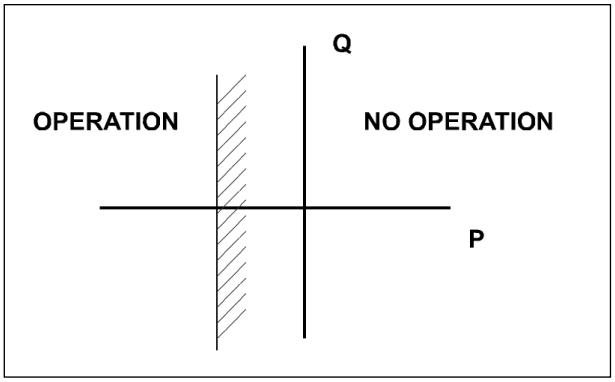


Figure 6.1.2 Angle Setting 180º and Pickup Setting Negative.

To check for not excessively low active power, angle must be set to 180º and pickup to a positive value.

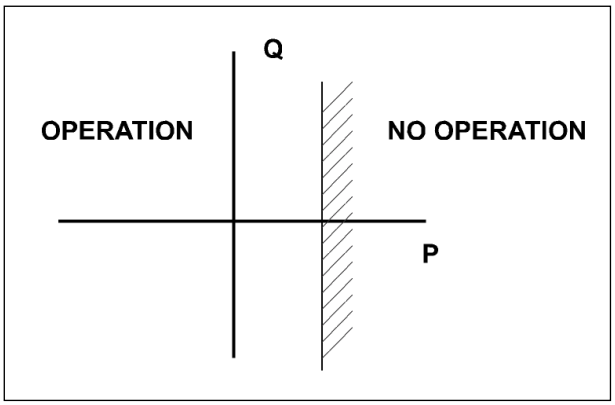


Figure 6.1.3 Angle Setting 180º and Pickup Setting Positive.

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Other settings are:

Angle 0º and pickup positive

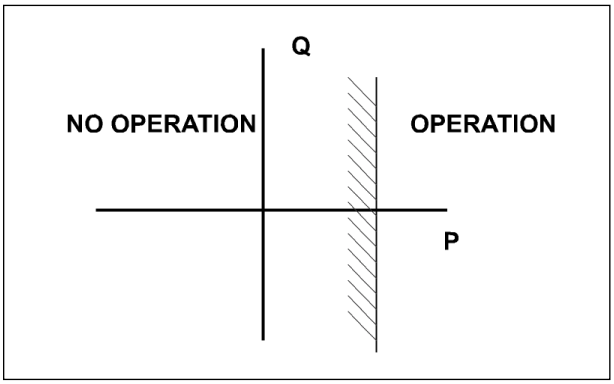


Figure 6.1.4 Angle Setting 0º and Pickup Setting Positive.

Angle 90º and pickup positive

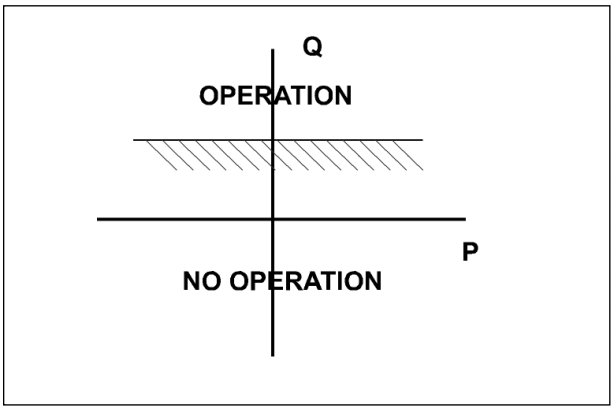


Figure 6.1.5 Angle Setting 90º and Pickup Setting Positive.

6.1.5 Setting Ranges

Protection / Directional Power (Units 1 and 2)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Dir. Power Enable	Dir. Power Enable	PDOP.LNInSvc	NO / YES		NO
Dir. Power Angle	Dir. Power Angle	PDOP.ChrAng	0-359.95º	0.05º	0º
Dir. Power PU	Dir. Power PU	PDOP.StrVal	-16000 to 16000 VA	1 V	0 V
Dir. Power Time	Dir. Power Time	PDOP.OpDlTmms	0-300 s	0.01 s	0 s

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6.1.6 Analog Inputs to the Unit

Table 6.1-1: Analog Inputs to the Directional Power Elements Module		
Name	**Description**	**IEC 61850**
P	Active Power	MMXU1.TotW
Q	Reactive Power	MMXU1.TotVAr

6.1.7 Digital Inputs to the Directional Power Elements Module

Table 6.1-2: Digital Inputs to the Directional Power Elements Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_DIRP1	Logic Inputs to Protection	PDOP1.Mod	Block Directional Power Unit 1	I	Input activation before trip generation blocks element operation. If activated after trip, trip resets.
IN_BLK_DIRP2		PDOP2.Mod	Block Directional Power Unit 2	I	
ENBL_DIRP1	Enabling Commands	PDOP1.Mod	Enable Directional Power Unit 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ENBL_DIRP2		PDOP2.Mod	Enable Directional Power Unit 2	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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6.1.8 Auxiliary Outputs and Events of the Directional Power Elements Module

Table 6.1-3: Auxiliary Outputs and Events of the Directional Power Elements Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_DIRP1	Pickup Protection Outputs	PDOP1.Str	Directional Power Unit 1 Pick Up	I,F	Pickup of Directional Power elements and timing start.
PU_DIRP2		PDOP2.Str	Directional Power Unit 2 Pick Up	I,F	
TRIP_DIRP1	Trip Protection Outputs	PDOP1.Op	Directional Power Unit 1 Trip	I,F	Trip of power elements (not affected by trip masks).
TRIP_DIRP2		PDOP2.Op	Directional Power Unit 2 Trip	I,F	
TRIP_DIRP1M	Masked Trips		Directional Power Unit 1 Masked Trip		Trip of power elements (affected by trip masks).
TRIP_DIRP2M			Directional Power Unit 2 Masked Trip		
DIRP1_ENBLD	Enabled Units Protection Outputs	PDOP1.Mod	Directional Power Unit 1 Enabled	I	Indication of enabled or disabled status of the element.
DIRP2_ENBLD		PDOP2.Mod	Directional Power Unit 2 Enabled	I	
DIRP1_ENBL	Enabled Units Protection Outputs	PDOP1.Mod	Directional Power Unit 1 Enabling Output	I	Indication of commissioning of the unit.
DIRP2_ENBL		PDOP2.Mod	Directional Power Unit 2 Enabling Output	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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6.1.9 IEC 61850 Logical Node

CLASS IRLPDOP		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Start
Op	ACT	Operate
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Operate delay time
Extended Data		
LNInSvc	EXT_SPG	In service
ChrAng	EXT_ASG	Characteristic angle

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6.1.10 Protection Elements Test

Set both elements to following settings:

Directional Power Element 1	
Enable	YES
Angle	0°
Element pickup	100 VA
Element timer	0s

Directional Power Element 2	
Enable	YES
Angle	90°
Element pickup	200 VA
Element timer	10s

- **Pickup and Reset**

Apply three identical phase current values and three also identical balanced phase voltages, such that phase angle difference between currents and respective phase voltage is 0º.

Under these conditions, Directional Power Element 1 must pickup when exceeding the setting value (100VA ± 3%) and reset when going down below 0.95 times the setting ± 3%.

Check that Directional Power Element 2 does not pickup.

Apply three identical phase current values and three also identical balanced phase voltages, such that phase angle difference between currents and respective phase voltage is 90º.

Under these conditions Directional Power Element 2 must pickup when exceeding the setting value (200VA ± 3%) and reset when going down below 0.95 times the setting ± 3%.

Check that Directional Power Element 1 does not pickup.

- **Operating Times**

Apply the currents and voltages stated in pickup and reset testing section and check that trip occurs within the margin ±1% or ±20ms (whichever is greater) of the selected timer setting. Bear in mind that operating time for a 0 ms setting will be between 20 and 25 ms.

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Chapter 7.

Recloser

7.1 Recloser

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7.1.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Recloser	RREC		79

7.1.2 General Block



7.1.3 Operation Principles

The purpose of the recloser is to close the breaker opened by a protection trip as many times as have been programmed and in accordance with how it has been set. **DLF** terminal unit Recloser allows up to four reclosing attempts, with independent reclosing timers (dead time delays) for the:

- First single-phase reclosing attempt.
- First three-phase reclosing attempt.
- Second reclosing attempt (always 3-Phase).
- Third reclosing attempt (always 3-Phase).
- Fourth reclosing attempt (always 3-Phase).

Second, third and fourth attempts are always three-phase reclosing. Also, the recloser is able to operate in any of the following four modes:

1P Mode	Only single-phase reclosing is allowed. The recloser will lockout after a three-phase trip. Therefore, this mode has a single reclosing attempt, independent of the number of attempts.
3P Mode	Only three-phase reclosing is allowed, forcing the tripping logic to make all the trips of this type.
1P / 3P Mode	Both single- and three-phase reclosing is allowed. The first attempt will be either single-phase or three-phase. The remaining attempts (depending on the **Reclosing Attempts** setting) will always be three-phase.
Dependent Mode	Only one reclosing will be attempted after a three-phase trip. For single-phase trips, the recloser will operate according to the number of attempts selected in the **Reclosing Attempts** setting.

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DLF relay automatic reclose function comprises one or two reclosers (depending on the selected model). In doble breaker models, the reclosers are coordinated with each other, designated Recloser 1 and Recloser 2, associated to breakers 1 and 2 respectively. The ***Number of reclosers*** setting (only available in double breaker models) defines whether there are one or two reclosers in operation. When said setting is set to **Selection by DI**, the number of reclosers in operation will be defined by logic input **IN_2REC** (**Two Reclosers in Operation Input**) state based on the following table:

IN_2REC	Result
0	1 Recloser in operation
1	2 Recloser in operation

Whenever two reclosers are in operation, reclose will take place in sequence, so that one of the reclosers must operate before the other. This recloser will be designated as Master recloser whereas the other will be the Slave recloser. Said selection is made through the setting ***Master Recloser***. If said setting is set to **Selection by DI** the selection of the master recloser will be made by logic input **IN_1MAS** (**Master Recloser 1 Input**) state based on the following table:

IN_1MAS	Result
0	Master recloser 2
1	Master recloser 1

When there is only one recloser in operation, the selection of the Master recloser (through setting or digital input) allows selecting the operating recloser, as there will not be a Slave recloser.

If the ***Reclose Mode*** of the relay is set to **Selection by DI**, the reclose mode will be defined by logic inputs **IN_1P** (**1P Mode Input**) and **IN_3P** (**3P Mode input**) state based on the following table:

E_1P	E_3P	Result
0	0	Dependent Mode
0	1	3P Mode
1	0	1P Mode
1	1	1P/3P Mode

Following figures show the recloser operation flow diagrams with the details for each reclosing mode. In these diagrams, the signal **RCLS** (**Recloser Start Element Activated**) corresponds to the logic output in charge of generating the trips that are allowed to be reclosed by the associated Recloser Start Masks.

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7.1.4 External Trips

The recloser operates in the same manner for trips generated by the **DLF** terminal unit or by external protection. Therefore, the four modes of operation are available to reclose trips generated by other protection terminals. To take advantage of this feature, the logic input signals **External A Pole Trip** (**IN_EXT_A**), **External B Pole Trip** (**IN_EXT_B**), **External C Pole Trip** (**IN_EXT_C**) or **External Protection Trip** (**IN_EXT**) and **External Protection Three-Phase Trip** (**IN_EXT_3PH**) must be used as follows:

1. When the external device only generates three-phase trips, the recloser can operate connecting the **IN_EXT** and **IN_EXT_3PH** inputs or otherwise using only the **IN_EXT_3PH** input.
2. When the external device generates both single-phase and three-phase trips, the three **IN_EXT_A**, **IN_EXT_B** and **IN_EXT_C** inputs or otherwise the two **IN_EXT** and **IN_EXT_3PH** inputs should be connected.

7.1.5 Reclose Start Logic

The recloser start can be produced when any distance zone, any of the phase, ground or negative sequence overcurrent elements, the open phase unit or the remote breaker open detector, distance or overcurrent protection scheme or any of the differential units is tripped, provided the **Recloser Start Mask** allows it.

Under all circumstances, the recloser start is equal to the **RCLS** signal activation. The remaining elements generate non-reclosable trips.

The **Reclose Start** (**RCLS)** can occur when any of these elements trip provided the setting **Reclose Initiate Mask** so enables:

Distance	**Instantaneous Overcurrent**
Zone 1 Ground	Phases
Zone 1 Phase	Neutral
Zone 2 Ground	Ground
Zone 2 Phase	Negative Sequence
Zone 3 Ground	**Time-Delayed Overcurrent**
Zone 3 Phase	Phases
Zone 4 Ground	Neutral
Zone 4 Phase	Ground
Zone 5 Ground	Negative Sequence
Zone 5 Phase	**Overcurrent Protection Scheme**
Zone 6 Ground	**Distance Protection Scheme**
Zone 6 Phase	**Remote breaker open detector**
Zone 7 Ground	**Programmable Trips**
Zone 7 Phase	**External trip**
Zone 8 Ground	
Zone 8 Phase	

The reclose mask will be a function of the reclose cycle. Separate masks exist for cycles 1, 2, 3 and 4. The masked trips will always be taken from each element. The rest of elements result into non reclosing trips.

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The Recloser will not start its close sequence if it detects that the number of trips has exceeded the set limit or if **IN_BLKRCLS (Recloser Initiate Block Input**) has been activated.

7.1.6 Reclosing Logic (Single Breaker Models)

Figures 7.1.1, 7.1.2, 7.1.3 and 7.1.4 depict the flow diagrams for the four different recloser operation modes for single breaker models.

Key for figures 7.1.1 to 7.1.4:

LEGEND	
RCLS	Reclose Start
RECLOSING	Recloser Sequence in Progress
RCLS_CMD	Reclose Command
TRIP	Trip
ACT_EXTR_3PH	External Three-Phase Activation Trip
SEQ_COOR	Sequence Coordination
OR_P_OP	Any Pole Open
3POL_OPEN	Three Pole Open
SUP_BRK	Breaker Supervision
SYNC_R	Breaker Synchronism Signal
n	Present Reclose
N	Number of Recloser Attempts
RCLS_STANDBY	Recloser in Standby Mode
REC_START	Recloser Initiation Time
REC_TSECn	Recloser in Security Time after Cycle n
LO_CMD	Recloser Lockout Command
LO_OPEN	Recloser Internal Lockout due to Open Breaker
LO_DT	Recloser Internal Lockout due to Definite Trip
LO_NO_SYNC	Recloser Internal Lockout due to Lack of Synchronism
LO_CLSF	Recloser Internal Lockout due to Closing Failure
LO_BF	Recloser Internal Lockout due to Initialization Failure

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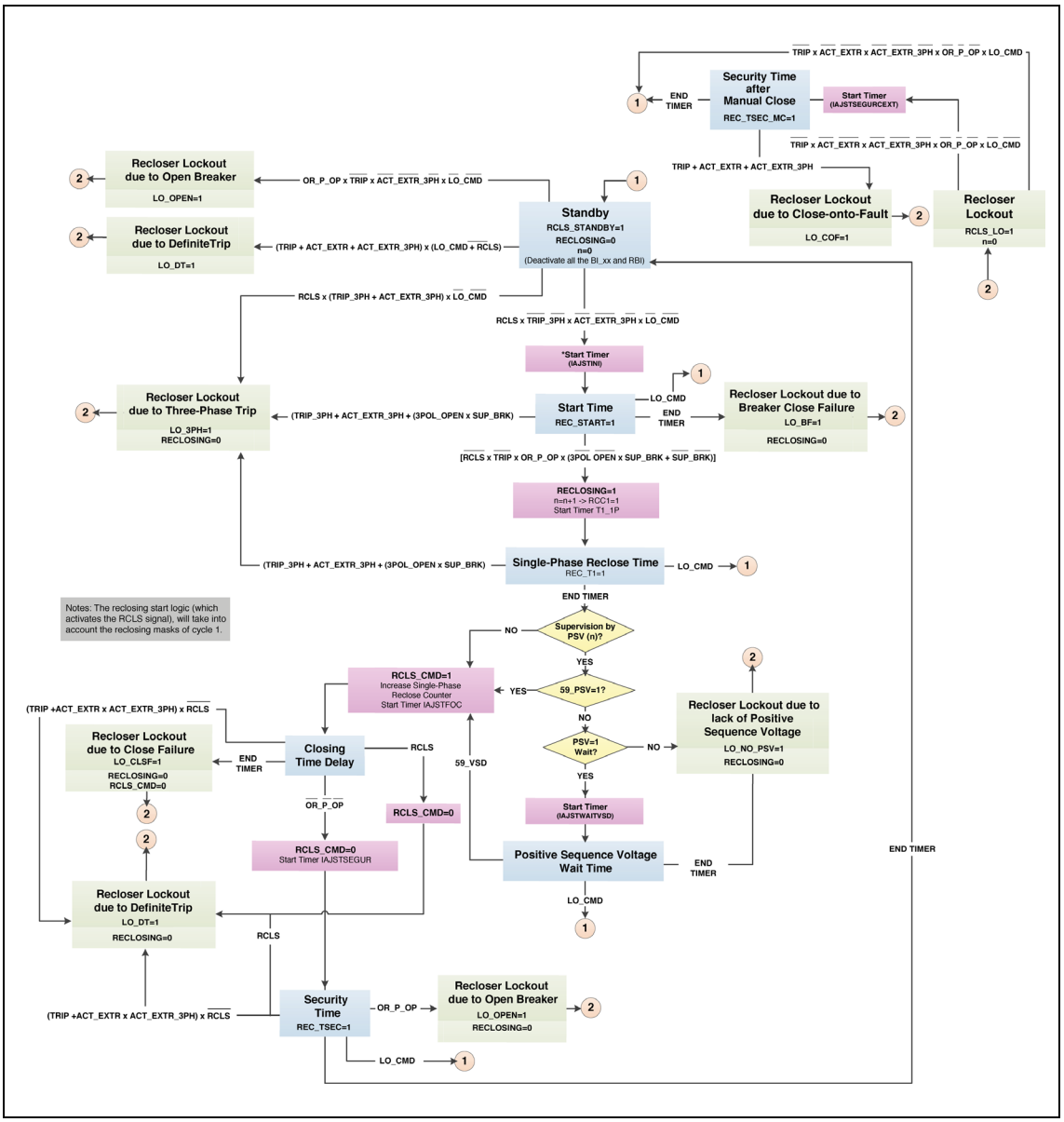


Figure 7.1.1 Recloser 1p Operation Flow Diagram.

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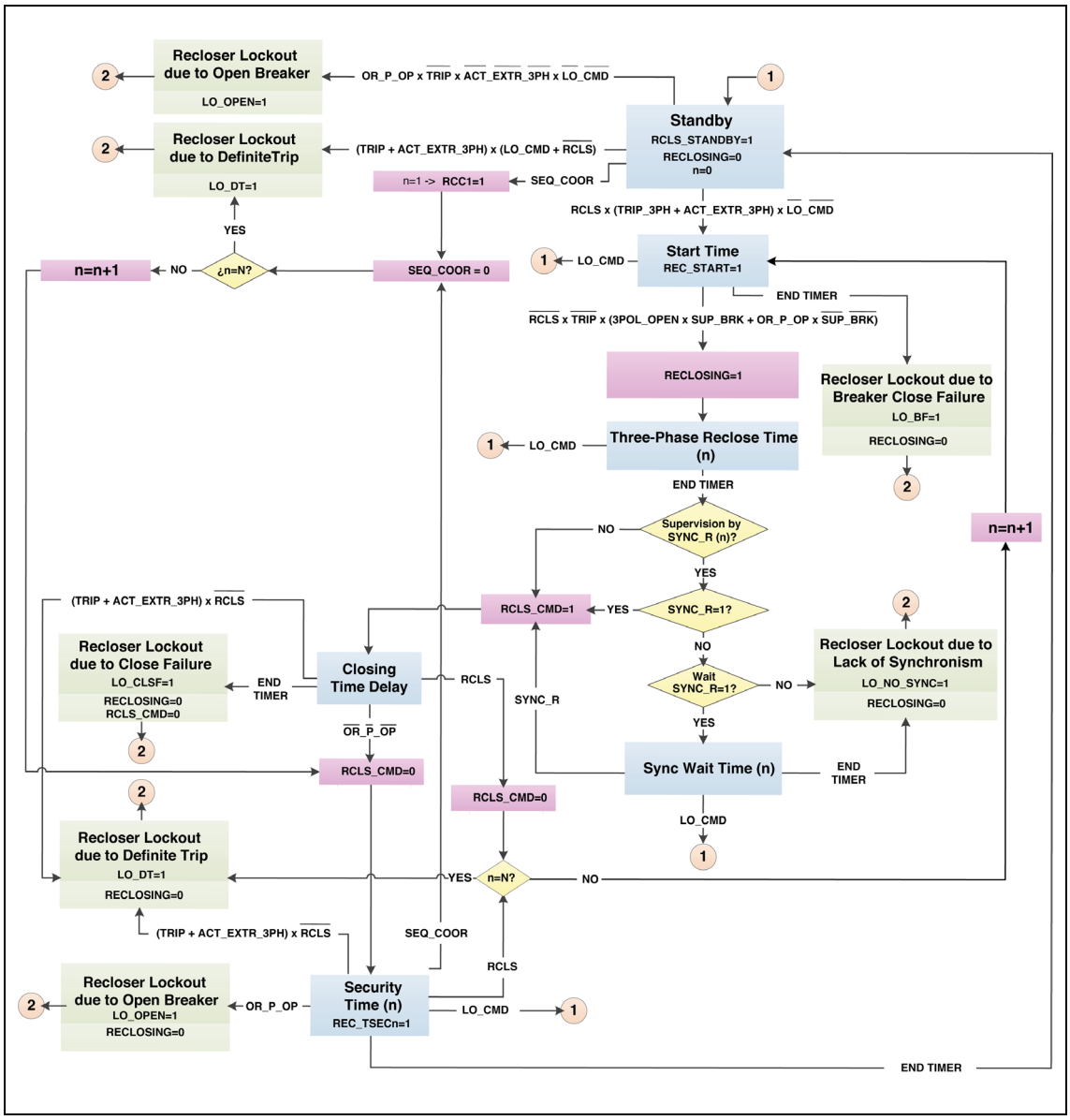


Figure 7.1.2 Recloser 3p Operation Flow Diagram.

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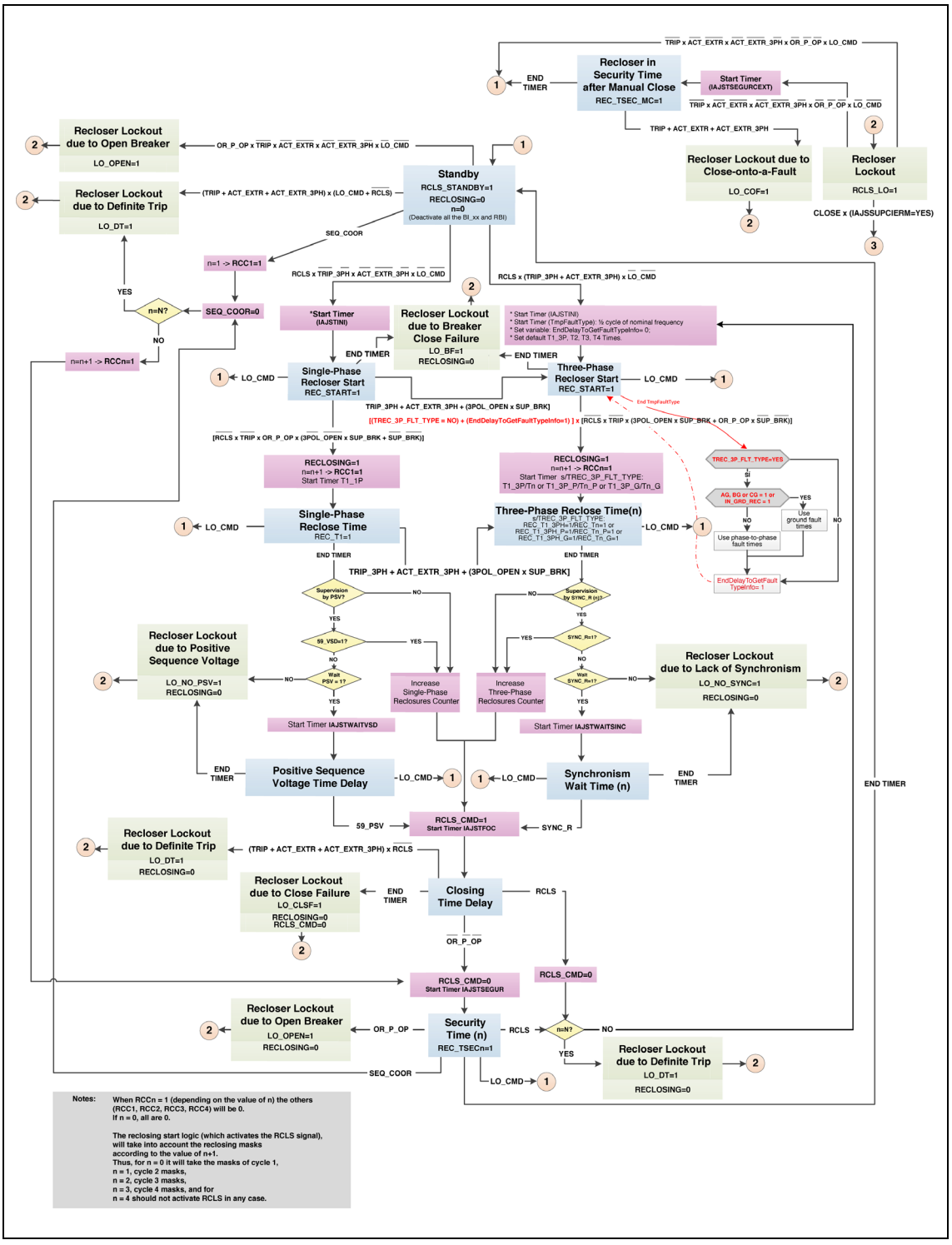


Figure 7.1.3 Recloser 1p/3p Operation Flow Diagram.

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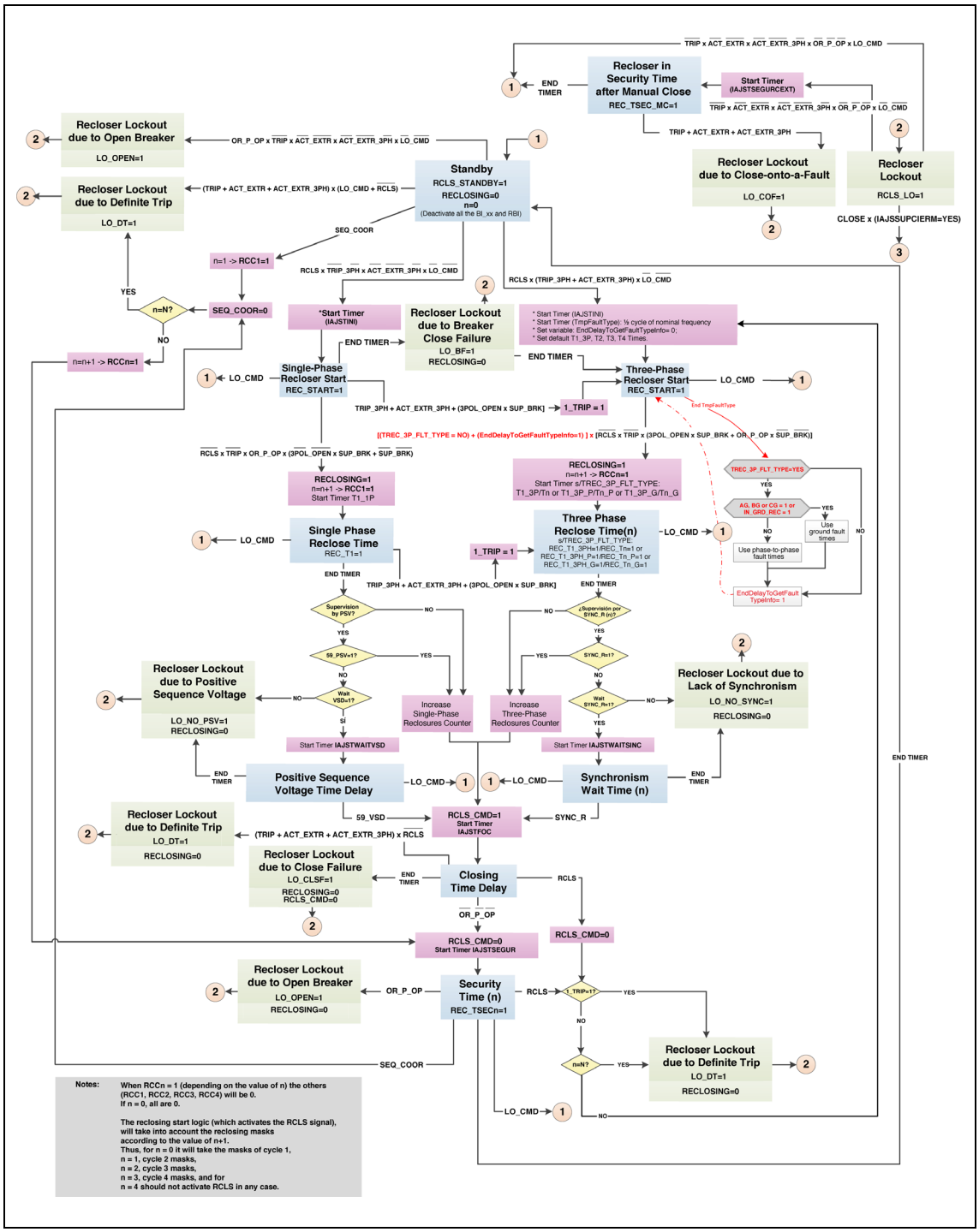


Figure 7.1.4 Recloser Dependent Mode Operation Flow Diagram.

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7.1.7 Reclosing Logic (Double Breaker of Breaker-and-a-Half Models)

Figures 7.1.5 to 7.1.16 depict the flow diagrams for the four different recloser operation modes for single breaker models.

Key for figures 7.1.5 to 7.1.16:

LEGEND	
RECLOSINGm	Recloser m in Sequence in Progress
LO_OPENm/s	Recloser m/s Internal Lockout on Open Breaker
LO_3PHm/s	Recloser m/s Internal Lockout on Three-phase Trip
LO_BFm/s	Recloser m/s Internal Lockout on Initialization Failure
LO_CLSFm/s	Recloser m/s Internal Lockout on Closing Failure
LO_DTm/s	Recloser m/s Internal Lockout on Final Trip
LO_NO_SYNCm/s	Recloser m/s Internal Lockout on Lack of Synchronism
BI_PSVL	Recloser m/s Internal Lockout due to Lack of Positive Sequence Voltage
LO_CFm/s	Recloser m/s Internal Lockout on Switch Onto Fault
LO_MASs	Recloser s Internal Lockout on Master Command
RCLS_Lom/s	Any Recloser m/s Internal Lockout State
RCLS_CMDm/s	Breaker m/s Reclose Command
SLV_PERM	Slave Recloser Enable
SLV_BLK	Slave Recloser Lockout
REPm/s	Recloser m/s in Standby
E_TINIMm/s	Single-Phase Initiation Time
E_TINITm/s	Three-Phase Initiation Time
E_TRMm/s	Single-Phase Reclose Time
E_TRTnm/s	Three-Phase Reclose n Time
E_ESP_SINCm/s	Synchronism Waiting Time
E_ESP_CIERm/s	Closing Waiting Time
E_TSEGm/s	Security Time 1
E_TSEGm/s	Security Time 2
E_SEG_CMm/s	Security Time after Manual Closing
E_ESP_CESCm	Waiting for Slave Closing
E_MAES_CMs	Waiting for Master after Single-Phase Sequence
E_MAES_CTs	Waiting for Master after Three-Phase Sequence
E_ESP_VSD1	Positive Sequence Voltage Waiting Time
E_TCM1	Manual Closing Waiting Time
COm/s	Recloser m/s Manual Close Order
TRIP	Trip
TRIP_3PH	Three Phase Trip
ACT_EXTR	External Protection Trip
ACT_EXTR_3PH	External Protection Three Phase Trip
52_ORPm_OP	m/s Breaker Any Pole Open
52_ANDPm_OP	m/s Breaker Three Pole Open
LO_CMD	External Lockout Order
RCLS	Reclose Order

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LEGEND	
Cont_mono	Single Phase Reclosure Counter
Cont_tri	Three Phase Reclosure Counter
59_VSD1	Positive Sequence Voltage Overvoltage
SEQ_COOR	Sequence Coordination
SUP_BRK	Breaker Supervision
AJ_SUP_VSD1	Positive Sequence Voltage Supervision Setting
AJ_ESP_VSD1	Positive Sequence Voltage Supervision Waiting Setting
AJ_SUP_SIN	Synchronism Supervision Setting
AJ_ESP_SINC	Synchronism Waiting Setting
AJ_PERM_ESC	Slave Permission Setting
AJ_CM_REENG	Manual Reclose Setting
nm	Reclose Sequence Recloser M
N	Adjust Sequence Recloser Number

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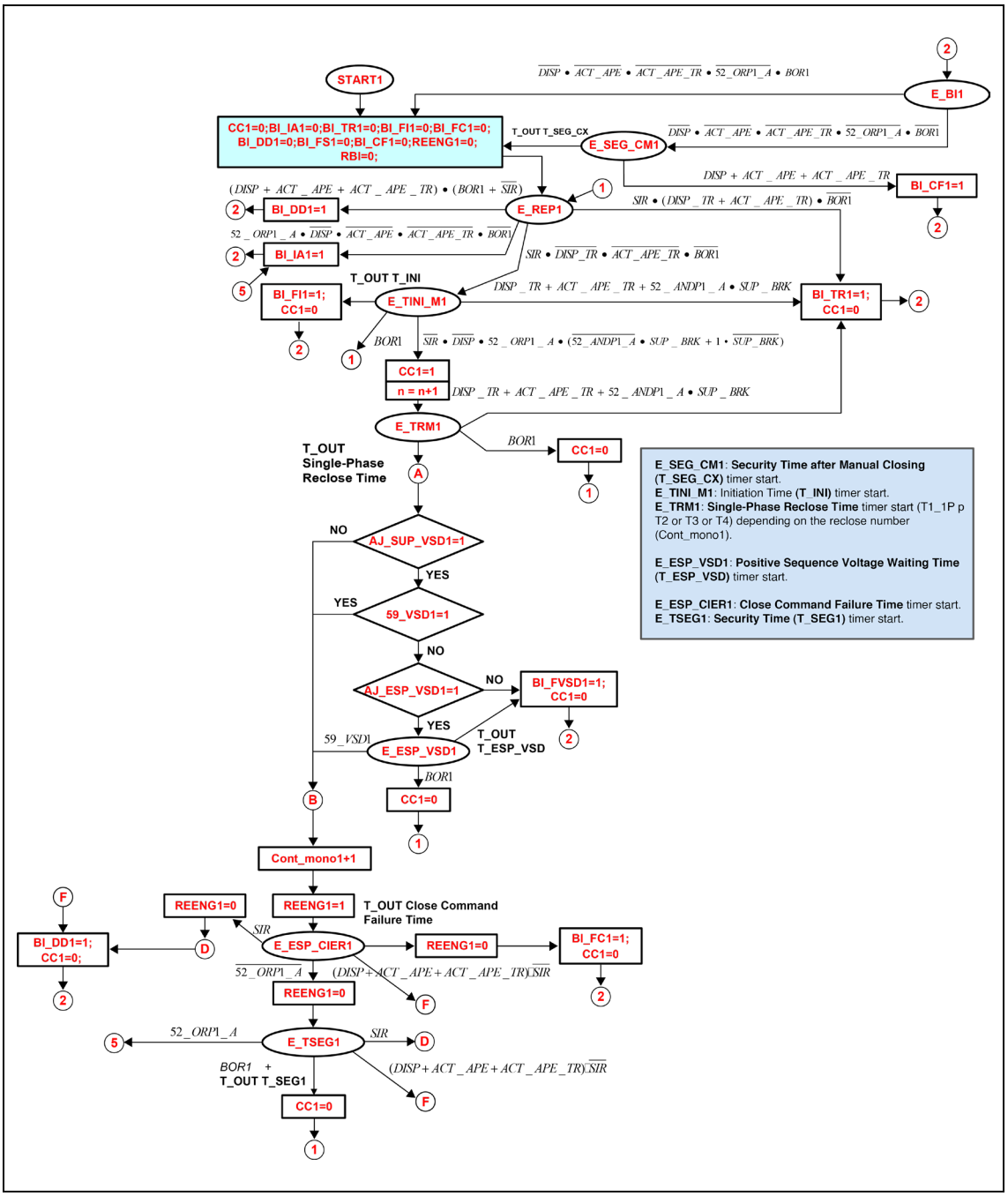


Figure 7.1.5 Breaker 1 Only 1P Mode.

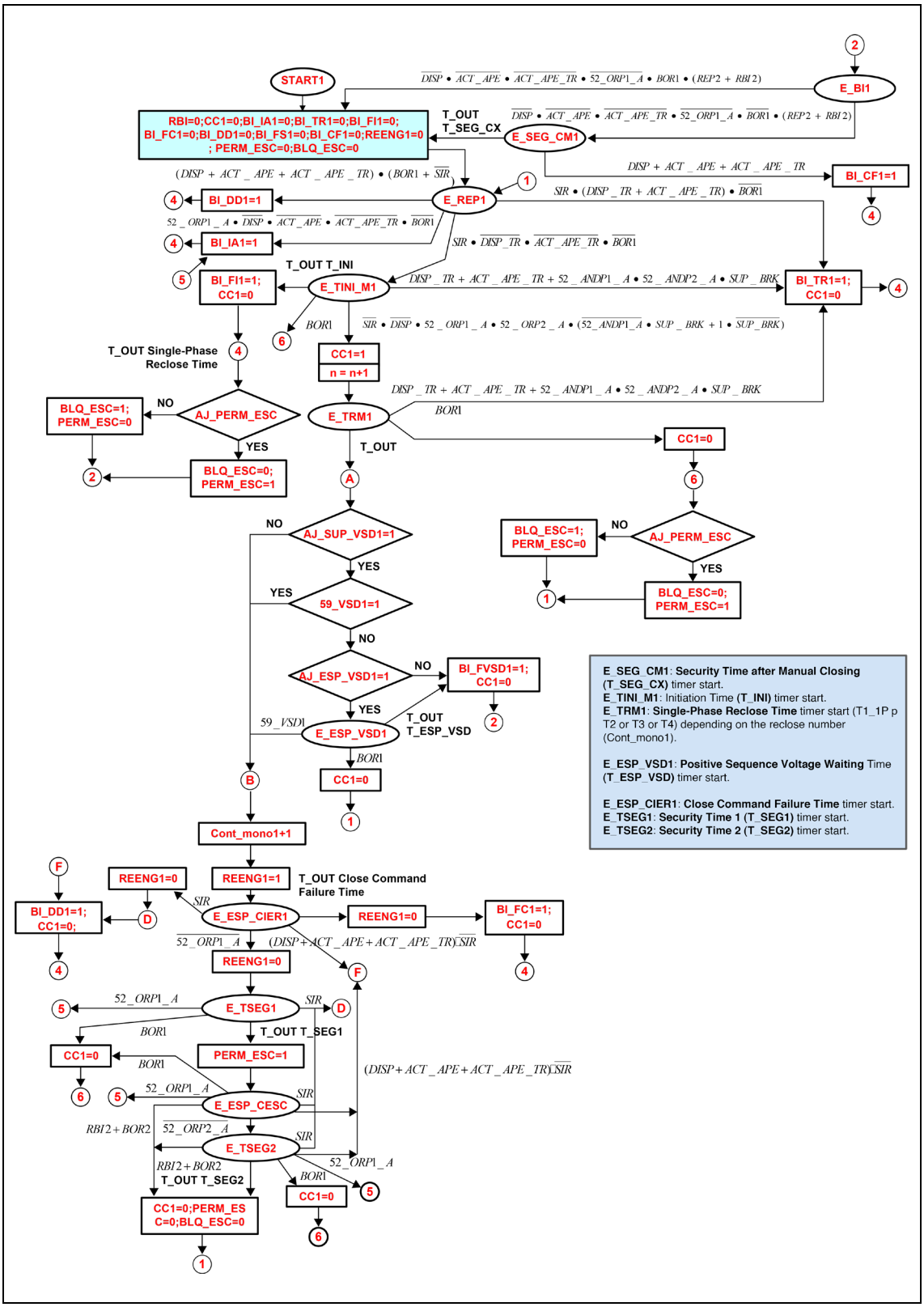


Figure 7.1.6 Breaker 1 Master 1P Mode.

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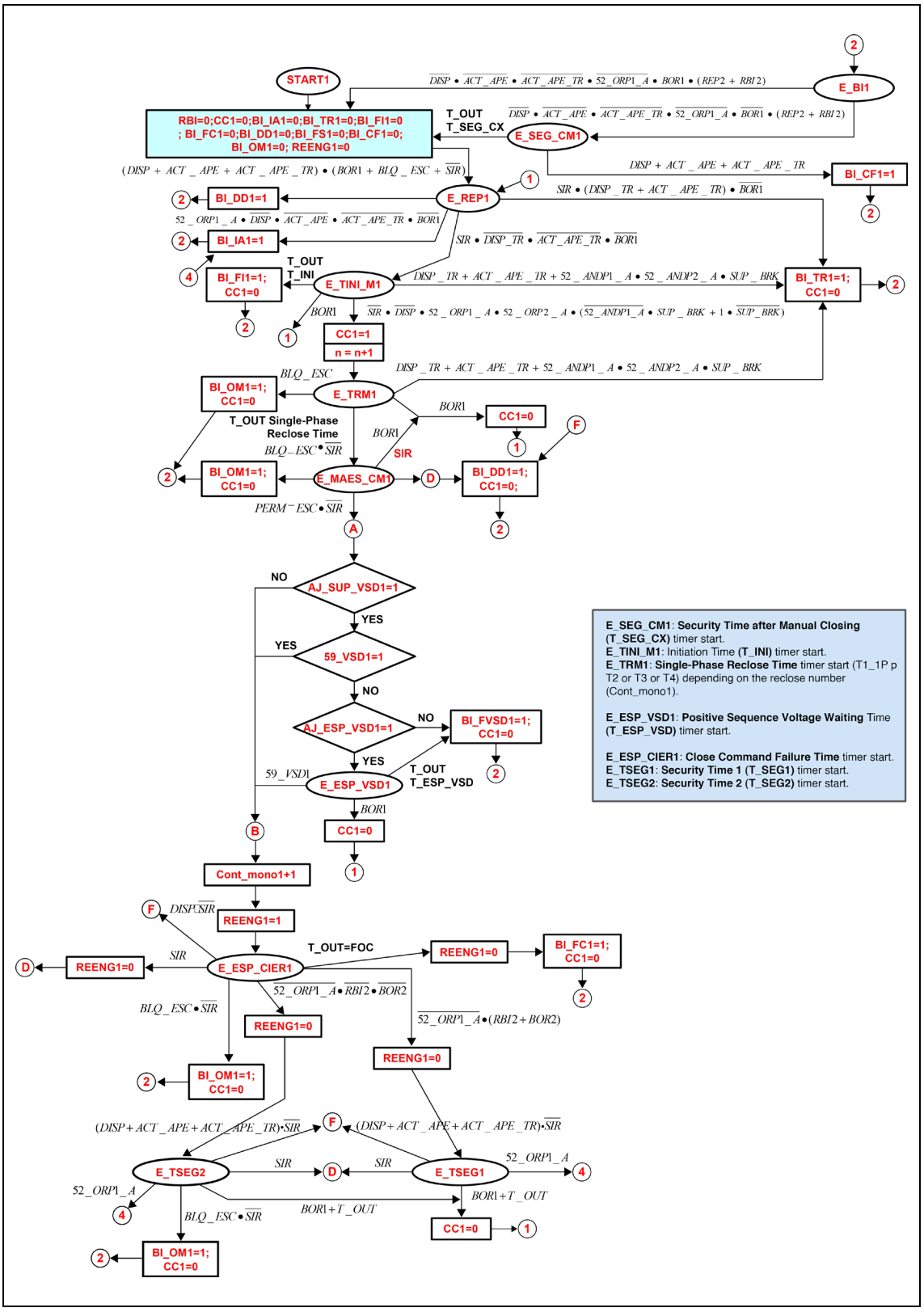


Figure 7.1.7 Breaker 1 Slave 1P Mode.

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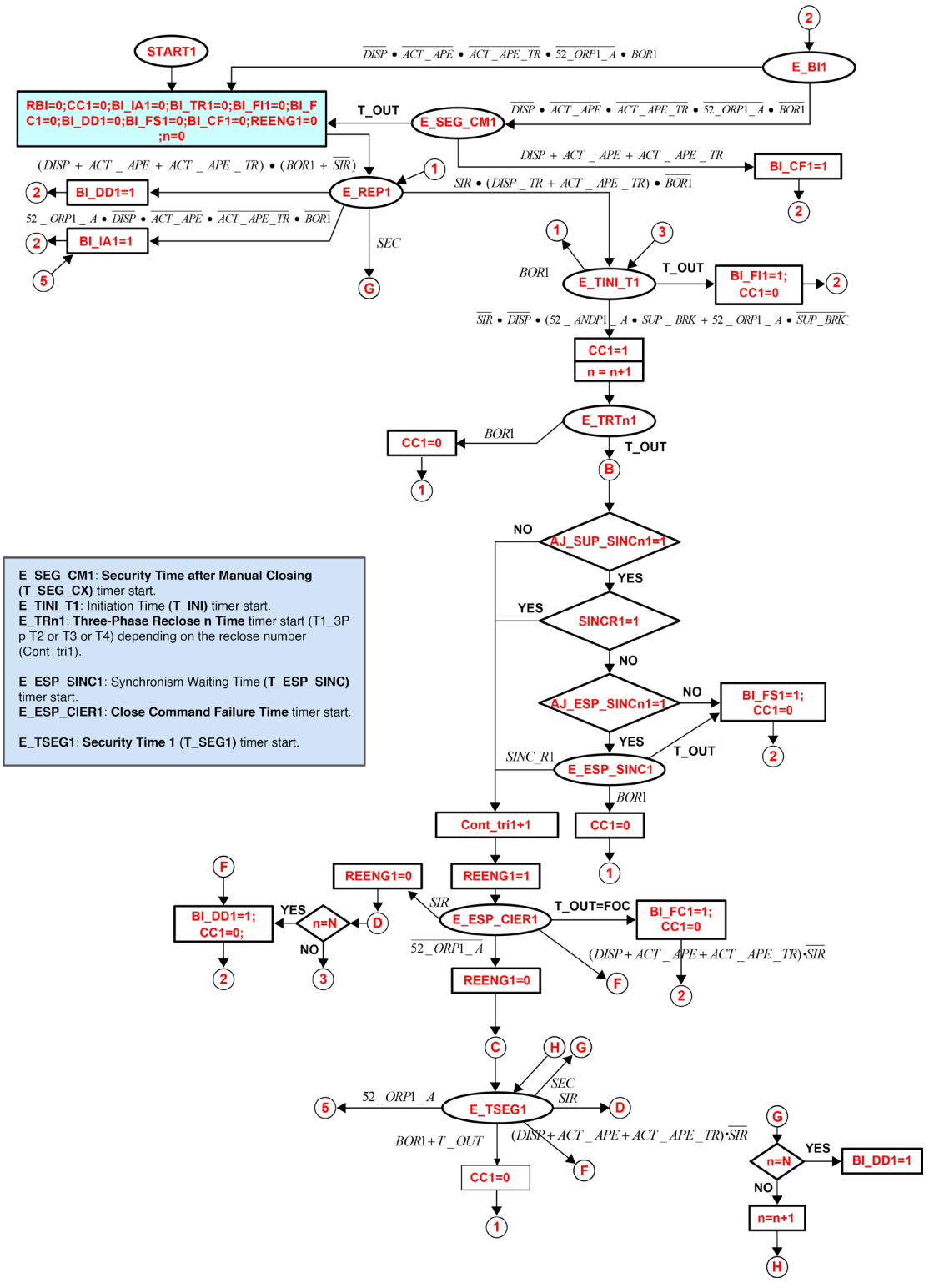


Figure 7.1.8 Breaker 1 Only 3P Mode.

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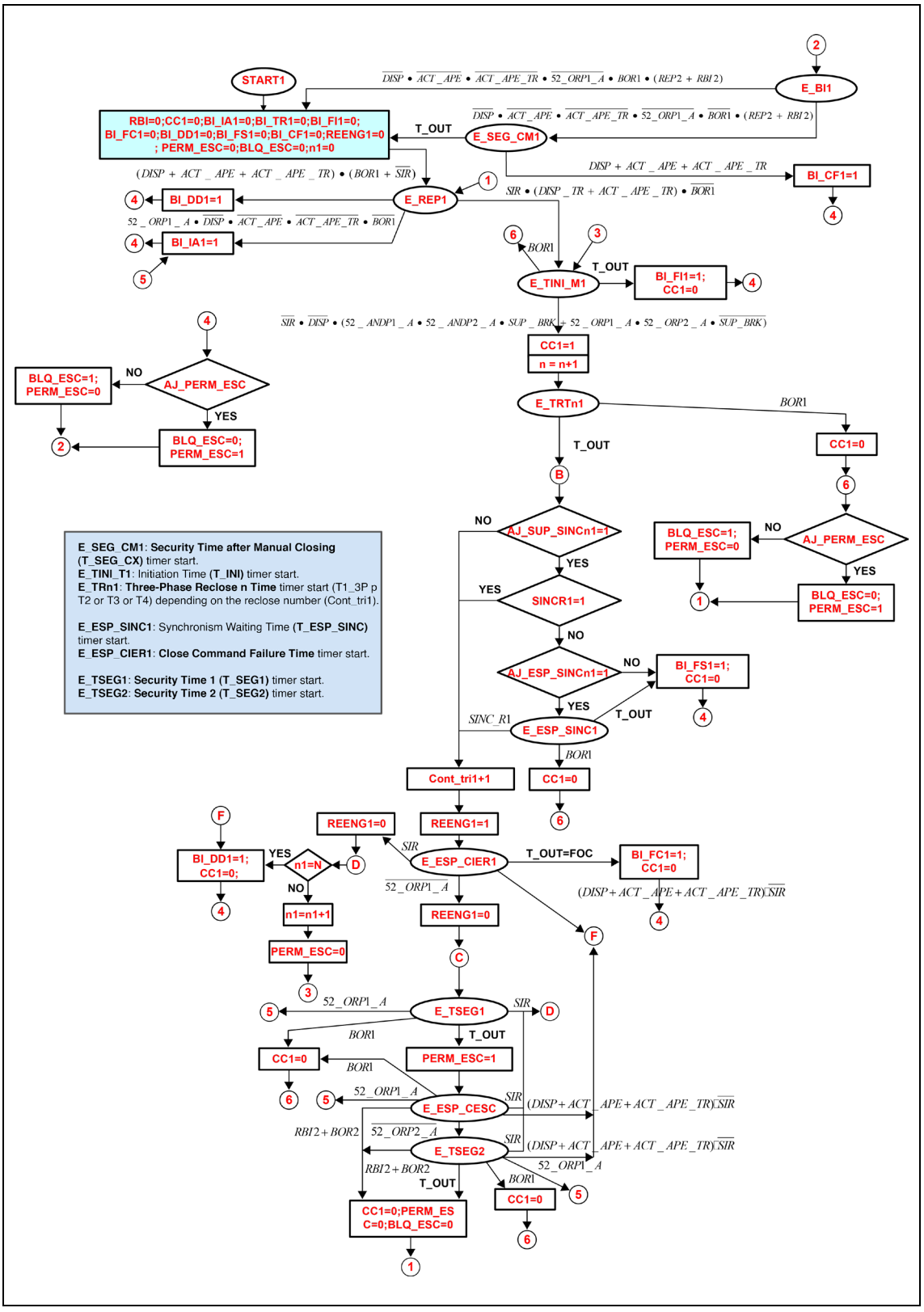


Figure 7.1.9 Breaker 1 Master 3P Mode.

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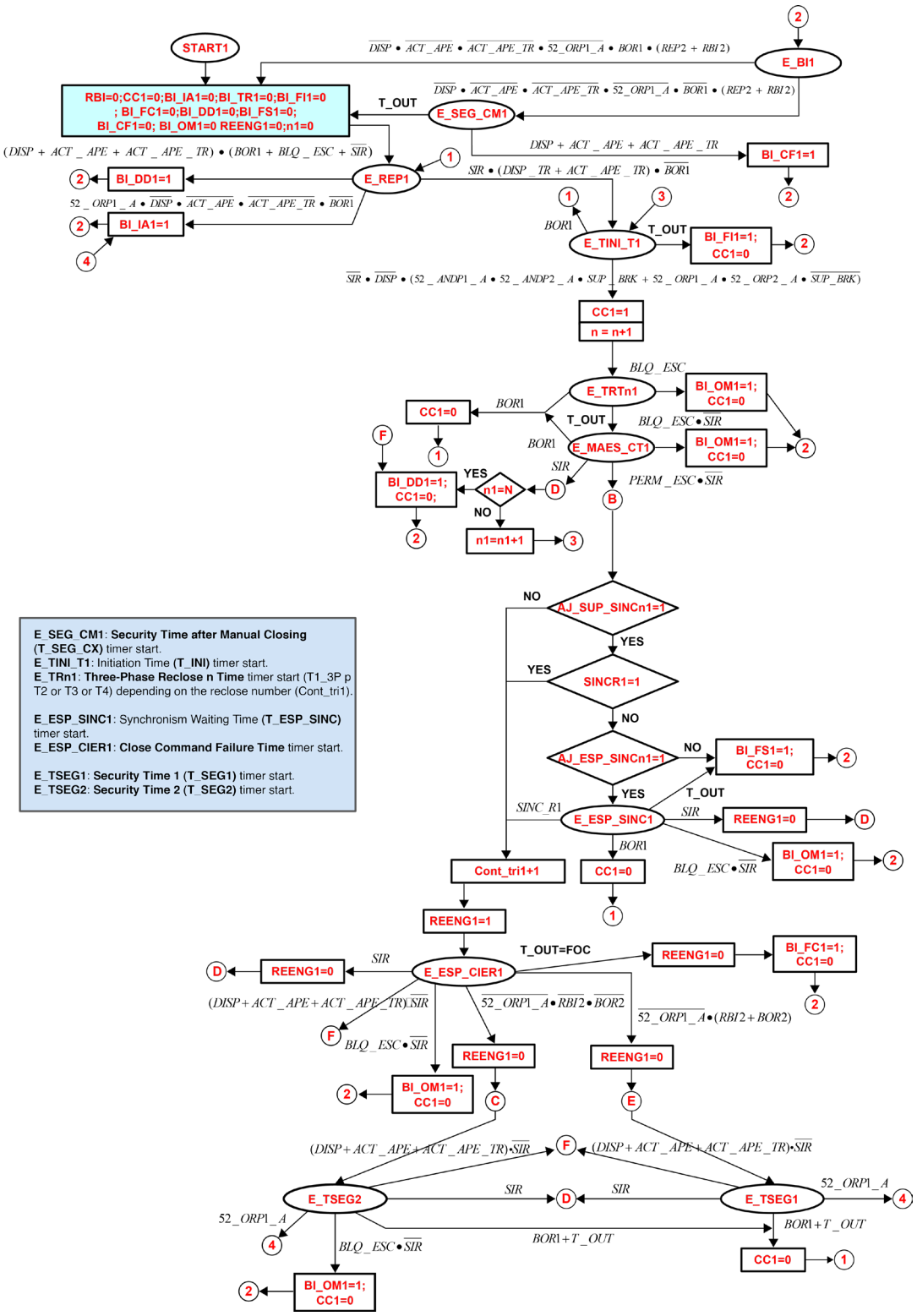


Figure 7.1.10 Breaker 1 Slave 3P Mode.

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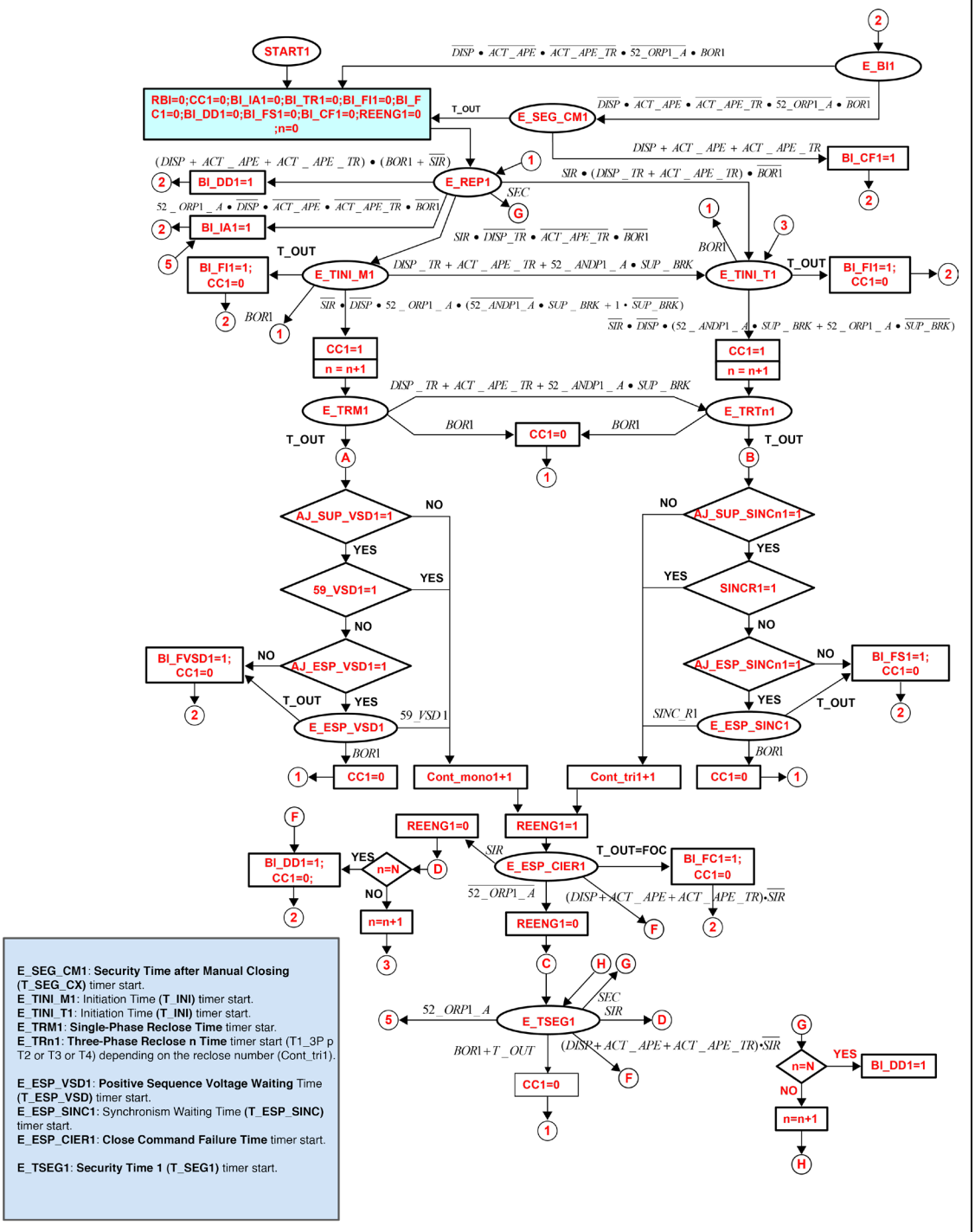


Figure 7.1.11 Breaker 1 Only 1P3P Mode.

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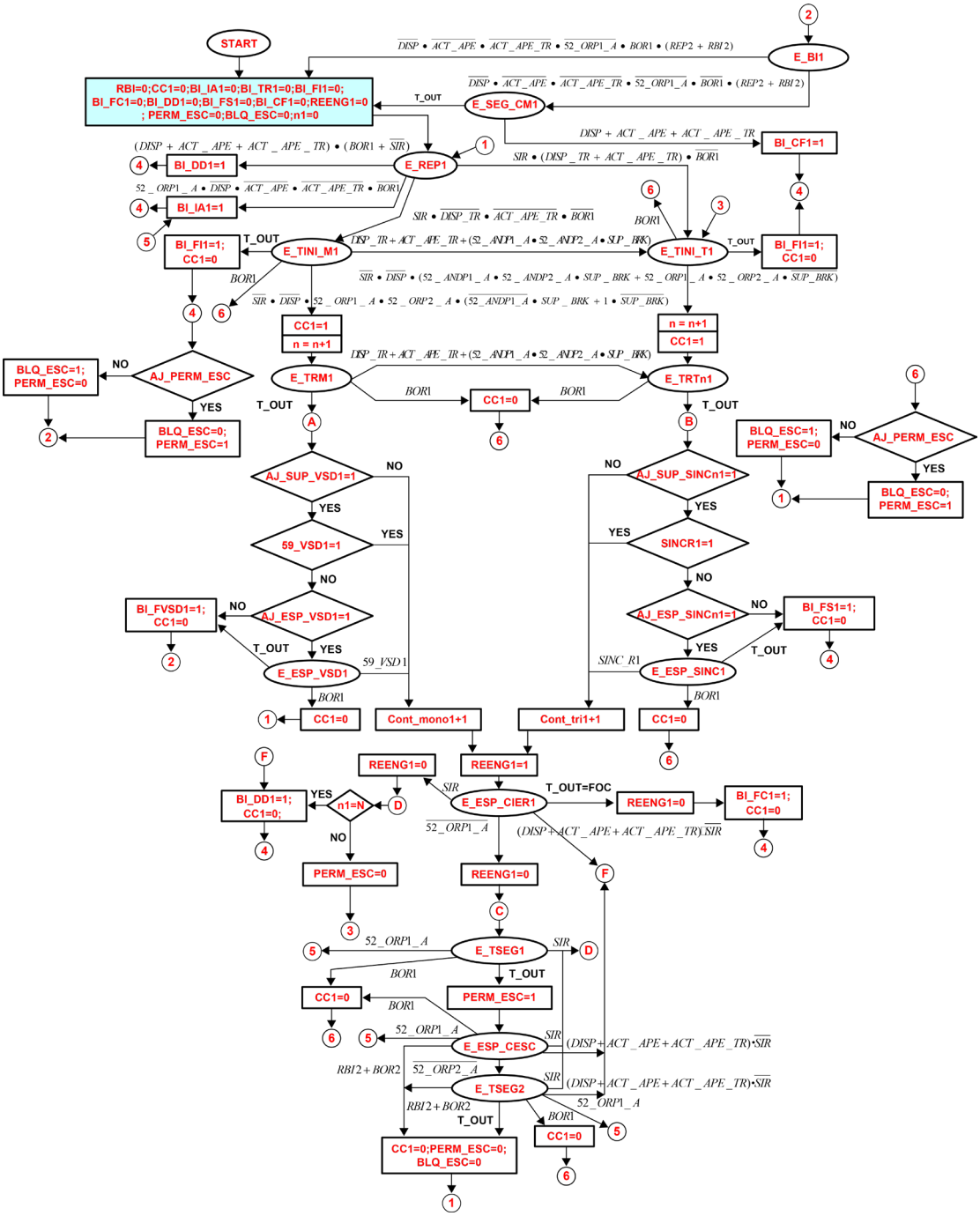


Figure 7.1.12 Breaker 1 Master 1P3P Mode.

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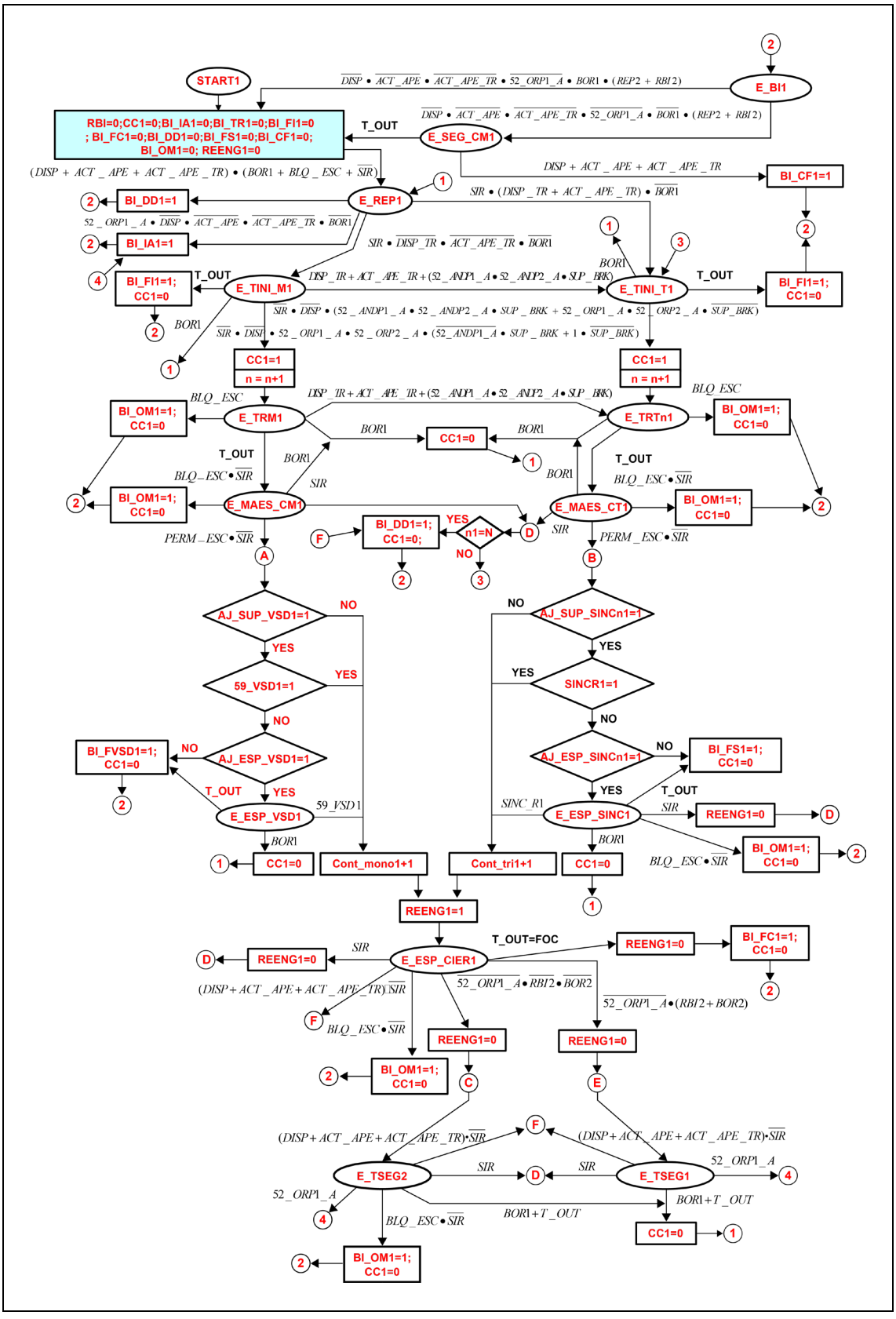


Figure 7.1.13 Breaker 1 Slave 1P3P Mode.

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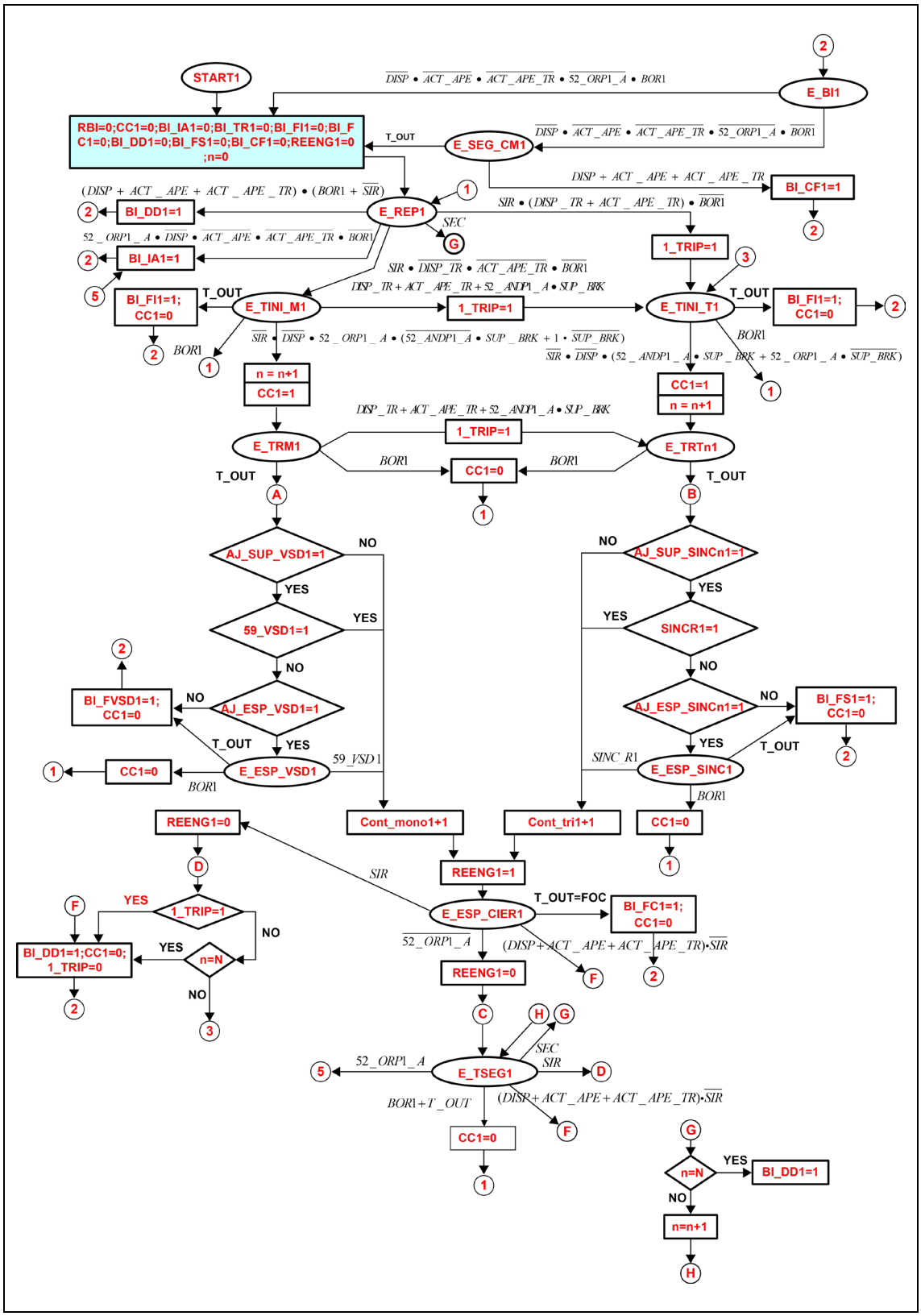


Figure 7.1.14 Breaker 1 Only DEP Mode.

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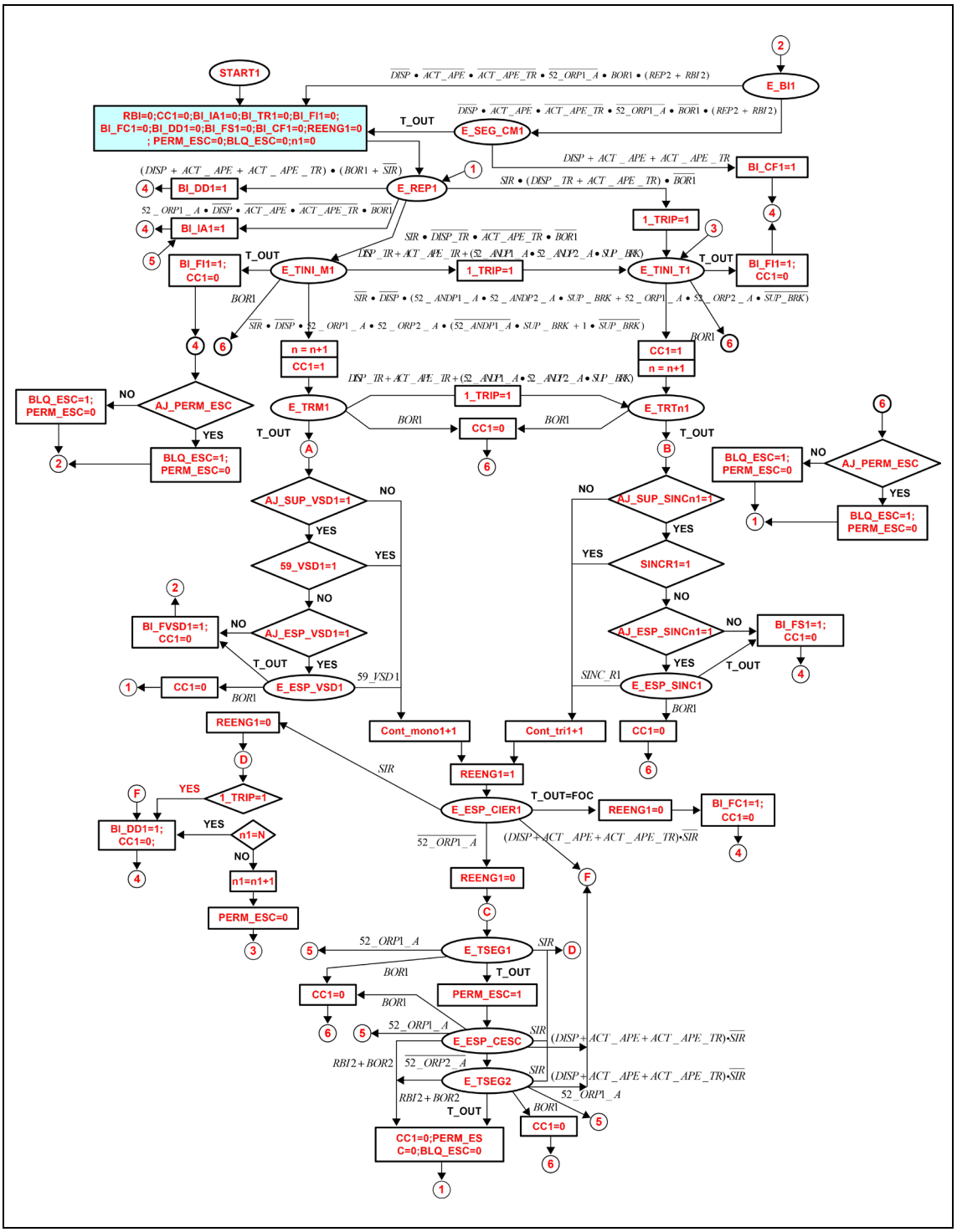


Figure 7.1.15 Breaker 1 Master DEP Mode.

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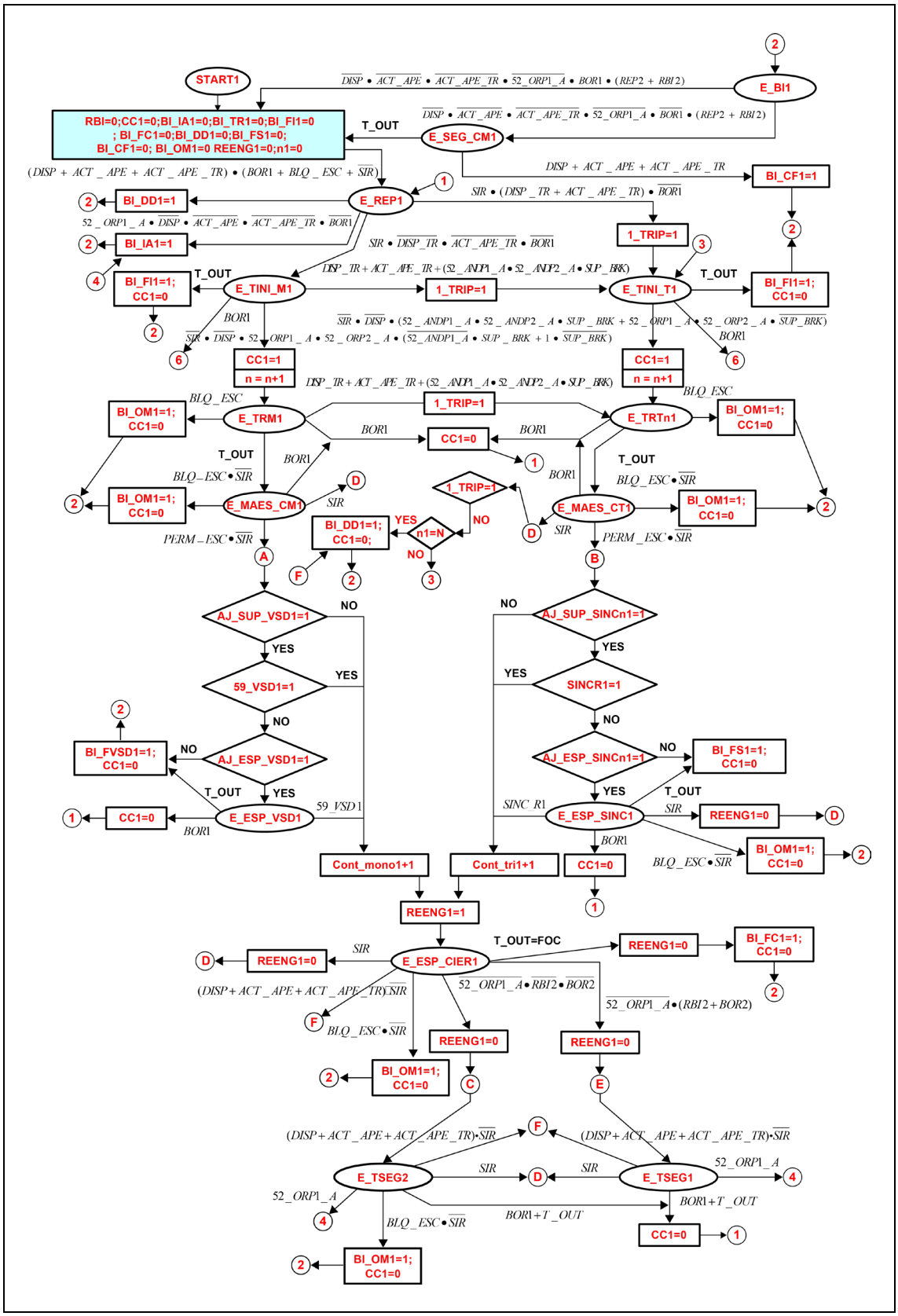


Figure 7.1.16 Breaker 1 Slave 1P3P Mode.

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7.1.8 Reclose Sequence

Up to four reclose attempts can be programmed in the reclose sequence. A sequence of operations takes place during each of these close attempts which is controlled by the recloser settings and by certain external events, detected through the digital input system or received from the protection units contained in the IED itself. Below are represented the different states of the automatic reclose function.

7.1.8.a Sequence Start

The **DLF** Recloser presents two start time states (**Single-Phase Start Time** state and **Three-Phase Start Time** state).

When the recloser is in the Recloser Reset state, reclosing is initiated as follows:

- In **1P Mode**, the operation starts on a single-phase trip being produced by any of the enable protection units or by the **External Trip Activation** (**ACT_EXTR**) signal, with the **External Three-Phase Activation Trip** (**ACT_EXTR_3PH**) deactivated.

  In either of the two cases, the **RCLS** signal will be activated, which will remove the Recloser from its Reset state to change it to the Single-Phase Start Time state provided the recloser is not blocked by command.

  If the **RCLS** activation is due to **Three-Phase Trip** (**TRIP_3PH** or **ACT_EXTR_3PH**), the Recloser evolves the Internal **Blocking due to Three-Phase Trip** state instead of starting a reclose sequence.

- In **3P Mode**, the operation starts on one of the enabled protection units producing a three-phase trip or by the **External Three-Phase Activation Trip** (**ACT_EXTR_3PH**) signal.

  In either of the two cases, the **RCLS** signal will be activated, which will remove the Recloser from its Reset State to change it to the **Three-Phase Start Time** state provided the recloser is not blocked by command.

- In **1p/3p** and **Dependent** modes, the operation of the Recloser is based on the combination of the two previous modes (**1p** for single-phase trips and **3p** for three-phase trips).

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Single-Phase Sequence Start

In the **Single-Phase Start Time** state, a time counter with **Start Time** setting is put into operation. If this time ends before detecting the fault reset (**RCLS** reset), the opening of the breaker (**OR_P_OP**) and the trip drop (**TRIP**), the system evolves to the **Internal Blocking Due to Breaker Failure** state, from which it can only leave through a close command to the breaker. Otherwise, the single-phase sequence starts activating the **RECLOSING** (Sequence in Progress) signal and generating the Recloser Sequence Start. The activation of **RECLOSING** produces the activation of **3PH_PREP** (**Three-Phase Trip Ready** signal), as is indicated in the single-phase/three-phase Tripping Logic, with which the following trips will be three phase up to the deactivation of **RECLOSINGm**.

Note: The RECLOSING signal will remain activated during the entire recloser sequence, since the first attempt sequence will continue until the recloser switches to the Reset or the Lockout state.

If the single-phase trip evolves to three-phase before the initiate timer times out, the recloser m switches to:

- **Internal Lockout on Three-Phase Trip**, in **1p Mode**.
- **Three-Phase Initiate Time**, in **1p/3p** and **Dependent Modes**.

Three-Phase Sequence Start

In the **Three-Phase Start Time** state, a time counter is put into operation with the **Start Time** setting. As in the single-phase case, if this time ends before the fault reset is detected (**RCLS** reset), the opening of the breaker (**OR_P_OP**) and trip drop (**TRIP**), the system evolves to the Internal Blocking Due to Breaker Failure state, from which it can only leave through a close command to the breaker. Otherwise, the three-phase sequence commences activating the **RECLOSINGm** (Sequence in Progress) signal and generating the Recloser Sequence Start. The activation of **RECLOSING** produces the activation of **3PH_PREP** (**Three-Phase Trip Ready** signal), as is indicated in the single-phase/three-phase Tripping Logic, with which the following trips will be three phase up to the deactivation of **RECLOSING**.

Note: The RECLOSING signal will remain activated during the entire recloser m sequence, since the first attempt sequence will continue until the recloser switches to the Reset or the Lockout state.

If the single-phase trip evolves to three-phase (activation of **TRIP_3PH** or **ACT_EXTR_3PH** signals) or if the breaker opens its three poles (activation of **AND_P_OP**) before the initiate timer times out, the recloser m switches to:

- **Internal Lockout on Three-Phase Trip**, in **1p Mode**.
- **Three-Phase Initiate Time**, in **1p/3p** and **Dependent Modes**.

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7.1.8.b Reclose Time

There are two different reclosing timers, according to the single-phase or three-phase character of the Reclose start. In both cases, the activation of the **Reclose Command** (**RCLS_CMD**) will produce the activation of the **Command CLOSE** output, with the latter giving a **Close Command** to the breaker.

Single-Phase Reclosing Timer

On entering this state (which only occurs in the first sequence of the **1P** and **1P/3P** modes), the adjusted **First Single-Phase Reclosing Time** will commence to be counted.

If a recloser block command is issued (activation of **LO_CMD**) before the timer times out, the recloser resets without reclosing. On the other hand, if the single-phase trip evolves to three-phase (activation of **TRIP_3PH** or **ACT_EXTR_3PH** signals) or if the breaker opens the three poles (activation of signal **AND_P_OP**) before the single-phase reclose time times out, the recloser switches to:

- **Internal Lockout on Three-Phase Trip** state, in **1p Mode**
- **Three-Phase Initiate Time** state, in **1p/3p** and **Dependent Modes**

Otherwise, if the counted timer times out the **Reclose Command** signal (**RCLS_CMD**) is generated and the **Closing Time** state is achieved.

Three-Phase Reclosing Timer

When the Three-Phase Reclosing Timer state is achieved, the corresponding timer will be started:

- The **First Three-Phase Reclosing Timer** will start for the first reclosing attempt after a three-phase trip.
- The **Second, Third or Fourth Reclosing Timer** will start for a second, third or fourth reclosing sequence (as previously noted, only three-phase reclosing is possible after the first recloser sequence).

As in the single phase wait status, if the recloser is manually blocked (activation of **LO_CMD**) before time-out, the recloser resets without reclosing. However, if the timer times-out, synchronism conditions are checked and then **RCLS_CMD** (**Reclose Command**) activates if synchronism conditions and positive sequence voltage are complied with.

First, the **Synchronism Supervision Enable** setting, adjustable separately for each of the four possible reclose cycles, is checked. If the setting of the current cycle is set to **NO**, **RCLS_CMD** (**Reclose Command**) is generated and the **Close Delay** status is entered (the **Positive Sequence Voltage Supervision Enable** setting is first checked).

However, if the enable setting is set to **YES**, **SYNC_R**, that indicates the presence of synchronism on the corresponding breaker, is checked. For this purpose, synchronism unit 1 is always considered for recloser logic. Consider that if the synchronism unit 1 is disable, then there will be always reclose permission by synchronism. If the **SYNC_R** signal is active, **RCLS_CMD** is generated and the **Close delay** status is entered (the **Positive Sequence Voltage Supervision Enable** setting is first checked).

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When synchronous conditions are not reached (**SYNC_R** deactivated), the **Synchronism Timer Enable** setting, independently adjustable for each of the three possible sequences of the recloser function, is checked. If this setting is set to **NO**, the recloser changes to the **Internal Lockout Due to Lack of Synchronism** state. If the setting is set to **YES**, the **Synchronism Wait Timer** starts to count down the adjusted time.

The activation of **SYNC_R** before delay time-out generates **RCLS_CMD** (**Reclose Command**) and the **Close Delay** status is entered (the **Positive Sequence Voltage Supervision Enable** setting is first checked). Otherwise, the recloser enters the **Internal Blocking by Lack of Synchronism** status.

Once synchronism has been checked, the **Positive Sequence Voltage Supervision Enable** setting value is checked. If the setting is set to **NO**, **RCLS_CMD** (**Reclose Command**) is generated and **Close Delay** status is entered.

However, if the enable setting is set to **YES**, the status of **59_VSD,** that indicates that the positive sequence voltage exceeds the setting value, is checked. If this signal is active, **RCLS_CMD** is generated and **Close Delay** status is entered.

If the positive sequence voltage does not exceed the setting value (**59_VSD** deactivated), the **Positive Sequence Voltage Delay Enable** setting value is checked. If the setting value is set to **NO**, the recloser switches to **Internal Blocking by Lack of Positive Sequence Voltage** status. Instead, if the delay setting is set to **YES**, the **Positive Sequence Voltage Delay Time** status is entered, and the **Positive Sequence Voltage Delay Time** starts counting (settable).

The activation of **59_VSD** before delay time-out generates **RCLS_CMD** (**Reclose Command**) and **Close Delay** status is entered. Otherwise, the recloser switches to **Internal Blocking by Lack of Positive Sequence Voltage** status.

7.1.8.c Closing Time

After issuing the **Reclose Command**, the recloser switches to the **Waiting for closing** state, in which setting **Close Command Failure Time** set via the **Command** module starts timing. If the timer times out before the three poles of the breaker close (deactivation of the **Any Pole Open**, **OR_P_OP** signal) the **FAIL_CLS** output (**Close Command Failure**) activates and the recloser switches to **Internal Lockout on Close Failure** state. If during the **Command Failure** time the three breaker poles are closed, the recloser will switch to **Security Time** state.

In both cases, the **RCLS_CMD** output will be deactivated.

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7.1.8.d Security Time

When this state is achieved, an adjustable **Security Time** timer is started. This setting is common for all the three reclosing sequences. The **Security Time** setting is used to determine whether two consecutive trips correspond to the same fault that has not been successfully cleared, or to two consecutive faults. If the **Security Time** is completed without a trip being initiated, the recloser switches to the recloser **Reset** state, and the reclose attempt is completed.

If a trip occurs (**RCLS** signal activated) before the **Security Time** is completed, the next step in the reclose sequence is determined by the number of **Reclose Attempts** setting. If a trip occurs after the last reclose attempt permitted by this setting, or if the recloser operates in **Dependent Mode** and the first trip has been three-phase, the Recloser switches to **Recloser Lockout Due to Definite Trip**. At this point, the reclose sequence ends. If the Recloser has not reached the last permitted reclose attempt, the trip signal that occurs before the **Reset Time** is completed will initiate a new reclose attempt. The recloser will then switch to the **Three-Phase Sequence Start** state.

Opening any breaker pole before **Security Time** times out switches the recloser to **Lockout due to Open Breaker** state. Also, if a recloser block command is issued before **Security Time** times out, it switches to **Reset** state.

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7.1.9 Recloser Lockout

Figure 7.1.17 shows the block diagram of the recloser lockout. This block diagram is common for each of the four reclosing modes.

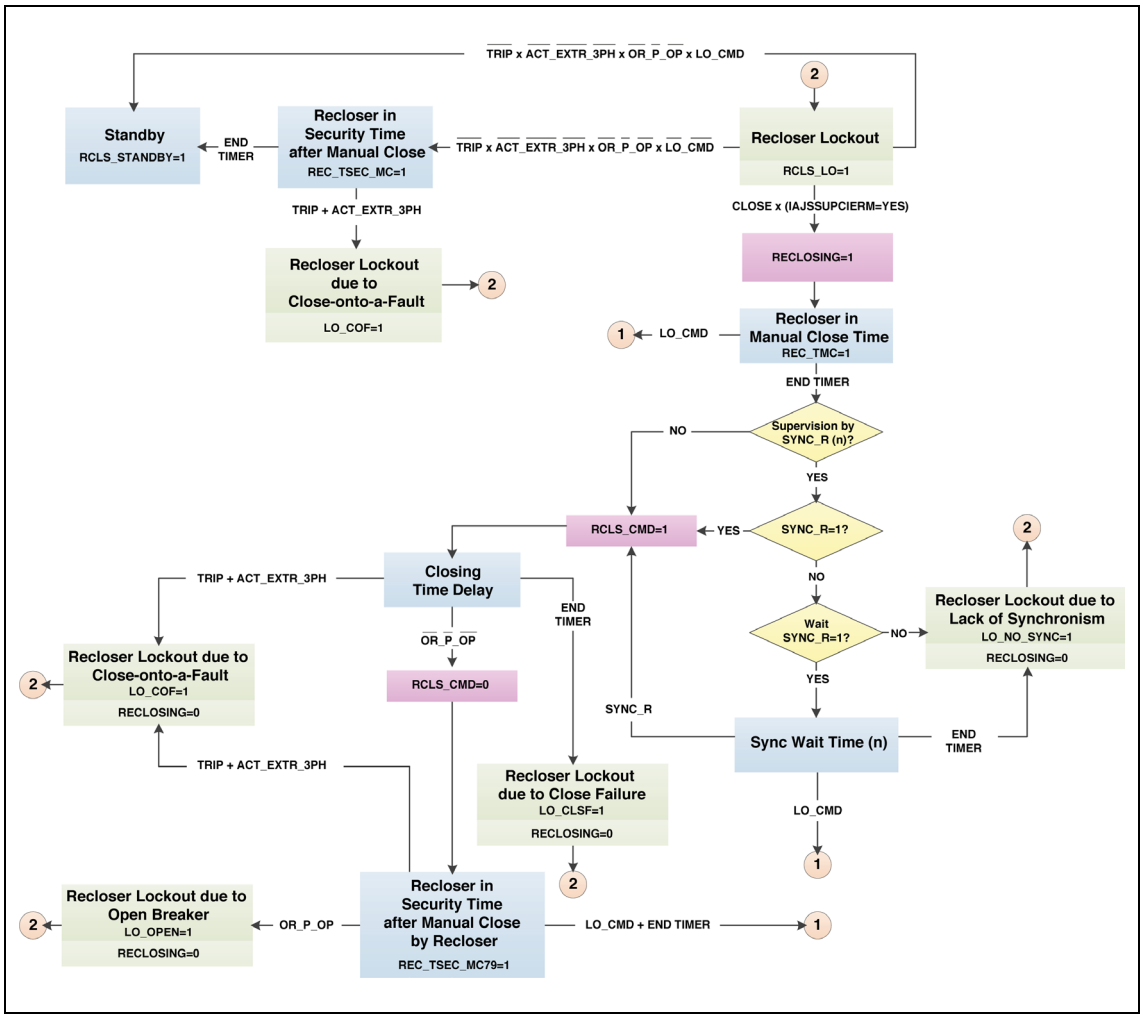


Figure 7.1.17 Recloser Flow Diagram (II).

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LEGEND	
RECLOSING	Recloser Sequence in Progress
RCLS_CMD	Reclose Command
TRIP	Trip
ACT_EXTR_3PH	External Three-Phase Activation Trip
CLOSE	Close Command
OR_P_OP	Any Pole Open
SYNC_R	Close by Synchronism Enabled
n	Current Reclose
N	Number of Programmed Reclose Attempts
RCLS_STANDBY	Recloser in Standby
REC_TMC	Recloser in Manual Close Time
REC_TSEC_MC	Recloser in Security Time after Manual Close
REC_TSEC_MC79	Recloser in Security Time after Manual Close by Recloser
LO_CMD	Recloser Lockout Command
LO_OPEN	Recloser Lockout due to Open Breaker
LO_COF	Recloser Lockout due to Close-Onto-a-Fault
LO_NO_SYNC	Recloser Lockout due to Lack of Synchronism
LO_CLSF	Recloser Lockout due to Close Failure
LO_BF	Recloser Lockout due to Breaker Close Failure
RCLS_LO	Recloser Lockout

The recloser will remain in any of the **Lockout** states until it detects that the breaker is closed. When this situation is detected, the recloser will leave the **Lockout** status and will enter the ***MC Reset Time*** status.

It may also leave the **Lockout** status when a ***Manual Close by Recloser*** command recloser is issued. This situation is produced when the relay command function generates a close Command to be carried out by the recloser itself. In order for this to occur the setting **Manual Close by Recloser** must be set to **YES**. The recloser will enter the ***Manual Close Delay*** status.

7.1.9.a Security Time after Manual Close

When this status is entered, the setting ***MC Reset Time*** starts counting after an external close. If this time times out and no trip occurs (from the relay itself or external), the recloser enters the idle status. If, otherwise, a trip occurs before timeout, the recloser enters the **Recloser Lockout due to Close-Onto-a-Fault** (**LO_COF**) and the trip will be final, without subsequent reclose.

7.1.9.b Manual Close Delay

When this status is entered the cycle starts and the **Recloser Sequence in Progress** (**RECLOSING**) is activated and the setting ***Manual Close Delay*** starts counting.

If a **Recloser Lockout** (**LO_CMD**) command is issued before timeout, the recloser comes back to idle status without reclosing. However, if the count times out, the next step is to check whether there are synchronism conditions and then **Reclose Command** (**RCLS_CMD**) is activated provided the synchronism conditions have been complied with.

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First, the value of the setting **Synchrocheck Supervision** enable, settable separately for each of four possible reclose cycles is checked. If the setting corresponding to the present cycle is **NO**, the **Reclose Command** (**RCLS_CMD**) is generated and the **Close time delay** status is entered. However, if the enable setting is **YES**, the **Close by Synchronism Enabled** (**SYNC_R**) status is checked of the corresponding syncrhonism unit 1, which indicates the presence of synchronism. If this signal is activated, the **Reclose Command** (**RCLS_CMD**) is generated and the **Closing Time Delay** status is entered.

If there is no synchronism (**SYNC_R** deactivated), the value of the setting **Synchrocheck Supervision** enable set separately for each of four possible reclose cycles is checked. If the setting corresponding to the present cycle is **NO**, the recloser enters the **Recloser Lockout due to Lack of Synchronism (LO_NO_SYNC)** status. However, if the delay setting is YES, the **Synchrocheck Wait Time** status is entered, in which **Sync Wait Time** (settable) starts counting.

The activation of **Close by Synchronism Enabled** (**SYNC_R**) before the delay time times out generates the **Reclose Command** (**RCLS_CMD**) and the **Closing Time Delay** status is entered. Otherwise, the recloser enters the **Recloser Lockout due to Lack of Synchronism (LO_NO_SYNC)** status.

The activation of the **Reclose Command** (**RCLS_CMD**) will activate the **CLOSE** command output, the latter giving a close command to the breaker.

7.1.9.c Closing Time

Once the **Reclose Command** (**RCLS_CMD**) is generated, the recloser enters the **Closing Time** status, and the **Fail to Close Time** set in the Control module starts counting.

If this time times out before the three breaker poles close (deactivation of the signal **Any Pole Open**, **OR_P_OP**) the **Close Command Failure** (**FAIL_CLS**) output activates and the recloser enters the **Recloser Internal Lockout on Closing Failure (LO_CLSF)** status.

If a trip (**RCLS** activation) occurs before the **Fail to Close Time** times out, the following step is a function of whether the number of programmed reclosures have been reached or not. If this limit has been reached, the recloser enters **Recloser Internal Lockout on Final Trip (LO_DT)** status, ending the cycle. Otherwise, a new trip initiates a new reclose cycle, and the system enters the **Start Time** status.

If during the **Fail to Close** time the three breaker poles close, the recloser enters the **Security Time** status.

If a trip occurs before the **Fail to Close Time** times out, the recloser enters **Recloser Lockout due to Close-Onto-a-Fault (LO_DT)** status, ending the cycle.

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7.1.9.d Security Time after Manual Close through Recloser

Entering this status will start a timer with the setting **Security Time after Manual Close through Recloser**, common to the four recloser cycles. This time is used to discern whether two consecutive trips correspond to the same fault not cleared successfully or, on the contrary, to two consecutive faults. If **Security Time** times out and no trip is issued, the recloser enters the **Standby** status, ending the cycle.

If a trip occurs before the **Security Time** times out, the recloser enters **Recloser Lockout due to Close-Onto-a-Fault (LO_COF)** status, ending the cycle.

If a breaker pole opens before the **Security Time** times out, the recloser enters the **Recloser Lockout due to Open Breaker (LO_OPEN)** status. Also, if a **Lockout** command is issued before the **Security Time** times out, the recloser enters the **Standby** status.

7.1.10 Recloser Block Command (Manual or External)

The recloser includes two types of blocking commands, which will bring it to the command blocking status: **Manual** command and **External** command.

Manual and external blocking commands are produced through the activation of **INBLK_MAN** (**Recloser Manual Block Command**) and **INBLK_EXT** (**Recloser External Block Command**) logic inputs respectively. The purpose of the **INBLK_MAN** logic input is to receive signals from the HMI or communications (in local or remote mode), whereas the purpose of the **INBLK_EXT** logic input is to receive external signals, which will arrive by means of the relay digital inputs.

The manual blocking command is always by pulse; the **Recloser Block Command** status will be entered via the **Recloser Manual Block Command** (**INBLK_MAN**) input activation pulse, whereas leaving this status requires an additional unblocking command, which will be given by the **Recloser Manual Unblock Command** (**IN_UNBLK_MAN**) input or **Recloser External Unblock Command** (**IN_UNBLK_EXT**) input activation pulse, provided the setting ***External Blocking*** is set to **Pulse**:

The external blocking command can be pulse or level, as a function of the setting ***External Blocking***. When this setting is set to **Pulse**, the **Recloser Block Command** status will be entered through the **Recloser External Block Command** (**INBLK_EXT**) input activation pulse, whereas departure from this status will be produced through **Recloser External Unblock Command** (**IN_UNBLK_EXT**) or **Recloser Manual Unblock Command** (**IN_UNBLK_MAN**) input activation pulse. However, if the setting ***External Blocking*** is set to **Level**, both the recloser blocking and unblocking will be produced through **INBLK_EXT** input. If this input is set to **1**, the recloser will be blocked and the status of **IN_UNBLK_EXT** and **IN_UNBLK_MAN** inputs will not be taken into account; if **INBLK_EXT** is set to **0**, the recloser will be unblocked and the status of **IN_BLK_MAN** input will not be taken into account.

If the recloser is performing a reclose cycle, it will be stopped when receiving the blocking command entering the idle status. In this status, no reclose attempt will be initiated after a trip, which will final in all cases, the **Recloser Lockout due to Close-Onto-a-Fault (LO_DT)** event being generated.

If the recloser is blocked in idle status and an unblocking command is received with the breaker open, the recloser will enter the **Recloser Lockout due to Open Breaker (LO_OPEN)** status, leaving this status when the breaker is closed. If, on the contrary, the breaker is closed, the recloser will remain in idle status.

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7.1.11 Definite Trip

The Recloser will generate a **Recloser in Internal Lockout Due to Definite Trip** (**LO_DT** output) signal when a trip is produced with the **Recloser Block Command** or in circumstances such that the Recloser Start Element Activated signal (**RCLS**) is not activated. In this case, the recloser changes to the Internal **Lockout Due to Definite Trip (LO_DT)** state.

Although not expressed in the flow diagrams, each time that **Internal Lockout Due to Close Failure** (**LO_BF**), **Recloser Internal Lockout on Closing Failure** (**LO_CLSF**) and **Internal Lockout Due to Synchronism Failure** (**LO_NO_SYNC**) signals are activated, the **LO_DT** (**Internal Lockout Due to Definite Trip**) signal should also be activated.

7.1.12 Recloser Not in Service

When the setting **AJ_SERV** (Recloser ***In Service***) sets to **0** (***Not*** in service), blocking and unblocking command control will not be carried out (logic and control function) nor the reclose control functions.

Recloser is out of operation whenever **Recloser In Service** setting is disabled.

7.1.13 Reclose Counter

A counter, accessed from the screen, indicates the number of reclose operations carried out since the last reset. This action can be made from the HMI, by digital input or communications.

7.1.14 Sequence Coordination

The function of the Sequence Coordination element is to keep the protection coordination between two relays, one upstream the other.

It is important that the overcurrent elements active in the upstream relay are coordinated with the elements of the downstream relay to prevent erroneous trips for faults to be clear by the latter. For this, the Sequence Coordination function is implemented in order for the upstream relay to increase its reclose cycles at the same time than the downstream relay.

The Sequence Coordination element detects overcurrent elements pickups and resets, such that when one of these signals is activated and reset without an intermediate trip, the relay takes it as a reclose cycle of the downstream relay and initiates a virtual reclose cycle. This virtual cycle increments the reclose counter without opening and closing the breaker, so as to change the settings associated to the cycle (trip masks) but keeps the coordination with the downstream relay, preventing in this way erroneous trips as a result of setting changes per each reclose cycle of the downstream relay.

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Once the cycle increment is carried out, the element waits for the **Safety Time** to time out, which must be greater than the sum of the reclose time plus the safety time of the recloser of the downstream relay. If another pickup and reset sequence takes place during this time without intermediate trip, the sequence coordination initiates the next cycle (up to a maximum of 4 cycles) after which the element switches to the **Recloser Lockout due to Definite Trip** status. If this sequence does not take place, the reclose counter switches to 0 and the function goes to the initial state.

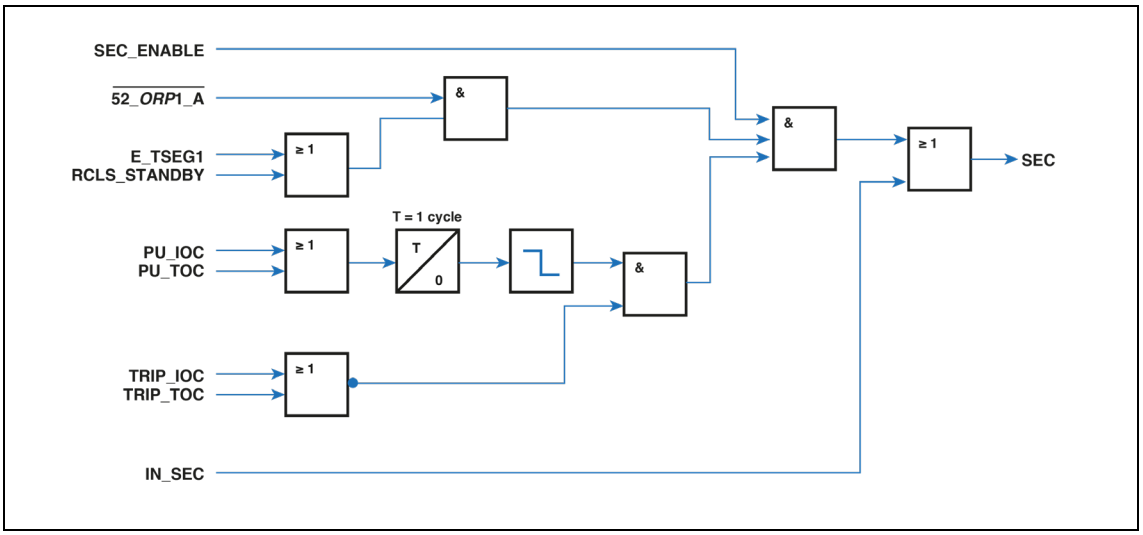


Figure 7.1.18 Sequence Coordination Logic.

LEGEND	
IN_SEC	Sequence Coordination Activation Input
PU_IOC	Pickup OR of all Instantaneous Overcurrent Elements
PU_TOC	Pickup OR of all Time Delayed Overcurrent Elements
TRIP_IOC	Trip OR of all Instantaneous Overcurrent Elements
TRIP_TOC	Trip OR of all Time Delayed Overcurrent Elements
RCLS_STANDBY	Recloser in Standby Mode
E_TSEG1	Recloser in Security Time 1

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7.1.15 Setting Ranges

Recloser						
Communications Program	**HMI**	**IEC 61850**	**IEC 61850***	**Range**	**Step**	**Default**
Recloser Control						
In Service	In Service	RREC1.LNInSvc	RRCF1.LNInSvc	NO / YES		YES
Number of Reclosers in Operation*	Reclosers Number	RREC1.RecNum	RRCF1.RecNum	1/2/Selection by DI		2
Master Recloser*	Master Recloser	RREC1.MrRec	RRCF1.MrRec	1/2/Selection by DI		1
Slave Recloser Permission*	Slave Permission	RREC1. SlvInSvc	RRCF. SlvInSvc	YES / NO		NO
Reclose Timer	Recloser Timers					
1st 1Ph Recl Attempt	1st 1Ph Recl Attempt	RREC.Rec1Tmms1	RRCF.Rec1Tmms1	0.05-600 s	0.01 s	0.5 s
1st 3Ph Recl Attempt	1st 3Ph Recl Attempt	RREC1.Rec3Tmms1	RRCF1.Rec3Tmms1	0.05-600 s	0.01 s	0.5 s
2nd Reclose Attempt	2nd Reclos Attempt	RREC1.Rec3Tmms2	RRCF1.Rec3Tmms2	0.05-600 s	0.01 s	1 s
3rd Recl. Attempt	3rd Recl. Attempt	RREC1.Rec3Tmms3	RRCF1.Rec3Tmms3	0.05-600 s	0.01 s	5 s
4th Recl. Attempt	4th Recl. Attempt	RREC1.Rec3Tmms4	RRCF1.Rec3Tmms4	0.05-600 s	0.01 s	10 s
Phase Reclose 1 Delay	T Phase Reclose 1	RREC1.RecPhTmms1	RRCF1.RecPhTmms1	0.05-600 s	0.01 s	0.5 s
Gnd Reclose 1 Delay	T Gnd Reclose 1	RREC1.RecGnTmms1	RRCF1.RecGnTmms1	0.05-600 s	0.01 s	0.5 s
Phase Reclose 2 Delay	T Phase Reclose 2	RREC1.RecPhTmms2	RRCF1.RecPhTmms2	0.05-600 s	0.01 s	1 s
Gnd Reclose 2 Delay	T Gnd Reclose 2	RREC1.RecGnTmms2	RRCF1.RecGnTmms2	0.05-600 s	0.01 s	1 s
Phase Reclose 3 Delay	T Phase Reclose 3	RREC1.RecPhTmms3	RRCF1.RecPhTmms3	0.05-600 s	0.01 s	5 s
Gnd Reclose 3 Delay	T Gnd Reclose 3	RREC1.RecGnTmms3	RRCF1.RecGnTmms3	0.05-600 s	0.01 s	5 s
Phase Reclose 4 Delay	T Phase Reclose 4	RREC1.RecPhTmms4	RRCF1.RecPhTmms4	0.05-600 s	0.01 s	10 s
Gnd Reclose 4 Delay	T Gnd Reclose 4	RREC1.RecGnTmms4	RRCF1.RecGnTmms4	0.05-600 s	0.01 s	10 s
3P Reclosing Time Dependent on the Type of Fault	3P Rec T Dep Fault	RREC1.FltTypEna	RRCF1.FltTypEna	YES / NO		NO
Syncrocheck Supervision (Breaker 1, Breaker 2)*	Syncrocheck Superv.					
1st Recl. Superv.	1st Recl. Superv.	RREC1.SynSup1	RRECF1.SynSup1	NO / YES		YES
2nd Recl. Superv.	2nd Recl. Superv.	RREC1.SynSup2	RRECF1.SynSup2	NO / YES		YES
3rd Recl. Superv.	3rd Recl. Superv.	RREC1.SynSup3	RREC1.SynSup3	NO / YES		YES
4th Recl. Superv.	4th Recl. Superv.	RREC1.SynSup4	RREC1.SynSup4	NO / YES		YES
1st Recl. Wait Time	1st Recl. Wait Time	RREC1.SynWait1	RREC1.SynWait1	NO / YES		YES
2nd Recl. Wait Time	2nd Recl. Wait Time	RREC1.SynWait2	RREC1.SynWait2	NO / YES		YES

(*) For models with Double Breaker of Breaker-and-a-Half Bay configuration capability.

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Recloser						
Communications Program	**HMI**	**IEC 61850**	**IEC 61850***	**Range**	**Step**	**Default**
3rd Recl. Wait Time	3rd Recl. Wait Time	RREC1.SynWait3	RREC1.SynWait3	NO / YES		YES
4th Recl. Wait Time	4th Recl. Wait Tim	RREC1.SynWait4	RREC1.SynWait4	NO / YES		YES
Positive Sequence Voltage Supervision	V1 Supervision					
Positive Sequence Voltage Level	V1 Level	RREC1. PsSeqVLev	RRCF1. PsSeqVLev	0-200 V		1 V
(Breaker 1, Breaker 2)*						
Positive Sequence Voltage Supervision	V1 Supervision	RREC1.PsSeqVSup	RREC1.PsSeqVSup	YES / NO		NO
Positive Sequence Voltage Supervision Waiting	V1 Sup. Waitinx	RREC1.PsSeqVWait	RREC1.PsSeqVWait	YES / NO		NO
Cycle Control	Sequence Control					
Manual Close by Recloser	MC by Recloser	RREC1.ManClsSup	RRCF1.ManClsSup	YES / NO		NO
External Blocking	External Blocking	RREC1.ExBlkTyp	RRCF1.ExBlkTyp	Level Pulse		Pulse
Reclose Attempts	Reclose Attempts	RREC1.MaxCyc	RRCF1.MaxCyc	1 - 4	1	3
Reclosing Mode	Reclosing Mode	RREC1.RecMod	RRCF. RecMod	1P Mode 3P Mode 1P / 3P Mode Dependent Mode Selection by DI		1P Mode
Sequence Coordination	Sequence coord	RREC1.SeqCrdEna	RRCF1.SeqCrdEna	YES / NO		NO
Type of Opening Supervision	Type opening sup.	RREC1.OpnTypSup	RRCF1.OpnTypSup	YES / NO		YES
Cycle Control Timers	Seq Control Timer					
Start Time	Start Time	RREC1.MaxTmms	RRCF1.MaxTmms	0.05 - 600 s	0.01 s	0.20 s
Security Time	Security Time	RREC1.RcITmms	RRCF1.RcITmms	0.05 - 600 s	0.01 s	10.00 s
Security Time 2*	Security Time 2	RREC2.RcITmms	RRCF2.RcITmms	0.05 - 600 s	0.01 s	10.00 s
MC Reset Time	MC Reset Time	RREC1.ExClsRclTm	RRCF1.ExClsRclTm	0.05 - 600 s	0.01 s	5.00 s
Sync Wait Time	Sync Wait Time	RREC1.SynTmms	RRCF1.SynTmms	0.05 - 600 s	0.01 s	5.00 s
Positive Sequence Voltage Time Delay	V1 Sup. Wait Time	RREC1.PsSeqVTmms	RRCF1.PsSeqVTmms	0.05 - 600 s	0.01 s	5.00 s
Manual Close Delay	Man. Close Delay	RREC1.ManClsTmms	RRCF1.ManClsTmms	0.05 - 600 s	0.01 s	1 s

(*) For models with Double Breaker of Breaker-and-a-Half Bay configuration capability.

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Recloser					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Recloser Enable	Recloser Enable				
Reclose Shot n (n=1, 2, 3, 4)	Reclose Cycle n				
DTT		RREC1.DTTPDIFRcn	YES / NO		NO
87 PHASE	DIFF	RREC1.PDIFRcn	YES / NO		NO
87 INST	INST DIFF	RREC1.NRPDIFRcn	YES / NO		NO
87 GROUND	87 GROUND	RREC1.GNDPDIFRcn	YES / NO		NO
87 POS SEQ	87 POS. SEQ.	RREC1.PSPDIFRcn	YES / NO		NO
87 NEG SEQ	87 NEG. SEQ.	RREC1.NSPDIFRcn	YES / NO		NO
Z1 GROUND	Z1 GROUND		YES / NO		NO
Z1 PHASE	Z1 PHASE		YES / NO		NO
Z2 GROUND	Z2 GROUND		YES / NO		NO
Z2 PHASE	Z2 PHASE		YES / NO		NO
Z3 GROUND	Z3 GROUND		YES / NO		NO
Z3 PHASE	Z3 PHASE		YES / NO		NO
Z4 GROUND	Z4 GROUND		YES / NO		NO
Z4 PHASE	Z4 PHASE		YES / NO		NO
Z5 GROUND	Z5 GROUND		YES / NO		NO
Z5 PHASE	Z5 PHASE		YES / NO		NO
Z6 GROUND	Z6 GROUND		YES / NO		NO
Z6 PHASE	Z6 PHASE		YES / NO		NO
Z7 GROUND	Z7 GROUND		YES / NO		NO
Z7 PHASE	Z7 PHASE		YES / NO		NO
Z8 GROUND	Z8 GROUND		YES / NO		NO
Z8 PHASE	Z8 PHASE		YES / NO		NO
REM OP BRK	REM OP BRK		YES / NO		NO
IOC PH1	IOC PH1	RREC1.PHIOC1Rcn	YES / NO		NO
IOC PH2	IOC PH2	RREC1.PHIOC2Rcn	YES / NO		NO
IOC PH3	IOC PH3	RREC1.PHIOC3Rcn	YES / NO		NO
IOC N1	IOC N1	RREC1.NIOC1Rcn	YES / NO		NO
IOC N2	IOC N2	RREC1.NIOC2Rcn	YES / NO		NO
IOC N3	IOC N3	RREC1.NIOC3Rcn	YES / NO		NO
IOC NEG SEQ1	IOC NEGSEQ1	RREC1.NSIOC1Rcn	YES / NO		NO
IOC NEG SEQ2	IOC NEGSEQ2	RREC1.NSIOC2Rcn	YES / NO		NO
IOC NEG SEQ3	IOC NEGSEQ3	RREC1.NSIOC3Rcn	YES / NO		NO
TOC PH1	TOC PH1	RREC1.PHTOC1Rcn	YES / NO		NO
TOC PH2	TOC PH2	RREC1.PHTOC2Rcn	YES / NO		NO
TOC PH3	TOC PH3	RREC1.PHTOC3Rcn	YES / NO		NO
TOC N1	TOC N1	RREC1.NTOC1Rcn	YES / NO		NO
TOC N2	TOC N2	RREC1.NTOC2Rcn	YES / NO		NO
TOC N3	TOC N3	RREC1.NTOC3Rcn	YES / NO		NO
TOC NEG SEQ1	TOC NEG SEQ1	RREC1.NSTOC1Rcn	YES / NO		NO
TOC NEG SEQ2	TOC NEG SEQ2	RREC1.NSTOC2Rcn	YES / NO		NO
TOC NEG SEQ3	TOC NEG SEQ3	RREC1.NSTOC3Rcn	YES / NO		NO
CHANNEL TRIP	CHANNEL TRIP	RREC1.PSCH1Rcn	YES / NO		NO
3PH_EXT_TRIP	CHANNEL TRIP_D	RREC1.ExProRcn	YES / NO		NO

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Recloser					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
EXT_A_TRIP	TRIP_EXT_A		YES / NO		NO
EXT_B_TRIP	TRIP_EXT_B		YES / NO		NO
EXT_C_TRIP	TRIP_EXT_C		YES / NO		NO
3PH_PR_TRIP	3PH PR TRIP	RREC1.ProgRcn	YES / NO		NO
3PH_PR_TRPFDS	3PH PR TRPFDS	RREC1.FDSProgRcn	YES / NO		NO
IOC GND1	IOC GND1	RREC1.GNDIOC1Rcn	YES / NO		NO
IOC GND2	IOC GND2	RREC1.GNDIOC2Rcn	YES / NO		NO
IOC GND3	IOC GND3	RREC1.GNDIOC3Rcn	YES / NO		NO
TOC GND1	TOC GND1	RREC1.GNDTOC1Rcn	YES / NO		NO
TOC GND2	TOC GND2	RREC1.GNDTOC2Rcn	YES / NO		NO
TOC GND3	TOC GND3	RREC1.GNDTOC3Rcn	YES / NO		NO

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7.1.16 Digital Inputs to the Recloser Module

Table 7.1-1: Digital Inputs to the Recloser Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_EXT_A	Automatons		A pole external trip input		Activation of this input indicates the existence of an A pole trip of the breaker generated by an external protection.
IN_EXT_B			B pole external trip input		Activation of this input indicates the existence of an B pole trip of the breaker generated by an external protection.
IN_EXT_C			C pole external trip input		Activation of this input indicates the existence of an C pole trip of the breaker generated by an external protection.
IN_EXT_3PH			Three-phase external trip input		Activation of this input indicates the existence of a three-phase trip of the breaker generated by an external protection.
IN_EXT			External trip input		Activation of this input indicates the existence of a trip of the breaker generated by an external protection.
INBLK_MAN		RRECx.BlkRec2	Recloser manual block command		An activation pulse of this input sends the recloser to the Block Command state.
IN_UNBLK_MAN		RRECx.RsBlkRec2	Recloser manual unblock command		An activation pulse of this input removes the recloser from the Block Command state (provided that the External Blocking Type setting is not at level and the BE input is active).

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 7.1-1: Digital Inputs to the Recloser Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INBLK_EXT	Automatons	RRECx.BlkRec1	Recloser external block command		An activation pulse of this input sends the recloser to the Block Command state (provided that the External Blocking Type setting is at Pulse).
IN_UNBLK_EXT		RRECx.RsBlkRec1	Recloser external unblock command		An activation pulse of this input removes the recloser from the Block Command state (provided that the External Blocking Type setting is at Pulse).
IN_BLKRCLS		RRECx.BlkRecStr	Reclose Initiate Block Input		Activating said input prevents reclose initiate
IN_1P		RREC1.SPIModIn	1P Mode Input		Together with input IN_3P, it defines the reclose mode, provided Reclose Mode is set to ED Selection.
IN_3P		RREC1.TPModIn	3P Mode Input		Together with input IN_1P, it defines the reclose mode, provided Reclose Mode is set to ED Selection.
RST_NUMREC			Reclose counter reset command		Said input resets the breaker shot counter.
IN_SEC		RRECx.SeqCrdIn	Sequence Coordination Activation input		
IN_GRD_REC		RRECx.RecGTmIn	Ground faults Reclose Time input		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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7.1.17 Auxiliary Outputs and Events of the Recloser Module

Table 7.1-2: Auxiliary Outputs and Events of the Recloser Module

Name	Group	IEC 61850	Description	Vis.	Function
RCLS	Automatons	RRECX.RecStr	Recloser start		Recloser start.
RECLOSING		RRECX.AutoRecSt	Reclose sequence in progress		Reclose sequence in progress.
RCLS_CMD		RRECX.Op	Reclose Command		Reclose command.
RCLS_LO			Recloser Lockout		LO_NO_SYNC + LO_DT + LO_CLSF + LO_COF + LO_BF + LO_3PH + LO_OPEN
LO_NO_SYNC		RRECX.IntnBlkSyn	Recloser Lockout due to Lack of Synchronism		Recloser lockout due to lack of synchronism.
LO_NO_VSD			Recloser lockout due to positive sequence voltage		Recloser lockout due to positive sequence voltage
LO_DT		RRECX.IntnBlkDTr	Recloser Lockout due to Definite Trip		Recloser lockout due to definite trip.
LO_BF		RRECX.IntnBlkBF	Recloser Lockout due to Breaker Close Failure		Recloser lockout due to breaker close failure.
LO_CLSF		RRECX.IntnBlkCls	Recloser Lockout due to Close Failure		Recloser lockout due to close failure.
LO_COF		RRECX.IntnBlkCOF	Recloser Lockout due to Close-onto-a-Fault		Recloser lockout due to close-onto-a-fault.
LO_OPEN		RRECX.IntnBlkOpn	Recloser Lockout due to Open Breaker		Recloser lockout due to open breaker.
LO_3PH			Recloser lockout due to three-phase trip		Recloser lockout due to three-phase trip
LO_CMD		RRECX.RecBlkCmd	Recloser Lockout Command		Recloser lockout command.
SEQ_COOR		RRECX.SeqCrd	Sequence Coordination		
RESET_C_RNG			Recloser Counters Reset		
BLK_CMD			Recloser Block Command		Recloser block command generated through manual or external block command.
UNBLK_CMD			Recloser Unblock Command		Recloser unblock command generated through manual or external block command.
REC_ENBLD		RRECX.Mod	Recloser Enabled		Automatic reclose function enabled or disabled state signal.

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Table 7.1-2: Auxiliary Outputs and Events of the Recloser Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
1P	Automatons	RRECX.Mod1St	1P Mode Active		Active 1P reclose mode signal.
3P		RRECX.Mod3St	3P Mode Active		Active 3P reclose mode signal.
1P/3P		RRECX.Mod13St	1P/3P Mode Active		Active 1P/3P reclose mode signal.
DEP		RRECX.ModDepSt	DEP Mode Active		Active dependent reclose mode signal
REC_STANDBY			Recloser in Standby		Signal states recloser is reset.
REC_START		RRECX.MaxTmSt	Recloser Start		Indication that the recloser is in start time.
REC_T1_3PH_G		RRECX.RecGnTmSt1	Recloser in Three Phase Reclose Cycle 1 with Ground Fault		Indication that the recloser is in reclosing time (first cycle).
REC_T1_3PH_P		RRECX.RecPhTmSt1	Recloser in Three Phase Reclose Cycle 1 with Fault between Phases		Indication that the recloser is in reclosing time (first cycle).
REC_T2_G		RRECX.RecGnTmSt2	Recloser in Three Phase Reclose Cycle 2 with Ground Fault		Indication that the recloser is in reclosing time (second cycle).
REC_T2_P		RRECX.RecPhTmSt2	Recloser in Three Phase Reclose Cycle 2 with Fault between Phases		Indication that the recloser is in reclosing time (second cycle).
REC_T3_G		RRECX.RecGnTmSt3	Recloser in Three Phase Reclose Cycle 3 with Ground Fault		Indication that the recloser is in reclosing time (third cycle).
REC_T3_P		RRECX.RecPhTmSt3	Recloser in Three Phase Reclose Cycle 3 with Fault between Phases		Indication that the recloser is in reclosing time (third cycle).
REC_T4_G		RRECX.RecGnTmSt4	Recloser in Three Phase Reclose Cycle 4 with Ground Fault		Indication that the recloser is in reclosing time (fourth cycle).
REC_T4_P		RRECX.RecPhTmSt4	Recloser in Three Phase Reclose Cycle 4 with Fault between Phases		Indication that the recloser is in reclosing time (fourth cycle).
REC_T1_3PH		RRECX.RecTmSt1	Recloser in Reclose Cycle 1 Time		Indication that the recloser is in reclosing time (first cycle).

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Table 7.1-2: Auxiliary Outputs and Events of the Recloser Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
REC_T2	Automatons	RRECX.RecTmSt2	Recloser in Reclose Cycle 2 Time		Indication that the recloser is in reclosing time (second cycle).
REC_T3		RRECX.RecTmSt3	Recloser in Reclose Cycle 3 Time		Indication that the recloser is in reclosing time (third cycle).
REC_T4		RRECX.RecTmSt4	Recloser in Reclose Cycle 4 Time		Indication that the recloser is in reclosing time (fourth cycle).
REC_TSEC1		RRECX.RclTmSt1	Recloser in Security Time after Cycle 1		Indication that the recloser is in security time after the first reclosing cycle.
REC_TSEC2		RRECX.RclTmSt2	Recloser in Security Time after Cycle 2		Indication that the recloser is in security time after the second reclosing cycle.
REC_TSEC3		RRECX.RclTmSt3	Recloser in Security Time after Cycle 3		Indication that the recloser is in security time after the third reclosing cycle.
REC_TSEC4		RRECX.RclTmSt4	Recloser in Security Time after Cycle 4		Indication that the recloser is in security time after the fourth reclosing cycle.
REC_TSEC_MC		RRECX.ExClsTmSt1	Recloser in Security Time after Manual Close.		Indication that the recloser is in security time after manual closing.
REC_TMC		RRECX.ManClsTmSt	Recloser in Manual Close Time		Indication that the recloser is in manual closing time.
REC_TSEC_MC79		RRECX.ExClsTmSt2	Recloser in Security Time after Manual Close by Recloser		Indication that the recloser is in security time after manual closing through the recloser.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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7.1.18 IEC 61850 Logical Node

CLASS IRLRREC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
OpCntRs	INC	Resettable Operation Counter
Controls		
BlkRec1	SPC	External block
BlkRec2	SPC	Manual block
Status information		
Auto	SPS	Automatic operation
Op	ACT	Operate
Extended Data		
SeqCrdIn	EXT_SPS	Sequence coordination activation input
BlkRecStr	EXT_SPC	Recloser start block input
RecStr	EXT_ACT	Recloser start
IntnBlkCOF	EXT_SPS	Internal block due to COF
IntnBlkDTr	EXT_SPS	Internal block due to definitive trip
IntnBlkCls	EXT_SPS	Internal block due to closing failure
IntnBlkBF	EXT_SPS	Internal block due to failure at the beginning
IntnBlkOpn	EXT_SPS	Internal block due to breaker in open status
IntnBlkSyn	EXT_SPS	Internal block due to lack of synchrocheck
IntnBlkTr	EXT_SPS	Internal block due to three phase trip
RecBlkCmd	EXT_SPS	Internal block due to command
AutoRecSt	EXT_ENS	Recloser in progress
IntnBlk	EXT_SPS	Block by any reason
RecGTmIn	EXT_SPS	Ground faults reclose time input
RsBlkRec1	EXT_SPC	External unblock command
RsBlkRec2	EXT_SPC	Manual unblock command
RecTmSt1	EXT_SPS	Recloser in three phase cycle time 1
RecGnTmSt1	EXT_SPS	Recloser in three phase cycle time 1 with ground fault
RecPhTmSt1	EXT_SPS	Recloser in three phase cycle time 1 with phase fault
ManClsTmSt	EXT_SPS	Recloser in manual close time
RecTmSt2	EXT_SPS	Recloser in cycle time 2
RecPhTmSt2	EXT_SPS	Recloser in cycle time 2 with phase fault
RecGnTmSt2	EXT_SPS	Recloser in cycle time 2 with ground fault
RecTmSt3	EXT_SPS	Recloser in cycle time 3
RecPhTmS3	EXT_SPS	Recloser in cycle time 3 with phase fault
RecGnTmSt3	EXT_SPS	Recloser in cycle time 3 with ground fault
RecTmS4	EXT_SPS	Recloser in cycle time 4
RecPhTmSt4	EXT_SPS	Recloser in cycle time 4 with phase fault
RecGnTmSt4	EXT_SPS	Recloser in cycle time 4 with ground fault
ExClsTmSt1	EXT_SPS	Recloser in security time after manual closing
ExClsTmSt2	EXT_SPS	Recloser in security time after manual closing through recloser

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Extended Data (Cont.)		
RclTmSt1	EXT_SPS	Recloser in security time after cycle 1
RclTmSt2	EXT_SPS	Recloser in security time after cycle 2
RclTmSt3	EXT_SPS	Recloser in security time after cycle 3
RclTmSt4	EXT_SPS	Recloser in security time after cycle 4
ExClsTmSt	EXT_SPS	Recloser in manual closing time
MaxTmSt	EXT_SPS	Recloser in start time
SeqCrd	EXT_SPS	Sequence coordination
ExTPTrIn	EXT_SPS	External three phase trip
RecCyc	EXT_INS	Recloser cycle magnitude
LNInSvc	EXT_SPG	In service
RecTmms1	EXT_ING	Three phase reclose time
RecTmms2	EXT_ING	Second reclose time
RecTmms3	EXT_ING	Third reclose time
RecTmms4	EXT_ING	Fourth reclose time
RecPhTmms1	EXT_ING	Phase reclose 1 delay time
RecGnTmms1	EXT_ING	Ground reclose 1 delay time
RecPhTmms2	EXT_ING	Phase reclose 2 delay time
RecGnTmms2	EXT_ING	Ground reclose 2 delay time
RecPhTmms3	EXT_ING	Phase reclose 3 delay time
RecGnTmms3	EXT_ING	Ground reclose 3 delay time
RecPhTmms4	EXT_ING	Phase reclose 4 delay time
RecGnTmms4	EXT_ING	Ground reclose 4 delay time
FltTypEna	EXT_SPG	Three phase reclosing time depending on the fault type
SynSup1	EXT_SPG	Reclose 1 synchrocheck supervision
SynSup2	EXT_SPG	Reclose 2 synchrocheck supervision
SynSup3	EXT_SPG	Reclose 3 synchrocheck supervision
SynSup4	EXT_SPG	Reclose 4 synchrocheck supervision
SynWait1	EXT_SPG	Reclose 1 synchrocheck wait time
SynWait2	EXT_SPG	Reclose 2 synchrocheck wait time
SynWait3	EXT_SPG	Reclose 3 synchrocheck wait time
SynWait4	EXT_SPG	Reclose 4 synchrocheck wait time
ManClsSup	EXT_SPG	Manual close supervised by recloser
ExBlkTyp	EXT_ENG	External blocking by pulse or level
MaxCyc	EXT_INGv	Reclose number of attempts
SeqCrdEna	EXT_SPG	Sequence coordination
OpnTypSup	EXT_SPG	Type of opening supervision
MaxTmms	EXT_ING	Start time
RclTmms	EXT_ING	Security time
ExClsRclTm	EXT_ING	MC reset time
SynTmms	EXT_ING	Synchrocheck wait time
ManClsTmms	EXT_ING	Manual close delay

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Extended Data (Cont.)		
PHIOC1RcY	EXT_SPG	Recloser enable mask
PHIOC2RcY	EXT_SPG	Recloser enable mask
PHIOC3RcY	EXT_SPG	Recloser enable mask
NIOC1RcY	EXT_SPG	Recloser enable mask
NIOC2RcY	EXT_SPG	Recloser enable mask
NIOC3RcY	EXT_SPG	Recloser enable mask
NSIOC1RcY	EXT_SPG	Recloser enable mask
NSIOC2RcY	EXT_SPG	Recloser enable mask
NSIOC3RcY	EXT_SPG	Recloser enable mask
PHTOC1RcY	EXT_SPG	Recloser enable mask
PHTOC2RcY	EXT_SPG	Recloser enable mask
PHTOC3RcY	EXT_SPG	Recloser enable mask
NTOC1RcY	EXT_SPG	Recloser enable mask
NTOC2RcY	EXT_SPG	Recloser enable mask
NTOC3RcY	EXT_SPG	Recloser enable mask
NSTOC1RcY	EXT_SPG	Recloser enable mask
NSTOC2RcY	EXT_SPG	Recloser enable mask
NSTOC3RcY	EXT_SPG	Recloser enable mask
PVOC1RcY	EXT_SPG	Recloser enable mask
CRVVOC1RcY	EXT_SPG	Recloser enable mask
SGIOC1RcY	EXT_SPG	Recloser enable mask
SGTOC1RcY	EXT_SPG	Recloser enable mask
ESGTOC1RcY	EXT_SPG	Recloser enable mask
PSDE1RcY	EXT_SPG	Recloser enable mask
PSCH1RcY	EXT_SPG	Recloser enable mask
ExProRcY	EXT_SPG	Recloser enable mask
ProgRcY	EXT_SPG	Recloser enable mask
FDSProgRcY	EXT_SPG	Recloser enable mask
GNDIOC1RcY	EXT_SPG	Recloser enable mask
GNDIOC2RcY	EXT_SPG	Recloser enable mask
GNDIOC3RcY	EXT_SPG	Recloser enable mask
GNDTOC1RcY	EXT_SPG	Recloser enable mask
GNDTOC2RcY	EXT_SPG	Recloser enable mask
GNDTOC3RcY	EXT_SPG	Recloser enable mask

Y: from 1 to 4, one setting per cycle/shot.

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Chapter 8.

Supervision & Control

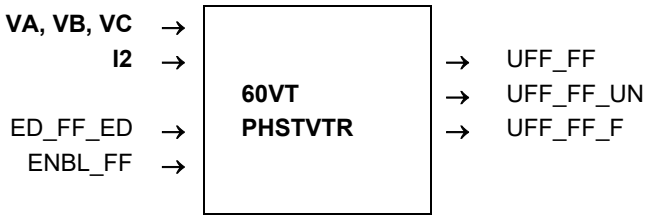
8.1 VT Fuse Failure Detector

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8.1.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
VT Fuse Failure Detector	PHSTVTR1	FUSEF	60VT

8.1.2 General Block



8.1.3 Operation Principles and Block Diagram

If the VT secondary circuit fuses blow, the terminal unit will lose the corresponding voltage analog input. This situation may cause unwanted operation of the Voltage Elements. Therefore, this condition must be detected and the measuring elements must be blocked before undesired tripping occurs. This unit will therefore complement the Voltage Measurement Circuit Supervision unit.

The fuse failure condition is detected when one of the three phase voltages drops below of the ***Voltage Level*** setting value). On not involving this phenomenon at the currents, there will not be a fault detection, for which the output of this detector (**FD**) is used as discriminator.

The opening of any pole of the breaker will generate a fuse failure condition if the voltage transformer is on the line side, for which the output of **Any Open Pole** (**OR_P_OP**) originating from the **Open Pole Detector** blocks the activation of the Fuse Failure Detector.

On the other hand, the Fuse Failure Detector is disabled if the value of the positive sequence current is below 0.05*In A.

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VT Fuse Failure Detection operation is shown in Figure 8.1.1.

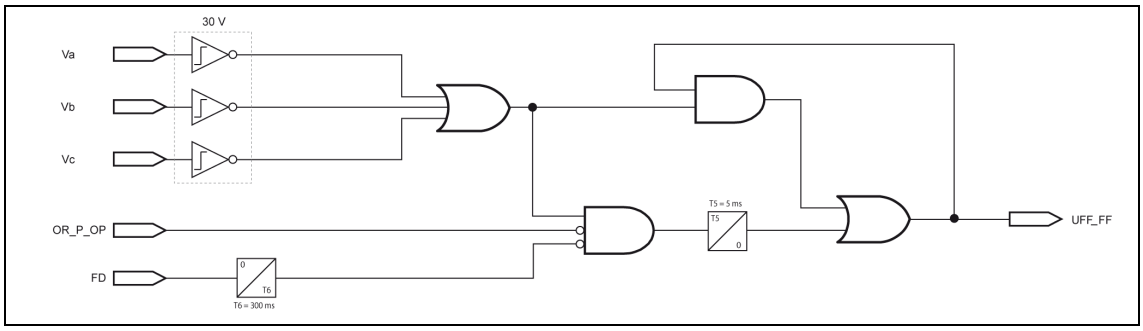


Figure 8.1.1 VT Fuse Failure Detector Block Diagram.

Legend	
OR_P_OP: Any Open Pole.	UFF_FF: Fuse Failure Activation
FD: Fault Detector.	

Undervoltage detectors pick up when this voltage is lower than the **Voltage Level** setting value and reset when it is greater than 100% of said voltage. The output of said initial logic (**UFF_FF**) is the **Fuse Failure Unit Activation** signal.

The output of the Fuse Failure unit will generate **Fuse Failure Detector Block** (**UFF_FF_UN**) output if ***FF Block Enable*** is set at **YES**. This last output will always block, if configured in the control logic, the activation of other units based on the voltage measurement, such as Undervoltage Units, Weak Infeed logic or Synchronism Unit, if the corresponding blocking settings are enabled. This **Fuse Failure Detector Block** (**UFF_FF_UN**) signal is taken into account together with the **Fuse Failure** (**ED_FF_ED**) protection input signal to generate the final output signal **Fuse Failure Blocking** (**UFF_FF_F**).

In order to block these voltage-based elements, both **Fuse Failure Detector Block** output signal (taking into account the above setting) and the previous **Fuse Failure Unit Activation** signal or directly the final signal, **Fuse Failure Blocking**, which will also take into account the enable setting, can be used.

The **Fuse Failure** (**ED_FF_ED**) digital input, originating from the contact position of a voltage thermalmagnetic circuit breaker, is another possibility which exists to detect the fuse failure condition. The activation of this input will always generate **Fuse Failure Blocking** output, originating from the enable and/or blocking adjustments of the Fuse Failure unit. The activation of the **Fuse Failure** digital input presents a fall time adjustment (***FF Input DropOut Time***), in order to maintain the blocking of the units on which acting during the voltage reset transient.

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The logic scheme encompasses the two possibilities of blocking due to fuse failure:

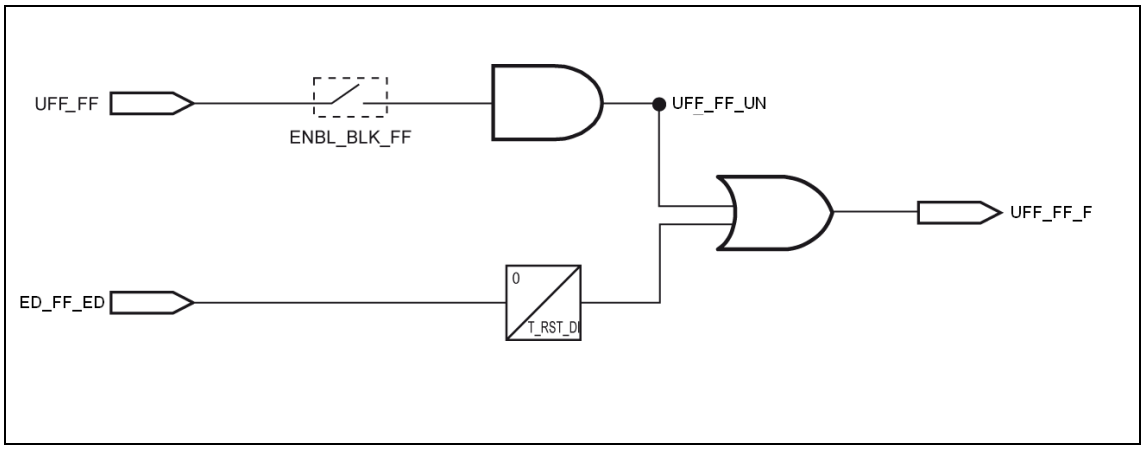


Figure 8.1.2 Logic Diagram of Blocking due to Fuse Failure.

Legend	
UFF_FF: Fuse Failure Unit Activation.	ENBL_BLK_FF: Fuse Failure Blocking Enable (setting)
ED_FF_ED: Fuse Failure Input	
UFF_FF_UN: Fuse Failure Detector Block.	T_RST_DI: Fuse Failure Digital Input Reset Time (Fuse Failure Input DropOut Time setting).
UFF_FF_F: Fuse Failure Blocking	

When a fuse failure condition arises, the directional units, supervisors of the overcurrent elements without **Torque Control** setting at **NO**, they do not have the necessary voltage to be polarized, for which they cannot act if there is a failure in this situation. In order to have an emergency non-directional overcurrent element, provided one does not already exist, the directional units present the ***Blocking due to Lack of Polarization*** setting. If this adjustment is set at **NO**, when the necessary voltage to polarize these is not available, they go on to issue actuation permission to the overcurrent units on which they depend, consequently converting these into non-directional.

In any case, as described above, element output signals can be used to block the desired elements internally or by control logic. As an example, the following logic performed through the configuration program ***ZIV e-NET tool***® could be carried out.

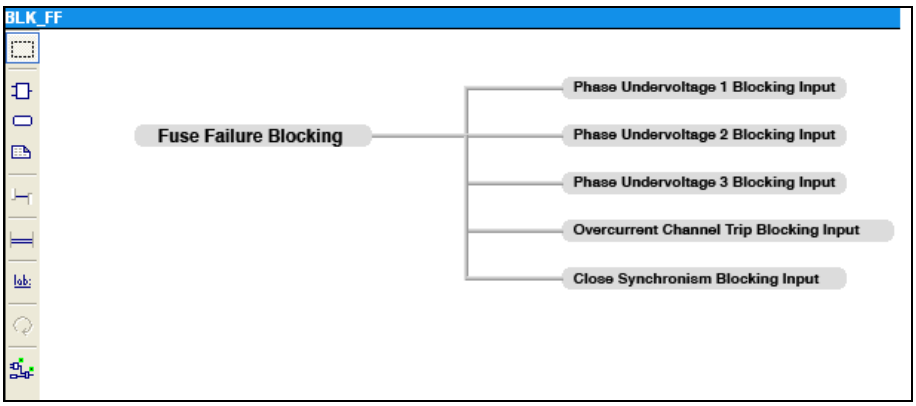


Figure 8.1.3 Example of Element Blocking Logic as a Function of the Fuse Failure Element.

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8.1.4 Setting Ranges

Protection / Fuse Failure					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
FF Detec Enable	FF Det Enable	PHSTVTR1.FuFailSvc	YES / NO		NO
FF Input DropOut Time	FF Input DO Dly	PHSTVTR1.FuInRsTmms	0-1000ms	50 ms	150 ms
FF Block Enable	FF Block Enable	PHSTVTR1.FuFailBlkE	YES / NO		NO
Voltage Level	Voltage Level	PHSTVTR1.FuFailMinV	5-70 V	0.01 V	30 V

8.1.5 Analog Inputs to the Unit

Table 8.1-1: Analog Inputs to the Fuse Failure Module		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
I2	Negative Sequence Current	MSQI1.SeqA.c2

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

8.1.6 Digital Inputs to the Fuse Failure Module

Table 8.1-2: Digital Inputs to the Fuse Failure Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_FF	Enabling Commands	PHSTVTR1.Mod	Fuse Failure Detector Enable Input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ED_FF_ED	Logic Inputs to Protection	PHSTVTR1.FuFailIn	Fuse Failure Detector Input	I	The activation of this input directly generates the blocking output due to fuse failure.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.1.7 Auxiliary Outputs and Events of the Fuse Failure Module

Table 8.1-3: Auxiliary Outputs and Events of the Fuse Failure Module

Name	Group	IEC 61850	Description	Vis.	Function
UFF_FF	Generic Outputs of Protection	PHSTVTR1.FuFail	Fuse Failure Detector Activation	I	Output of the Fuse Failure detector.
UFF_FF_UN		-	Fuse Failure Detector Block	I	Blocking output due to fuse failure condition detected by the unit itself taking into account the FF Block Enable setting.
UFF_FF_F		PHSTVTR1.FuFailBlk	Fuse Failure Blocking	I	Blocking output due to fuse failure condition. It takes into account the Fuse failure Detector Block and the Fuse Failure Detector Input.
FF_ENBLD	Enabled Units Protection Outputs	PHSTVTR1.Mod	Fuse Failure Detector Enabled	I	Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.1.8 IEC 61850 Logical Node

CLASS IRLPHSTVTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
Vol	SAV	Voltage
Status information		
FuFail	ACD	TVTR fuse failure
Settings		
VRtg	ASG	Rated Voltage
Rat	ASG	Winding ratio of external voltage transformer
Extended Data		
SupEna	EXT_SPC	TVTR supervision enable command
SupBlk	EXT_SPC	TVTR supervision block command
SupFailIn	EXT_SPS	Supervision failure input
SupFail	EXT_SPS	Supervision failure signal
SupSvc	EXT_SPG	Supervision in service
SupTmms	EXT_ING	Supervision delay time
SupMinA	EXT_ASG	Supervision minimum current
SupMinV	EXT_ASG	Supervision minimum voltage
FuFailIn	EXT_SPS	Fuse failure input
FuFailBlk	EXT_SPS	Fuse failure block
FuFailSvc	EXT_SPG	Fuse failure in service
FuFailBlkE	EXT_SPG	Enable fuse failure block
FuInRsTmms	EXT_ING	Fuse failure delay time
FuFailMinV	EXT_ASG	Fuse failure minimum operating voltage

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8.1.9 VT Fuse Failure Detector Test

Enable the Fuse Failure Detector and the Fuse Failure Detector Block. Disable all of the other Auxiliary Units. The setting ***Voltage Level*** will take the default value (30 V).

Table 8.1-4: Outputs Configuration for the Fuse Failure Detector Test	
SLOT B SD1	Fuse Failure Detector Activation
SLOT B SD2	Fuse Failure Detector Block

During the test, consult the indicators:

Display In the **Information** - **Status** - **Measuring Elements** - **VT Fuse Failure Detector** screen,

ZIV e-NET tool®. In the **Status** screen (**Status** - **Elements**- **VT Fuse Failure Detector**).

For this test, apply a three-phase balanced system of voltages and current of 65 Vac with angles of 0º, 120º and 240º; and 1 A ac with inductive angles of 25º, 145º and 265º, respectively for phases A, B and C. The current will reflect a shift phase with respect to the voltage of 25º inductive.

Simultaneously reduce the voltages of the three-phases to 28.5 Vac (27.64 Vac to 29.35 Vac). The contacts of the outputs AUX-5 and AUX-6 should close and the indicators mentioned previously should activate.

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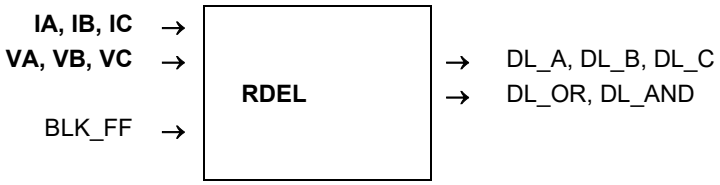
8.2 Dead Line Detector

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8.2.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Dead Line Detector	RDEL1		

8.2.2 General Block



8.2.3 Operation Principles and Block Diagram

The devices incorporate a Dead Line detection element to detect de-energized line condition with no need for supervising any physical digital input. This is based on the operation of one undercurrent and one undervoltage elements the pickup values of which are given by the ***Current Level*** and ***Voltage Level*** settings respectively. Said elements activate at 95% of the pickup setting and reset at 100% of said setting.

The Dead Line Detector can be applied only when the voltage transformer is on the line side, in order for it to activate with no need for digital inputs, when both manual reset and reclose are operated externally to the relay.

The Dead Line Detector will be blocked when the **Fuse Fail Block** signal (**BLK_FF**) activates, given the lack of reliability of undervoltage detectors on fuse failure conditions. Figure 8.2.1 shows the operation of this element.

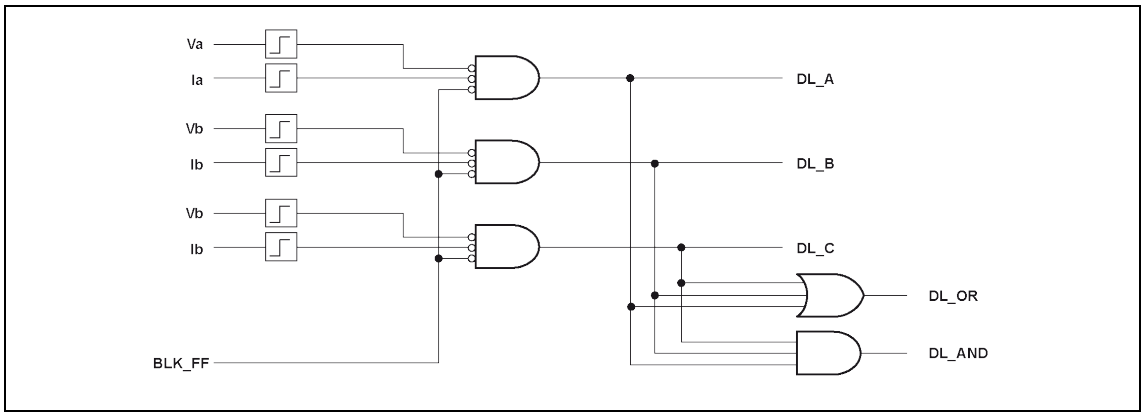


Figure 8.2.1 Logic Diagram of the Dead Line Detector.

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Legend	
BLK_FF: Fuse Failure Blocking.	DL_OR: Any Phase Dead
DL_X: Phase X Dead	DL_AND: Three Phase Dead

8.2.4 Setting Ranges

Protection / Dead Line Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
DL Detec Enable	DL Detec Enable	RDEL1.LNInSvc	YES / NO		NO
Current Level	Current Level	RDEL1.StrValA	0.04 - 4 A	0.01 A	0.04 A
Voltage Level	Voltage Level	RDEL1.StrValV	2 - 70 V	0.01 V	45 V

8.2.5 Analog Inputs to the Unit

Table 8.2-1: Analog Inputs to the Overcurrent Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

8.2.6 Digital Inputs to the Dead Line Detector Module

Table 8.2-2: Digital Inputs to the Dead Line Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_DL	Enabling Commands	RDEL1.Mod	Dead Line Detector Enable Input	I	Its activation sets the element into operation. It can be assigned to a level digital input or communications protocol or HMI command. Default value of this logic input is "1".

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.2.7 Auxiliary Outputs and Events of the Dead Line Detector Module

Table 8.2-3: Auxiliary Outputs and Events of the Dead Line Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
DL_A	Generic Outputs of Protection	RDEL1.Op	Phase A Dead	I	Indication of phase A deenergized.
DL_B		RDEL1.Op	Phase B Dead	I	Indication of phase B deenergized.
DL_C		RDEL1.Op	Phase C Dead	I	Indication of phase C deenergized.
DL_OR		RDEL1.Op	Aby Phase Dead	I	Indication of any phase deenergized.
DL_AND		RDEL1.Op3Ph	Three Dead Phases	I	Indications of three-phases deenergized.
DL_ENBLD	Enabled Units Protection Outputs	RDEL1.Mod	Dead Line Detector Enabled	I	Indication of element enabled or disabled state.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.2.8 IEC 61850 Logical Node

CLASS IRLRDEL		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status		
Op	ACT	Operation
Op3Ph	ACT	3 phase operation (and of 3 phases)
Settings		
LnInSvc	SPG	In service
StrValA	ASG	Current threshold
StrValV	ASB	Voltage threshold

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8.3 Remote Open Breaker Detector

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8.3.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Remote Breaker Open detector			

8.3.2 General Block



8.3.3 Operation Principles and Block Diagram

The IEDs are provided with a Remote Open Breaker Detector, which generates a signal to instantaneously open the local breaker when the Zone 2 element activates and the remote-end three-phase breaker opens. Under these conditions, the trip is instantaneous, since the fault is located inside the line (Zone 2 elements adjusted over 100% of the length of the protected line).

Detector operation is blocked under the following conditions:

1. The fault is detected by the Zone 1 element at the local end; therefore, tripping is instantaneous.
2. The trip signal is activated. If this signal is activated before the detector output signal becomes activated, the trip signal will initiate tripping the breaker.
3. A three-phase fault occurs, since it is not possible to see beyond the fault.

If the circumstances described do not arise and it is detected that the remote breaker is open, the operation of the detector will only be permitted when zone 2 is activated without the activation of zone 1. Given that in a failure in zone 1, zone 2 will also be activated (even before zone 1 itself); a timeout is applied to the pickup signal of zone 2.

The Remote Breaker Open Detector is based on if there is a three-phase aperture at the remote end during a non-three-phase fault, the current through any of the phases (one if the fault is two phase and two if single phase) will be very small (capacitive current), while in the remaining phase(s) it will continue to detect the fault in zone 2. For this, the unit has an undercurrent unit whose level is given by the ***Minimum Current Level*** setting.

In case of long lines, the current which circulates through the phases without fault once the remote end is open may be higher than the ***Minimum Current Level*** setting, due to the ground capacities. For this reason, it is also possible to detect the aperture of the remote breaker through the presence of capacitive current if the ***Det by Cap Current*** (**D_CAP_CUR**) adjustment is set at **YES**.

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8.3.4 Capacitive Current Detectors

There are three capacitive current detectors, one per phase. Each one activates when the phase current leads the phase voltage by $90º \pm \delta_DIRA$ (under ideal conditions, pure capacitive current leads phase voltage by 90º). The following table shows capacitive current detector operation and polarization phasors, as well as the applied operation criteria.

Table 8.3-1: Capacitive Current Detection			
Phase	**Fop**	**Fpol**	**Criteria**
A	Ia	Va	$90º - \delta_DIRA \le \left[arg(Fop) - arg(Fpol)\right] \le 90º + \delta_DIRA$
B	Ib	Vb	
C	Ic	Vc	

Where:

Ia, Ib, Ic	Phase currents
Va, Vb, Vc	Phase voltages
δ_DIRA	Capacitive current drift angle (15º)

The block diagram shows the operation of the Remote Open Breaker Detector logic.

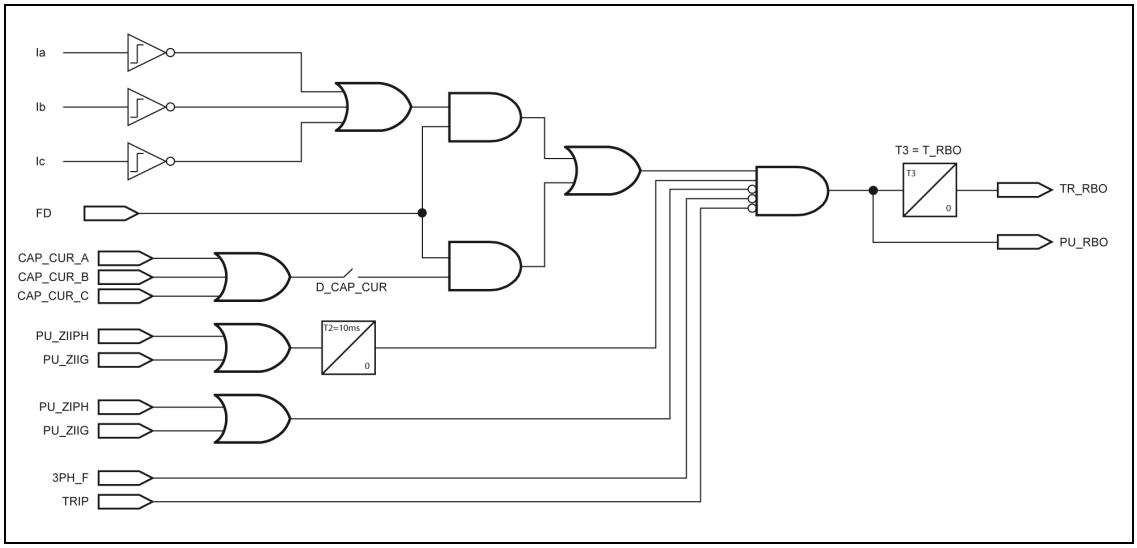


Figure 8.3.1 Remote Open Breaker Detector Block Diagram.

Legend	
CAP_CUR_X: Phase X Capacitive Current Detection Unit Activation.	PU_RBO: Remote Breaker Open Detector Pickup.
	FD: Fault Detector Activated.
PU_ZnX: Zone n Phase / Ground unit Pickup.	D_CAP_CUR: Capacitive Current Detection (setting).
3PH_F: ABC Fault.	
TRIP: Trip	T_RBO: Remote Open Breaker Detector Delay (setting)
TR_RBO: Remote Breaker Open Detector Trip.	

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8.3.5 Setting Ranges

Protection / Remote Open Breaker Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable Remote Open Breaker Detector	`Rem Brk Op Det Ena`		YES / NO		NO
Remote Open Breaker Detector Delay	`Rem Open Brk Time`		0.00-2000 ms	5 ms	0 ms
Detection by Capacitive Current	`Det. By cap. Current`		YES / NO		NO
Minimum Current Level	`Min. Curr. Level`		(0-1) In A	0.01 A	0.15 In

8.3.6 Analog Inputs to the Unit

Table 8.3-2: Analog Inputs to the Remote Open Breaker Detector Module		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
Va	Phase A Voltage	MMXU1.PhV.phsA
Vb	Phase B Voltage	MMXU1.PhV.phsB
Vc	Phase C Voltage	MMXU1.PhV.phsC

8.3.7 Digital Inputs to the Remote Open Breaker Detector Module

Table 8.3-3: Digital Inputs to the Remote Open Breaker Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_RBO	Enabling Commands	RDEL1.Mod	Remote Breaker Open Detector Enable Input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.3.8 Auxiliary Outputs and Events of the Remote Open Breaker Detector Module

Table 8.3-4: Auxiliary Outputs and Events of the Remote Open Breaker Detector Module

Name	Group	IEC 61850	Description	Vis.	Function
PU_RBO	Pickup protection outputs		Remote breaker open detector pickup	I	Pickup of the unit.
TR_RBO	Trip protection outputs		Remote breaker open detector trip	I	Trip of the unit.
RBO_ENBLD	Enabled units protection outputs		Remote breaker open detector enabled	I	Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.3.9 Remote Breaker Open Detector Test

Prepare the system to measure the time between the application of the current and the close of any of the trip contacts. The Remote Breaker Open Detector should be enabled, and the remaining Auxiliary Units should be disabled. During the test, consult the following indicators:

Display	In the **Information** – **Status** – **Measuring Elements** – **Remote Breaker Open Detector** screen,
ZIVercomPlus®	In the status screen (**Status** - **Elements**- **Remote Breaker Open Detector**).

Introduce a fault in Zone 2, which won't be tripped by the distance elements. For this test, apply a three-phase balanced system of voltages set at 12 Vac with inductive angles of 0º, 120º and 240º in phases A, B and C, respectively.

Apply a current of 5 A ac with phase A at 50º, and simultaneously apply 1 A ac at 170º and 290º for phases B and C, respectively.

Remove the current to phases B and C (or lower the value below the ***Min. Cur. Level*** setting). The state of the metering element indicator should activate and the equipment should trip. The last trip indicator in the display, as well as in the ***ZIVercomPlus***®, program, should show a fault AG with a trip by Remote Breaker Open Detector (RA). The measured time should be less than 45 ms.

The test should be repeated with an adjusted time of 2000 ms. The measured time should then be between 1900 ms and 2100 ms.

The timing will again be adjusted to 0 s and the ***Det by Cap Current*** setting enabled. The fault in zone 2 of the previous test will be introduced and the intensity angle of phase B or C modified, in order that this takes a capacitive value (between 75º and 105º) with respect to the voltage of the same phase.

As in the previous case, the last trip indicator in the display, as well as in the ***ZIVercomPlus***® program, should show a fault AG with a trip by Remote Breaker Open Detector (**RBO**). The measured time should be less than 45 ms.

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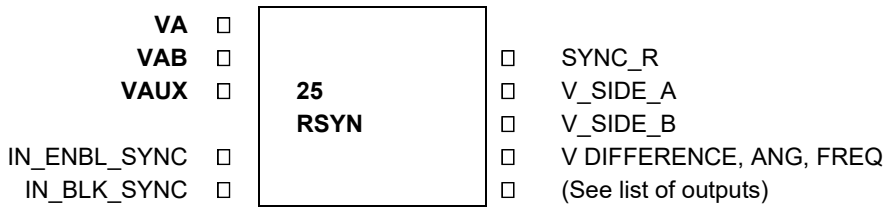
8.4 Synchronism Unit

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8.4.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Synchronism Unit	RSYN1	SYNC	25

8.4.2 General Block



8.4.3 Operation Principles and Block Diagram

The IEDs incorporate two synchronism check units per breaker (depending on the model) the function of which is to check whether the conditions at both ends of the supervised breaker are suitable to closing it (either by reclose or manual reset) and that there will be no oscillations. Recloser verifies the output of Unit 1.

Each Synchronism Unit consists of four elements each of which has Permission or **Enable** setting:

- Sides A and B Voltage Elements.
- Voltage Difference Elements.
- Phase Difference Elements.
- Frequency Difference Elements.

The functioning of the Synchronism unit is based, on one hand, on comparing the module, phase and/or frequency of the voltages on **Side A** (**VA Channel Meter**) and **Side B** (**VSinc, Synchronous Channel Meter**) to check if the two voltages are the same. On the other hand, the element can detect synchronism according to the energization on both sides of the breaker, that is, in terms of the possible combinations of presence/absence of voltage on sides A and B.

When the synchrocheck of a single breaker has to be checked, the IED will use the side A voltage and different side B voltages (VSYNC1, VSYNC2 or VSYNC3) depending on the busbar configuration.

When the synchrocheck of two breakers associated to the same breaker and a half or double bay position has to be checked, the IED will use:

- Side A (line): the selected voltage (by setting: VA, VB, VC). Side A can be the selected phase voltage or VSYNC1 depending on the configuration of the disconnectors. If side A voltage is VSYNC1, there will be no angular and module compensation as it is considered that all the synchrocheck inputs (VSYNC1, VSYNC2 and VSYNC3) have the same wiring.

- Side B: VSYNC1, VSYNC2 and VSYNC3 depending on the single/double configuration and the status of the line disconnectors. By setting: VA, VB, VC, VAB, VBC, VCA. Same setting for the 3 VSYNC analogue inputs as it has been explained before.

In the following table, all the different combinations are defined. When VSYNC1 is the side A voltage, it takes in account all the settings of the side A (voltage detection levels, etc.):

89B1_NC	89B2_NC	VX (A SIDE)	VSINC1	VSINC2	VSINC3	Single Breaker Configuration	
Not used	Not used	√	√	Not used	Not used	Single busbar	CB1
0	0	√	√	Not used	Not used	Double busbar	
0	1	√	√	Not used	Not used		
1	0	√	Not used	√	Not used		
1	1	√	√	Not used	Not used		
89L1_NC	**89L2_NC**	**VX (A SIDE)**	**VSINC1**	**VSINC2**	**VSINC3**	**Breaker and a half Configuration**	
0	0	√	√	Not used	Not used	52_1 (lateral) 89L1 and 89L2 independents	CB1
0	1	√	√	Not used	Not used		
1	0	Not used	√	Not used	√		
1	1	Not used	√	√	Not used		
0	Not used	√	√	Not used	Not used	52_1 (lateral) 89L1 and 89L2 commuted.	
1	Not used	Not used	√	√	Not used		
0	0	√	Not used	Not used	√	52_2 (central) 89L1 and 89L2 independents	CB2
0	1	√	Not used	√	Not used		
1	0	Not used	√	Not used	√		
1	1	Not used	√	√	Not used		
0	Not used (*)	√	Not used	√	Not used	52_2 (central) 89L1 y 89L2 commuted.	
1	Not used (*)	Not used	√	√	Not used		

Note (*): Voltage wired externally as per 89L2.

The setting ***DI Supervision for VSYNC Selection*** has the following options:

- 89L: Breaker and a half configuration. The synchrocheck unit will use the corresponding voltage input depending on the status of the 89L inputs.
- 89B: Double busbar with single breaker. The synchrocheck unit will use the corresponding voltage input depending on the status of the 89B inputs.
- No. Single busbar or double busbar with double breaker. Breaker 1 synchrocheck unit will use VSYNC1 and breaker 2 synchrocheck unit will use VSYNC2.

In single breaker positions with single or double busbar:

- 89B1_NC: Busbar 1 Isolator opened (*).
- 89B2_NC: Busbar 2 Isolator opened.
- VX (A side): Selected voltage of side A.
- VSINC1: Side B voltage (busbar 1).
- VSINC2: Side B voltage (busbar 2).

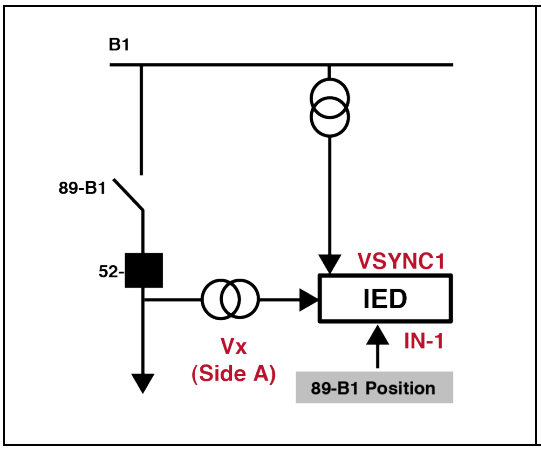


Figure 8.4.1 Single Busbar Configuration.

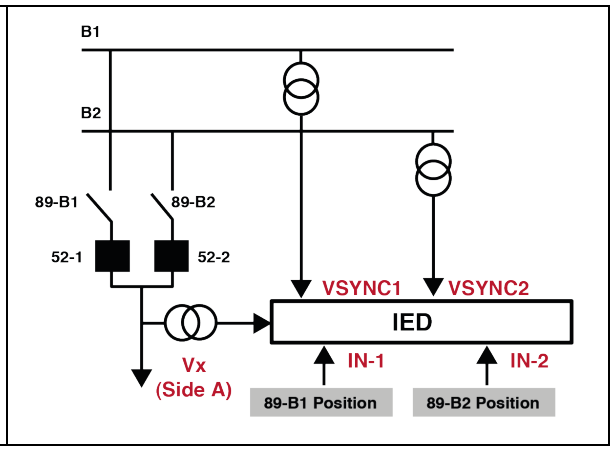


Figure 8.4.2 Double Busbar with Double Breaker Configuration.

In breaker and a half positions:

- 89B1_NC: Line 1 Isolator opened (**).
- 89B2_NC: Line 2 Isolator opened.
- VX (A side): Selected voltage of side A.
- VSINC1: Side B voltage (busbar 1).
- VSINC2: Side B voltage (busbar 2).
- VSINC3: Side B voltage (line 2).

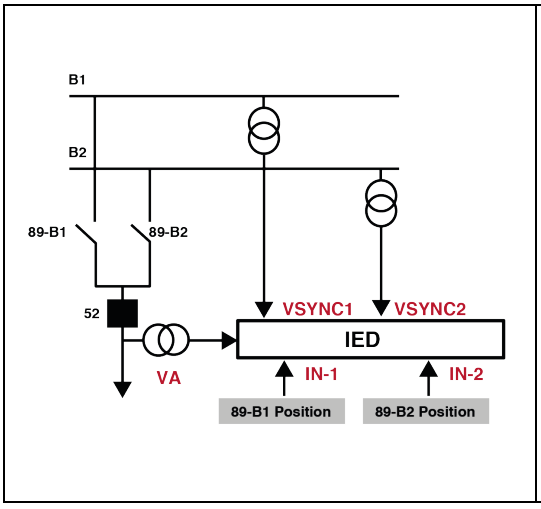


Figure 8.4.3 Double Busbar and Single Breaker Configuration.

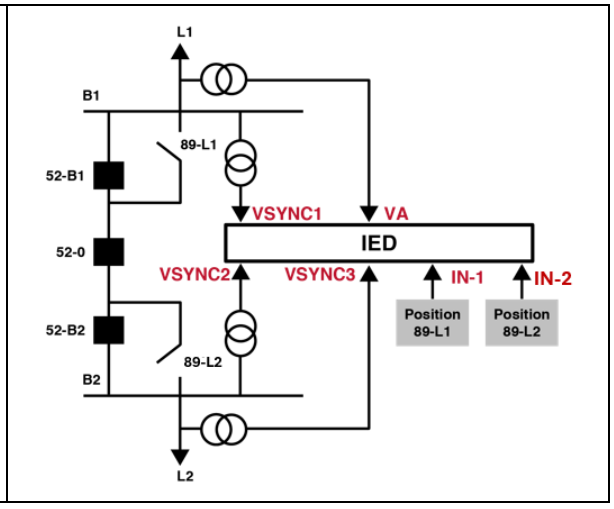


Figure 8.4.4 Breaker and a Half Configuration.

(*) The unit selects automatically the double busbar logic when configuring the input signals "Busbar 1 Isolator Open Input" and "Busbar 2 Isolator Open Input".

(**) The unit selects automatically the breaker and a half logic when configuring the input signals "Line 1 Isolator Open input" and "Line 2 Isolator Open input".

For **IRF** devices. The voltage on **Side A**, which is used to determine the existence or not of synchronism, is that of phase A or AB if using phase-phase voltages. Whether one or the other is used is determined by the ***VT Number*** setting, which indicates whether three phase-ground voltage transformers or two phase-phase voltage transformers are being used. This voltage is always necessary to be able to calculate the system frequency on side A of the breaker.

The voltage on **Side B** can be phase A, B or C, or phase-phase voltages AB, BC or CA, depending on the situation of the transformer for voltage measurement. To compare this voltage with that of **Side A**, the ***Side B Voltage*** setting must be properly configured.

Since there can be phase or line voltages on both sides and both types can even be combined, one on each side, the voltages measured are internally standardized to make them comparable in magnitude as well as in angle. **The criterion for the magnitude is to standardize the values measured considering that the voltages are simple on both sides**. The criterion for the angle is to compensate angles according to the values in Table 8.4-1. For both cases, the phase to neutral voltages VA are used internally by the unit to check if both sides of the breaker are synchronized.

The magnitudes are standardized and the angles are compensated according to the following settings:

- ***For IRF devices: VT Number***: With the set point at 3, the voltages on **Side A** are phase voltages (phase-ground). The magnitude measured by the first voltage channel is VA. With the set point at 2, the voltages on **Side A** are line voltages (phase-phase). In this case, the measurement of the first voltage channel (VAB) is used to calculate the VA vector. The unit uses this (calculated) value for calculations. The set point does not affect the voltage on **Side B**.
- ***Bus Voltage Compensation*** (**K_{LB}**). Considering as the reference voltage the one on **Side A**, the voltage on **Side B** has to be duly compensated by multiplying it by **K_{LB}** so that both voltages can be considered for the "voltage difference" criteria when checking the synchronism conditions.

  Factor **K_{LB}** will be calculated as:

$$K_{LB} = \frac{Vnominal_{VA\ in\ SIDE_A}}{Vnominal_{VSYNC\ in\ SIDE_B}}$$

- ***Side B Voltage***. This is to set the voltage to be considered for **Side B** of the CB and to calculate the angle compensation to be applied. **It is not intended to be used to standardize magnitudes**.

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The functioning of the Synchronism Unit also takes into account the system's type of rotation (ABC or ACB). The appropriate angle compensations depend on the ***Phase Sequence*** (ABC/ACB) setting.

For example, if the **Side A** voltage is phase A and that of **Side B** is phase B, for an ABC system, the angle compensation will be 120º; if the system rotation is ACB, the compensation will be 240º.

Table 8.4-1 shows all the angle compensation possibilities:

Table 8.4-1:Angle Compensation (Phase Sequence)

Side A	Side B Voltage Setting	ABC Sequence	ACB Sequence
VA	VA	+0º	+0º
VA	VB	+120º	+240º
VA	VC	+240º	+120º
VA	VAB	+330º	+30º
VA	VBC	+90º	+270º
VA	VCA	+210º	+150º
VB	VA	+240º	+120º
VB	VB	+0º	+0º
VB	VC	+120º	+240º
VB	VAB	+210º	+150º
VB	VBC	+330º	+30º
VB	VCA	+90º	+270º
VC	VA	+120º	+240º
VC	VB	+240º	+120º
VC	VC	+0º	+0º
VC	VAB	+90º	+270º
VC	VBC	+210º	+150º
VC	VCA	+330º	+30º

All the angles indicated refer to V_A.

See the block diagram of the Synchronism unit in next Figure.

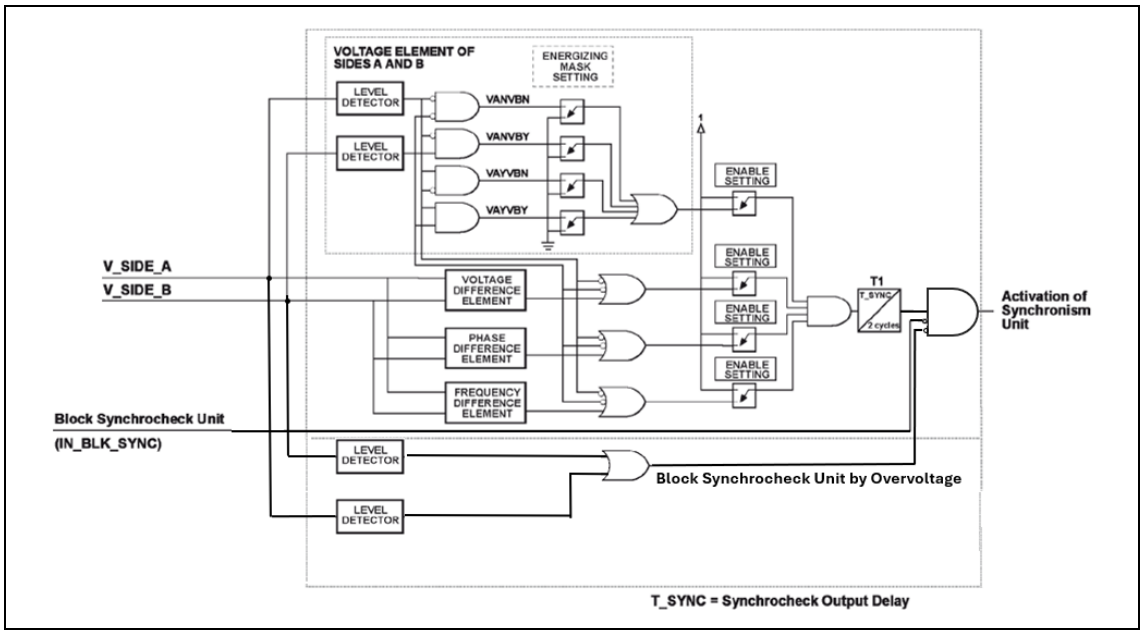


Figure 8.4.5 Block Diagram of the Synchronism Unit.

Note: the diagram shows that, if a permission value is 0 (element disabled), the input of the AND gate corresponding to this element will be at 1 as if this element were picked up. Therefore, if all the elements are disabled, the synchronism unit will be activated (unless it is blocked externally).

Note: the diagram shows that, if the Side A overvoltage element and/or the Side B overvoltage element are reset, the inputs to the AND gate corresponding to the voltage difference, angle difference and frequency difference elements are always at 1.

The Synchronism unit output can be blocked with the **Synchronism Check Block** (**IN_BLK_SYNC**) digital input.

8.4.3.a Voltage Difference Element

This element picks up when the voltage difference between the signals of sides A and B is less than or equal to the set value (in percentage), and resets when the ratio between the voltages of sides A and B is equal to or greater than 105% of the set value.

Once standardized, their difference is stored in absolute value: $|VsideA - VsideB| = Dif_V$

The pickup value is determined as follows: $Dif_V \leq GreaterSide * Setting/100$. Where *VgreaterSide* is the greater of the voltages read (side A or side B).

8.4.3.b Phase Difference Element

This element picks up when the phase displacement between the signals of sides A and B is less than or equal to the setting and resets when the phase displacement angle is greater than 105% of the set value or greater than the set value +2º.

The angles of the signals of sides A and B used are values already compensated according to Table 8.4-1.

When the ***Brk Close T Comp*** (Breaker Closing Time Compensation setting) is set to **YES**, the Phase Difference Element will consider the phase angle difference between voltages at the two sides A and B at the moment when the breaker closes, taking into account the operating time through the ***Brk Close T*** (Breaker Closing Time setting) and the slip between the voltages at the two sides A and B. For this, the following phase angle difference will be added to the phase angle difference between voltages at the two sides A and B:

$$\frac{Tclose\,(ms)}{1000} \cdot 360 \cdot \left(f_A - f_B\right)$$

where *Tclose* is breaker closing time, f_A is the frequency of the voltage at side A and f_B is the frequency of the voltage at side B.

In this way, if side A voltage is faster than side B voltage ($f_A > f_B$), the above phase angle difference will be positive, whereas if side A voltage is slower than side B voltage ($f_A < f_B$), the angle correction to be taken into account will be negative.

8.4.3.c Frequency Difference Element

This element picks up when the frequency difference between the signals of sides A and B is less than the pickup (100% of the setting), and resets when this difference is greater than the setting + 0.01 Hz.

8.4.3.d Difference Magnitudes

The Voltage, Phase and Frequency Difference elements are calculating the difference in module, phase and frequency between the line voltage and the busbar voltage. Those three magnitudes will be available as output magnitudes of the unit/protection and so they appear in the status, HMI and in the control logic.

The magnitudes will be calculated just when enabling the corresponding difference element and when the voltage element is in active status. In any other case they will be invalid.

8.4.3.e Voltage Element of Sides A and B

These elements consist of four overvoltage elements for each breaker (two element for each side of the breaker) and two undervoltage elements for each breaker (one element for each side of the breaker). Based on these six settings, four different voltage bands will be determined, four for Side A (Line) and four for Side B (Busbar). In IRF-A devices, whether Side A measurement comes from Line or Bus is selectable by the “Side A measurement” setting, changing the logic of the Bus/Line Live/Dead/Overvoltage signals.

For live line or busbar detection, each overvoltage element, picks up when the RMS of the input voltage exceeds 100% of the pickup value (setting value) and resets when it is below 95% of this value. The voltages used are standard phase voltages.

For dead line or busbar detection, each undervoltage element picks up when the RMS of the input voltage is below 100% of the pickup value (setting value) and resets when it exceeds 95% of this value. The voltages used are standard phase voltages.

The voltage elements intended to detect whether **Sides A** and **B** are live or dead are provided with 4 outputs that show the following signals for each side of each breaker. The voltage elements intended to detect overvoltage provide 2 outputs to block synchronism. Signal “Block Synchrocheck Unit by Overvoltage” activates by an overvoltage on either bus side or line side.

- **Live line**: This signal will activate when the line voltage (SIDE A) ≥ ***Live Line*** setting set to live.
- **Dead line**: This signal will activate when the line voltage (SIDE A) < ***Dead Line*** setting.
- **Live bus**: This signal will activate when the busbar voltage (SIDE B) ≥ ***Live Bus*** setting.
- **Dead bus**: This signal will activate when the busbar voltage (SIDE B) < ***Dead Bus*** setting.
- Line overvoltage: This signal will activate when the line voltage (SIDE A) ≥ Line Overvoltage setting.
- Bus overvoltage: This signal will activate when the busbar voltage (SIDE B) ≥ Bus Overvoltage setting.

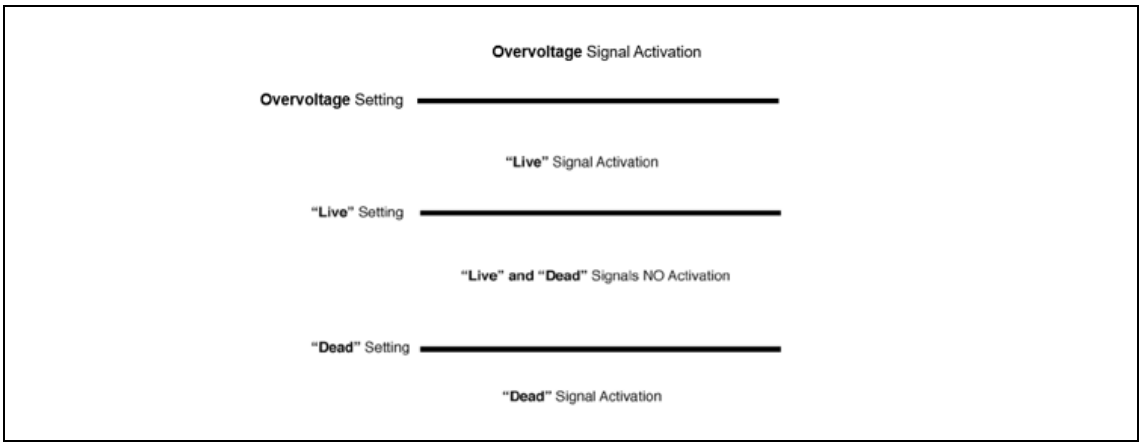


Figure 8.4.6 Activation Thresholds to Determine Live Line / Dead Line and Live Bus / Dead Bus and Line/Bus Overvoltage.

These outputs are generated whether they have of have not been selected through the ***Energization*** setting, whose sole function is to set the combinations to be used to detect synchronism. This will occur provided we are in the live or dead zone, since if the voltage at any side of the breaker is in the **No activation of "Live" and "Dead" Signals** zone, shown in Figure 8.4-6, the outputs of the side involved will not be calculated independently from the rest of the synchronism element settings.

The activation of any of the overvoltage signals blocks the activation of synchronism units.

*For **IRF-A** devices, in which Side A Measurement is selectable to be done at Bus or Line side, the following logic is followed:*

*If setting **Side A Measurement** = **Line**:*

- ***Live line**: This signal will activate when the line voltage (SIDE A) ≥ Live Line setting.*
- ***Dead line**: This signal will activate when the line voltage (SIDE A) < Dead Line setting.*
- ***Live bus**: This signal will activate when the busbar voltage (SIDE B) ≥ **Live Bus** setting.*
- ***Dead bus**: This signal will activate when the busbar voltage (SIDE B) < **Dead Bus** setting.*
- ***Line overvoltage**: This signal will activate when the line voltage (SIDE A) ≥ **Line Overvoltage** setting.*
- ***Bus overvoltage**: This signal will activate when the busbar voltage (SIDE B) ≥ **Bus Overvoltage** setting.*

*If setting **Side A Measurement** = **Bus**:*

- ***Live line**: This signal will activate when the line voltage (SIDE B) ≥ Live Line setting.*
- ***Dead line**: This signal will activate when the line voltage (SIDE B) < **Dead Line** setting.*
- ***Live bus**: This signal will activate when the busbar voltage (SIDE A) ≥ **Live Bus** setting.*
- ***Dead bus**: This signal will activate when the busbar voltage (SIDE A) < **Dead Bus** setting.*
- ***Line overvoltage**: This signal will activate when the line voltage (SIDE B) ≥ **Line Overvoltage** setting.*
- ***Bus overvoltage**: This signal will activate when the busbar voltage (SIDE A) ≥ **Bus Overvoltage** setting.*

8.4.3.f Selection of Type of Synchronism

The Recloser as well as the Command Logic (for closing operations of the breaker) use the **SYNC_R** signal, which indicates the presence or absence of synchronism prior to the breaker closing.

This information can be supplied to the IED by the output of the IED's own synchronism unit or by the digital input of **External Synchronism** (**SYNC_EXT** signal). The setting that determines the origin of the synchronization signal is the ***Type of Sync*** (Type of Synchronism) setting, as follows:

- If this setting takes the value of **Calculated**, synchronization signal **SYNC_R** will take the value of the IED's synchronism unit output (**SYNC_CALC**).
- If this setting takes the value of **External**, synchronization signal **SYNC_R** will take the value of the digital input of External Synchronism (**SYNC_EXT**).

8.4.4 Application of the Synchronism Function

The synchronism function is used to monitor the connection of the two parts of the circuit by the reset of a breaker. It verifies that the voltages on both sides of the breaker ($V_{SIDE\ A}$ and $V_{SIDE\ B}$) are within the magnitude, angle and frequency limits established in the settings.

Verification of synchronism is defined as the comparison of the voltage difference of two circuits with different sources to be joined through an impedance (transmission line, feeder, etc.), or connected with parallel circuits of defined impedances. The voltages on both sides of a breaker are compared before executing its reset so as to minimize possible internal damage due to the voltage difference in phase, as well as magnitude and angle. This is very important in steam-powered power plants where the reclosings of the output lines with considerable angle differences can cause very serious damage to the shaft of the turbine.

The difference in voltage level and phase angle at a given point in time is the result of the load existing between remote sources connected through parallel circuits (load flow). It is also a consequence of the impedance of the elements that join them (even when there is no load flow in the parallel circuits or because the sources to connect to each other are totally independent and isolated from each other).

In meshed systems, the angle difference between two ends of an open breaker is not normally significant since their sources are joined remotely by other elements (equivalent or parallel circuits). Nevertheless, in isolated circuits, as in the case of an independent generator, the angle difference, the voltage levels and the relative phase shift of the voltage phasors can be very considerable. The relative phase shift of their voltages can even be very small or null in such a way that they will be in phase very infrequently. Due to the changing conditions of an electricity system (connection-disconnection of loads, sources and new inductive-capacitive elements) the relative phase shift of one phasor in respect of the other is not null, making synchronization necessary.

In the first case, although the length of the line whose ends (sources) will be connected to determine the angle difference between them should be considered, this is not sufficient to set the synchronism conditions before closing the breaker. Experience indicates that the angle difference window between voltage phasors must be set to 15º-20º.

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8.4.5 Setting Ranges

Protection / Synchrocheck (Single Breaker Bay configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Type of Sync	Type of Sync	RSCF1.SynMod	External Internal		External
Side A Measurement	Side A Measurement	RSCF1.SideAMod	0=Line, 1= Bus		Line
Side A Voltage Selection	Side A Selection	RSCF1.VAMod	V_A / V_B / V_C		V_A
Side B Voltage Selection	Side B Selection	RSCF1.VBMod	V_A / V_B / V_C / V_{AB} / V_{BC} / V_{CA}		V_A
Side B Voltage Compensation	Side B Volt. Compens.	RSCF1.VCorFact	0.1-4	0.01	1
Voltage Supervision Enable	Voltage Suprv Enbl	RSCF1.VSupEna	NO / YES		NO
Live Line	Live line	RSCF1.LivLinVal	0 - 200 V	1 V	51 V
Dead Line	Dead Line	RSCF1.DeaLinVal	0 - 200 V	1 V	19 V
Live Bus	Live bus	RSCF1.LivBusVal	0 - 200 V	1 V	51 V
Dead Bus	Dead bus	RSCF1.DeaBusVal	0 - 200 V	1 V	19 V
Overvoltage Line	Overvoltage Line	RSCF1.OVLinVal	0 – 300 V	1 V	150 V
Overvoltage Bus	Overvoltage Bus	RSCF1.OVBusVal	0 – 300 V	1 V	150 V
Brk Close T Comp	Brk Close T Comp	RSCF1.CbTmComp	YES / NO		NO
Brk Close T	Brk Close T	RSCF1.BkrTmms	5-1000 ms	5 ms	100 ms
Unit 1	Unit 1				
Sync Enable	Sync Enable	Rsyn1.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn1.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn1.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn1.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn1.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn1.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn1.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn1.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn1.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn1.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn1.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn1.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn1.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn1.OVBlk	0=None, 1= Yes		0=None

Protection / Synchrocheck (Single Breaker Bay configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Unit 2	Unit 2				
Sync Enable	Sync Enable	Rsyn2.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn2.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn2.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn2.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn2.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn2.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn2.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn2.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn2.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn2.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn2.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn2.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn2.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn2.OVBlk	0=None, 1= Yes		0=None

Protection / Synchrocheck (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
DI Supervision for VSYNC selection	DI superv VSYN sel	LPHD.BusTyp	NO/89B/89L		NO
Breaker 1					
Type of Sync	Type of Sync	RSCF1.SynMod	External Internal		External
Side A Voltage Selection	Side A Selection	RSCF1.VAMod	V_A / V_B / V_C		V_A
Side B Voltage Selection	Side B Selection	RSCF1.VBMod	V_A / V_B / V_C / V_{AB} / V_{BC} / V_{CA}		V_A
Side B Voltage Compensation	Side B Volt. Compens.	RSCF1.VCorFact	0.1-4	0.01	1
Voltage Supervision Enable	Voltage Suprv Enbl	RSCF1.VSupEna	NO / YES		NO
Live Line	Live line	RSCF1.LivLinVal	0 - 200 V	1 V	51 V
Dead Line	Dead Line	RSCF1.DeaLinVal	0 - 200 V	1 V	19 V
Live Bus	Live bus	RSCF1.LivBusVal	0 - 200 V	1 V	51 V
Dead Bus	Dead bus	RSCF1.DeaBusVal	0 - 200 V	1 V	19 V
Overvoltage Line	Overvoltage Line	RSCF1.OVLinVal	0 – 300 V	1 V	150 V
Overvoltage Bus	Overvoltage Bus	RSCF1.OVBusVal	0 – 300 V	1 V	150 V
Brk Close T Comp	Brk Close T Comp	RSCF1.CbTmComp	YES / NO		NO
Brk Close T	Brk Close T	RSCF1.BkrTmms	5-1000 ms	5 ms	100 ms

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Protection / Synchrocheck (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Unit 1	Unit 1				
Sync Enable	Sync Enable	Rsyn1.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn1.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn1.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn1.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn1.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn1.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn1.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn1.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn1.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn1.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn1.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn1.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn1.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn1.OVBlk	0=None, 1= Yes		0=None
Unit 2	Unit 2				
Sync Enable	Sync Enable	Rsyn2.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn2.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn2.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn2.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn2.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn2.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn2.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn2.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn2.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn2.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn2.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn2.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn2.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn2.OVBlk	0=None, 1= Yes		0=None

Protection / Synchrocheck (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Breaker 2					
Type of Sync	Type of Sync	RSCF2.SynMod	External Internal		External
Side A Voltage Selection	Side A Selection	RSCF2.VAMod	V_A / V_B / V_C		V_A
Side B Voltage Selection	Side B Selection	RSCF2.VBMod	V_A / V_B / V_C / V_{AB} / V_{BC} / V_{CA}		V_A
Side B Voltage Compensation	Side B Volt. Compens.	RSCF2.VCorFact	0.1-4	0.01	1
Voltage Supervision Enable	Voltage Suprv Enbl	RSCF2.VSupEna	NO / YES		NO
Live Line	Live line	RSCF2.LivLinVal	0 - 200 V	1 V	51 V
Dead Line	Dead Line	RSCF2.DeaLinVal	0 - 200 V	1 V	19 V
Live Bus	Live bus	RSCF2.LivBusVal	0 - 200 V	1 V	51 V
Dead Bus	Dead bus	RSCF2.DeaBusVal	0 - 200 V	1 V	19 V
Overvoltage Line	Overvoltage Line	RSCF2.OVLinVal	0 – 300 V	1 V	150 V
Overvoltage Bus	Overvoltage Bus	RSCF2.OVBusVal	0 – 300 V	1 V	150 V
Brk Close T Comp	Brk Close T Comp	RSCF2.CbTmComp	YES / NO		NO
Brk Close T	Brk Close T	RSCF2.BkrTmms	5-1000 ms	5 ms	100 ms
Unit 1	Unit 1				
Sync Enable	Sync Enable	Rsyn3.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn3.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn3.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn3.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn3.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn3.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn3.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn3.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn3.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn3.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn3.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn3.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn3.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn3.OVBlk	0=None, 1= Yes		0=None

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Protection / Synchrocheck (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Unit 2	Unit 2				
Sync Enable	Sync Enable	Rsyn4.LnInSvc	YES / NO		NO
Energization Mask	Energization Mask				
D BUS / D LINE	D BUS/D LINE	Rsyn4.DeaADeaB	YES / NO		NO
H BUS / D LINE	H BUS/D LINE	Rsyn4.DeaALivB	YES / NO		YES
D BUS / H LINE	D BUS/H LINE	Rsyn4.LivADeaB	YES / NO		NO
H BUS / H LINE	H BUS/H LINE	Rsyn4.LivALivB	YES / NO		YES
Voltage Difference Enable	Volt. Diff. Enable	Rsyn4.DifVEna	YES / NO		NO
Maximum Voltage Difference	Max. Voltage Diff.	Rsyn4.DifV	2%-30 %	1 %	2 %
Phase Difference Enable	Phase Diff. Enable	Rsyn4.DifAngEna	YES / NO		NO
Maximum Phase Difference	Max. Phase Diff.	Rsyn4.DifAng	2 - 80º	1º	2º
Frequency Difference Enable	Freq. Diff. Enable	Rsyn4.DifHzEna	YES / NO		NO
Maximum Frequency Difference	Max. Freq. Diff.	Rsyn4.DifHz	0.005-2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	Sync Delay	Rsyn4.OpDlTmms	0.00-300 s	0.01 s	0 s
FF Sync Block	FF Sync. Block	Rsyn4.FuFailBlk	NO / YES		NO
Block Sync by Overvoltage	Block Sync by OV	Rsyn4.OVBlk	0=None, 1= Yes		0=None



CAUTION

If, while the Enable setting is YES, the four bits of the Energization Mask are set to NO, the Voltage Element is deactivated and, consequently, the Synchronism Unit. Therefore, if you want to disable the Voltage Element of Sides A and B, set that element's permission to NO and not the four bits of the Energization Mask.

8.4.6 Analog Inputs to the Unit

Table 8.4-2:Analog Inputs to the Synchronism Module (Single Breaker Configuration models)		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VAB	VAB Phase Voltage	MMXU1.PPV.phsAB
VSYNC	Synchronism Channel Voltage	MMXU1.VSyn
FREQ S	Synchronism Channel Frequency	MMXU1.HzSyn

Table 8.4-3:Analog Inputs to the Synchronism Module (For Double Breaker or Breaker-and-a-Half Bay Configuration models)		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VAB	VAB Phase Voltage	MMXU1.PPV.phsAB
V1	Synchronism Channel 1 Voltage	V1TVTR1.V1
V2	Synchronism Channel 2 Voltage	V2TVTR1.V2
V3	Synchronism Channel 3 Voltage	V3TVTR3.V3
FREQ S 1	Synchronism Channel 1 Frequency	MMXU1.HzSyn1
FREQ S 2	Synchronism Channel 2 Frequency	MMXU1.HzSyn2
FREQ S 3	Synchronism Channel 3 Frequency	MMXU1.HzSyn3

8.4.7 Analog Outputs of the Unit

Table 8.4-4: Analog Outputs of the Synchronism Module		
Name	**Description**	**IEC 61850**
VSYNC_DIFF_M	Synchrocheck Voltage Difference	RSYN1.DifVClc
VSYNC_DIFF_PH	Synchrocheck Phase Difference	RSYN1.DifAngClc
VSYNC_DIFF_F	Synchrocheck Frequency Difference	RSYN1.DifHzClc

8.4.8 Digital Inputs to the Synchronism Module

Table 8.4-5: Digital Inputs to the Synchronism Module (Single Breaker Configuration models)

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_SYNC1	Enabling Commands	Rsyn1.Mod	Enable Synchrocheck Unit	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ENBL_SYNC2		Rsyn2.Mod	Enable Synchrocheck Unit 2	I	
IN_BLK_SYNC	Synchronism Unit	RSCF1.Mod	Block Synchrocheck Unit	I	Activation of the input blocks the activation of the synchronism unit output (calculated synchronism).
SYNC_EXT		RSCF1.SynEx	External Synchrocheck Input	I	Activation of the input is necessary to permit the recloser to generate a close command if the supervision by synchronism setting is enabled and the synchronism mode chosen is "external."

Table 8.4-6: Digital Inputs to the Synchronism Module (Double Breaker or Breaker-and-a-Half Bay Configuration models)

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_SYNC1	Enabling Commands	Rsyn1.Mod	Enable Synchrocheck Unit 1 Breaker 1	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a "1."
ENBL_SYNC2		Rsyn2.Mod	Enable Synchrocheck Unit 2 Breaker 1	I	
ENBL_SYNC3		Rsyn3.Mod	Enable Synchrocheck Unit 1 Breaker 2	I	
ENBL_SYNC4		Rsyn4.Mod	Enable Synchrocheck Unit 2 Breaker 2	I	
IN_BLK_SYNC1	Synchronism Unit	RSCF1.Mod	Block Synchrocheck Breaker 1	I	Activation of the input blocks the activation of the synchronism unit output (calculated synchronism).
IN_BLK_SYNC2		RSCF2.Mod	Block Synchrocheck Breaker 2	I	
SYNC_EXT1		RSCF1.SynEx	External Synchrocheck Breaker 1	I	Activation of the input is necessary to permit the recloser to generate a close command if the supervision by synchronism setting is enabled and the synchronism mode chosen is "external."
SYNC_EXT2		RSCF2.SynEx	External Synchrocheck Breaker 2	I	

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.4.9 Auxiliary Outputs and Events of the Synchronism Module

Table 8.4-7: Auxiliary Outputs and Events of the Synchronism Module (Single Breaker Configuration models)

Name	Group	IEC 61850	Description	Vis.	Function
P_SYNC_DPH1	Synchronism Unit 1	Rsyn1.AngInd	Synchrocheck Phase Difference Close Permission Unit 1	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF1		Rsyn1.HzInd	Synchrocheck Frequency Slip Close Permission Unit 1	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV1		Rsyn1.VInd	Synchrocheck Voltage Difference Close Permission Unit 1	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL1		Rsyn1.VStChkOk	Hot Line Hot Bus Close Permission Unit 1	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R1		Rsyn1.Rel	Synchrocheck Close Permission Unit 1	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD1		Rsyn1.Mod	Synchrocheck Unit Activation Unit 1	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV		Rsyn1.OVBlk	Synchrocheck blocked by Overvoltage Unit 1		Synchrocheck blocked by overvoltage Unit 1
P_SYNC_DPH2	Synchronism Unit 2	Rsyn2.AngInd	Synchrocheck Phase Difference Close Permission Unit 2	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF2		Rsyn2.HzInd	Synchrocheck Frequency Slip Close Permission Unit 2	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV2		Rsyn2.VInd	Synchrocheck Voltage Difference Close Permission Unit 2	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 8.4-7: Auxiliary Outputs and Events of the Synchronism Module (Single Breaker Configuration models)					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
P_SYNC_EL2		Rsyn2.VStChkOk	Hot Line Hot Bus Close Permission Unit 2	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R2		Rsyn2.Rel	Synchrocheck Close Permission Unit 2	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD2		Rsyn2.Mod	Synchrocheck Unit Activation Unit 2	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV		Rsyn2.OVBlk	Synchrocheck blocked by Overvoltage Unit 2	I	Synchrocheck blocked by overvoltage Unit 2
LIVELINE		RSCF1.LivLin	Live Line	I	It indicates presence of voltage on Line
DEADLINE		RSCF1.DeaLin	Dead Line	I	Indicates absence of voltage on Line
LIVEBUS		RSCF1.LivBus	Live Bus	I	It indicates presence of voltage on Bus
DEADBUS		RSCF1.DeaBus	Dead Bus	I	Indicates absence of voltage on Bus
LINE_OV		RSCF1.OVLine	Overvoltage on line side	I	Indication of Overvoltage on line side.
BUS_OV		RSCF1.OVBus	Overvoltage on bus side	I	Indication of Overvoltage on bus side.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

Table 8.4-8: Auxiliary Outputs and Events of the Synchronism Module (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
Breaker 1					
P_SYNC_DPH11	Synchronism Unit 1	Rsyn1.AngInd	Synchrocheck Phase Difference Close Permission Unit 1 Breaker 1	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF11		Rsyn1.HzInd	Synchrocheck Frequency Slip Close Permission Unit 1 Breaker 1	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV11		Rsyn1.VInd	Synchrocheck Voltage Difference Close Permission Unit 1 Breaker 1	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL11		Rsyn1.VStChkOk	Hot Line Hot Bus Close Permission Unit 1 Breaker 1	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R11		Rsyn1.Rel	Synchrocheck Close Permission Unit 1 Breaker 1	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD11		Rsyn1.Mod	Synchrocheck Unit Activation Unit 1 Breaker 1	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV11		Rsyn1.OVBlk	Synchrocheck blocked by overvoltage Unit 1 Breaker 1		Synchrocheck blocked by overvoltage.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 8.4-8: Auxiliary Outputs and Events of the Synchronism Module (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
Breaker 1					
P_SYNC_DPH12	Synchronism Unit 2	Rsyn2.AngInd	Synchrocheck Phase Difference Close Permission Unit 2 Breaker 1	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF12		Rsyn2.HzInd	Synchrocheck Frequency Slip Close Permission Unit 2 Breaker 1	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV12		Rsyn2.VInd	Synchrocheck Voltage Difference Close Breaker 1Permission Unit 2	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL12		Rsyn2.VStChkOk	Hot Line Hot Bus Close Permission Unit 2 Breaker 1	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R12		Rsyn2.Rel	Synchrocheck Close Permission Unit 2 Breaker 1	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD12		Rsyn2.Mod	Synchrocheck Unit Activation Unit 2 Breaker 1	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV12		Rsyn2.OVBlk	Synchrocheck blocked by overvoltage Unit 2 Breaker 1		Synchrocheck blocked by overvoltage
LIVELINE1		RSCF1.LivLin	Live Line 1	I	It indicates presence of voltage on Line
DEADLINE1		RSCF1.DeaLin	Dead Line 1	I	Indicates absence of voltage on Line
LIVEBUS1		RSCF1.LivBus	Live Bus 1	I	It indicates presence of voltage on Bus
DEADBUS1		RSCF1.DeaBus	Dead Bus 1	I	Indicates absence of voltage on Bus
LINE_OV1		RSCF1.OVLine	Overvoltage on line side Breaker 1	I	Indication of Overvoltage on line side.
BUS_OV1		RSCF1.OVBus	Overvoltage on bus side Breaker 1	I	Indication of Overvoltage on bus side.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

Table 8.4-8: Auxiliary Outputs and Events of the Synchronism Module (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
Breaker 2					
P_SYNC_DPH21	Synchronism Unit 1	Rsyn3.AngInd	Synchrocheck Phase Difference Close Permission Unit 1 Breaker 2	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF21		Rsyn3.HzInd	Synchrocheck Frequency Slip Close Permission Unit 1 Breaker 2	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV21		Rsyn3.VInd	Synchrocheck Voltage Difference Close Permission Unit 1 Breaker 2	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL21		Rsyn3.VStChkOk	Hot Line Hot Bus Close Permission Unit 1 Breaker 2	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R21		Rsyn3.Rel	Synchrocheck Close Permission Unit 1 Breaker 2	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD21		Rsyn3.Mod	Synchrocheck Unit Activation Unit 1 Breaker 2	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV21		Rsyn3.OVBlk	Synchrocheck blocked by overvoltage Unit 1 Breaker 2		Synchrocheck blocked by overvoltage

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 8.4-8: Auxiliary Outputs and Events of the Synchronism Module (Double Breaker or Breaker-and-a-Half Bay Configuration models)					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
P_SYNC_DPH22	Synchronism Unit 2	Rsyn4.AngInd	Synchrocheck Phase Difference Close Permission Unit 2 Breaker 2	I	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DF22		Rsyn4.HzInd	Synchrocheck Frequency Slip Close Permission Unit 2 Breaker 2	I	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV22		Rsyn4.VInd	Synchrocheck Voltage Difference Close Permission Unit 2 Breaker 2	I	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL22		Rsyn4.VStChkOk	Hot Line Hot Bus Close Permission Unit 2 Breaker 2	I	The synchronism unit determines that there are close conditions by the criterion of presence / absence of voltages on sides A and B.
SYNC_R22		Rsyn4.Rel	Synchrocheck Close Permission Unit 2 Breaker 2	I	It is the signal that the recloser receives to monitor the close by synchronism. Its activation indicates that there is permission, and depending on how the selector is set, it will be external or calculated synchronism.
SYNC_ENBLD22		Rsyn4.Mod	Synchrocheck Unit Activation Unit 2 Breaker 2	I	Indication of enabled or disabled status of the unit.
SYNCH_BLK_OV22		Rsyn1.OVBlk	Synchrocheck blocked by overvoltage Unit 2 Breaker 2		Synchrocheck blocked by overvoltage
LIVELINE2		RSCF2.LivLin	Live Line 2	I	It indicates presence of voltage on Line
DEADLINE2		RSCF2.DeaLin	Dead Line 2	I	Indicates absence of voltage on Line
LIVEBUS2		RSCF2.LivBus	Live Bus 2	I	It indicates presence of voltage on Bus
DEADBUS2		RSCF2.DeaBus	Dead Bus 2	I	Indicates absence of voltage on Bus
LINE_OV2		RSCF2.OVLine	Overvoltage on line side Breaker 2	I	Indication of Overvoltage on line side.
BUS_OV2		RSCF2.OVBus	Overvoltage on bus side Breaker 2	I	Indication of Overvoltage on bus side.

The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.4.10 IEC 61850 Logical Node (IRFA)

CLASS RSYN		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured Values		
DifVClc	MV	Calculated difference in voltage. NEW
DifAngClc	MV	Calculated difference in phase angle. NEW
DifHzClc	MV	Calculated difference in frequency. NEW
Status information		
Rel	SPS	Release. Synchrocheck close permission
VInd	SPS	Voltage difference permission indication
AngInd	SPS	Angle difference permission indication
HzInd	SPS	Frequency difference permission indication
Settings		
DifV	ASG	Difference voltage
DifHz	ASG	Difference frequency
DifAng	ASG	Difference angle
DeaLinVal	ASG	Dead Line Value
LivLinVal	ASG	Live Line Value
DeaBusVal	ASG	Dead Bus Value
LivBusVal	ASG	Live Bus Value
OVLinVal	ASG	OV Line Value
OVBusVal	ASG	OV Bus Value
BrkTmms	ING	Closing time of breaker
Controls		
SynPrg	SPC	Synchrocheck/Synchronizing in progress. It will be a SPC non controllable just to show the status. It will be ON while the unit is in service and calculating (Mod = ON or TEST). NEW
Extended Data		
VStChkOk	EXT_SPS	Both sides energization permission
LivLin	EXT_SPS	Voltage presence in line
DeaLin	EXT_SPS	Voltage absence in line
LivBus	EXT_SPS	Voltage presence in bus
DeaBus	EXT_SPS	Voltage absence in bus
SynIn	EXT_SPS	Internal calculated synchrocheck permission
SynEx	EXT_SPS	External synchrocheck permission
OVLine	EXT_SPS	Line overvoltage indication.
OVBus	EXT_SPS	Bus overvoltage indication.
OVBlk	EXT_SPS	Synchrocheck blocked by overvoltage.
Vsyn	EXT_CMV	Synchrocheck channel voltage
HzSync	EXT_MV	Synchrocheck channel frequency
LNInSvc	EXT_SPG	In service
SynMod	EXT_ENG	Synchrocheck Mode (internal/external)
SideAMod	EXT_ENG	Side A Measurement
VMod	EXT_ENG	Type of voltage in bus side

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VCorFact	EXT_ASG	Voltage compensation factor
VsupEna	EXT_SPG	Enable supervision at both sides of breaker
ManClsChk	EXT_SPG	Manual Close Synchrocheck Supervision
DifVEna	EXT_SPG	Enable voltage difference
DifAngEna	EXT_SPG	Enable angle difference
DifHzEna	EXT_SPG	Enable frequency difference
OVBlk	EXT_SPG	Enable synchrocheck block by overvoltage.
OpDlTmms	EXT_ING	Time delay
FuFailBlkE	EXT_SPG	Enable synchrocheck block due to fuse failure
CbTmComp	EXT_SPG	Enable breaker close time compensation
DeaADeaB	EXT_SPG	Enable energization mask dead A, dead B
DeaALivB	EXT_SPG	Enable energization mask dead A, live B
LivADeaB	EXT_SPG	Enable energization mask live A, dead B
LivALivB	EXT_SPG	Enable energization mask live A, live B

8.4.11 IEC 61850 Logical Node (IRFB, IRFC, ZLFB, ZLFC, DLFA, DLFB)

CLASS RSCF		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Settings		
DeaLinVal	ASG	Dead Line Value
LivLinVal	ASG	Live Line Value
DeaBusVal	ASG	Dead Bus Value
LivBusVal	ASG	Live Bus Value
OVLinVal	ASG	OV Line Value
OVBusVal	ASG	OV Bus Value
Extended Data		
LivLin	EXT_SPS	Voltage presence in line
DeaLin	EXT_SPS	Voltage absence in line
LivBus	EXT_SPS	Voltage presence in bus
DeaBus	EXT_SPS	Voltage absence in bus
SynEx	EXT_SPS	External synchrocheck permission
OVLine	EXT_SPS	Line overvoltage indication.
OVBus	EXT_SPS	Bus overvoltage indication.
SynMod	EXT_ENG	Synchrocheck Mode (internal/external)
SideAMod	EXT_ENG	Side A Measurement
LinVTyp	EXT_ENG	Type of voltage in line side
BusVTyp	EXT_ENG	Type of voltage in bus side
VCorFact	EXT_ASG	Voltage compensation factor
VsupEna	EXT_SPG	Enable supervision at both sides of breaker
ManClsChk	EXT_SPG	Manual Close Synchrocheck Supervision
CbTmComp	EXT_SPG	Enable breaker close time compensation

CLASS RSYN		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured Values		
DifVClc	MV	Calculated difference in voltage. NEW
DifAngClc	MV	Calculated difference in phase angle. NEW
DifHzClc	MV	Calculated difference in frequency. NEW
Status information		
Rel	SPS	Release. Synchrocheck close permission
VInd	SPS	Voltage difference permission indication
AngInd	SPS	Angle difference permission indication
HzInd	SPS	Frequency difference permission indication
Settings		
DifV	ASG	Difference voltage
DifHz	ASG	Difference frequency
DifAng	ASG	Difference angle
Controls		
SynPrg	SPC	Synchrocheck/Synchronizing in progress. It will be a SPC non controllable just to show the status. It will be ON while the unit is in service and calculating (Mod = ON or TEST). NEW
Extended Data		
VStChkOk	EXT_SPS	Both sides energization permission
DifVEna	EXT_SPG	Enable voltage difference
DifAngEna	EXT_SPG	Enable angle difference
DifHzEna	EXT_SPG	Enable frequency difference
OVBlk	EXT_SPG	Enable synchrocheck block by overvoltage.
OpDlTmms	EXT_ING	Time delay
FuFailBlkE	EXT_SPG	Enable synchrocheck block due to fuse failure
DeaADeaB	EXT_SPG	Enable energization mask dead A, dead B
DeaALivB	EXT_SPG	Enable energization mask dead A, live B
LivADeaB	EXT_SPG	Enable energization mask live A, dead B
LivALivB	EXT_SPG	Enable energization mask live A, live B

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8.4.12 Synchronism Unit Test

To verify this unit, first the protection units are disabled. Then, the system is prepared to measure the time between the injection of the voltage and the activation of the Synchronism Unit. Lastly, the signals indicated in Table 8.4-9 are checked.

Table 8.4-9: Configuration of the Outputs

Logic signal	Description of logic signal
SYNC_CALC	Activation of the synchronism unit
Side A Voltage	Voltage on side A detected
Side B Voltage	Voltage on side B detected

Voltage Elements Test

Disable the Voltage Difference, Phase Difference and Frequency Difference elements. The Synchronism Unit is set as follows:

Synchronism enable	**YES**
Type of synchronism	**1: Internal**
Side B voltage	**1: VB**
K_{LB} Factor	**1**

Voltage Supervision Elements

Enable	**YES**
Live Line	**51 V**
Dead Line	**25 V**
Live Bus	**51 V**
Dead Bus	**25 V**
Energizing masks	
No voltage side A; No voltage side B	**NO**
No voltage side A; Voltage side B	**YES**
Voltage side A; No voltage side B	**YES**
Voltage side A; Voltage side B	**NO**

Voltage Difference Element

Enable	**YES**
Maximum voltage difference	**10%**

Phase Difference Element

Enable	**YES**
Maximum voltage difference	**20%**

Frequency Difference Element

Enable	**YES**
Maximum voltage difference	**0.20Hz**
Synchronism output time delay	**0.00s**

- **Pickups**

Three tests are run. They correspond to three different pickup settings.

A voltage of 15 Vac and phase 0º is applied to phase A and of 65 Vac and phase 0º to the voltage channel of side B. The Synchronism unit must activate.

Afterwards, phase A voltage is gradually increased until the Synchronism unit is deactivated. The voltage at which it is deactivated must be in the range corresponding to the pickup setting for which this test is performed. The voltage ranges are listed in Table 8.4-10.

Table 8.4-10: Voltage Supervisory Elements Test (Pickups)

Pickup Setting (V)	Pickup value (V)		Reset value (V)	
	Minimum	Maximum	Minimum	Maximum
25	24.25	25.75	23.04	24.46
45	43.65	46.35	41.47	44.03
60	58.20	61.80	55.29	58.71

The reset must be instantaneous and a voltage included in the range of Table 8.4-9 corresponding to the setting used.

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- **Voltage Difference Element Test**

The Voltage Difference element is enabled and the Voltage, Phase Difference and Frequency Difference elements are disabled.

Pickups

Three tests are run. They correspond to three different pickup settings.

A voltage of 30 Vac and phase 0º is applied to phase A and of 65 Vac and phase 0º to the voltage channel of side B. All the outputs must deactivate.

Afterwards, phase A voltage is gradually increased until the Synchronism unit activates and remains stable. The voltage at which it is enabled must be in the range corresponding to the pickup setting for which this test is performed. The voltage ranges are listed in Table 8.4-11. The reset must be instantaneous and a voltage included in the range of Table 8.4-11 corresponding to the setting used.

Table 8.4-11: Voltage Difference Element Test (Pickups)

Pickup Setting (p.u.)	Pickup value (V)		Reset value (V)	
	Minimum	Maximum	Minimum	Maximum
10%	56.75	60.26	56.42	59.92
20%	50.44	53.56	49.81	52.89
30%	44.14	46.87	43.19	45.87

- **Phase Difference Element Test**

The Phase Difference element is enabled and the Voltage, Voltage Difference and Frequency Difference elements are disabled.

Pickups

Three tests are run. They correspond to three different pickup settings.

A voltage of 65 Vac and phase 50º is applied to phase A and 65 Vac and phase 0º to the voltage channel of side B.

Afterwards, phase A voltage is gradually decreased until the Synchronism unit activates and remains stable. The angle at which it is enabled must be in the range corresponding to the pickup setting for which this test is performed. The angle ranges are listed in Table 8.4-12.

The reset must be instantaneous and a voltage included in the range of Table 8.4-12 corresponding to the setting used.

Table 8.4-12: Phase Difference Element Test (Pickups)

Pickup Setting (º)	Pickup value (º)		Reset value (º)	
	Minimum	Maximum	Minimum	Maximum
20	19	21	21	23
30	29	31	31	33
40	39	41	41	43

Frequency Difference Element Test

The Frequency Difference element is enabled and the rest are disabled.

Pickups

Three tests are run. They correspond to three different pickup settings.

A voltage of 65 Vac, phase 0º and 53 Hz frequency is applied to phase A and of 65 Vac, phase 0º and 50 Hz frequency to the voltage channel of side B. All the outputs must deactivate.

Afterwards, phase A voltage frequency is gradually decreased until the Synchronism unit activates and remains stable. The frequency difference for which it activates must be within the range specified in Table 8.4-13.

The reset will be instantaneous and for a frequency difference within the range specified in Table 8.4-13.

Table 8.4-13: Frequency Difference Element Test (Pickups)

Pickup Setting (Hz)	Pickup difference (Hz)		Reset difference (Hz)	
	Minimum	Maximum	Minimum	Maximum
0.20	0.19	0.21	0.20	0.22
1.00	0.97	1.03	0.98	1.04
2.00	1.94	2.06	1.95	2.07

- **Time Delay Test**

Three tests are run for three different time settings (0.10 s, 1 s and 10 s).

The system is prepared to measure the time between the injection of the voltage and the reset of the Synchronism unit contact.

Only the Voltage Difference element is enabled between sides A and B.

A voltage of 65 V and 0º is applied to phase A and to the voltage channel of side B. The Synchronism unit must activate within the margin of ±1% of the setting or ±20 ms.

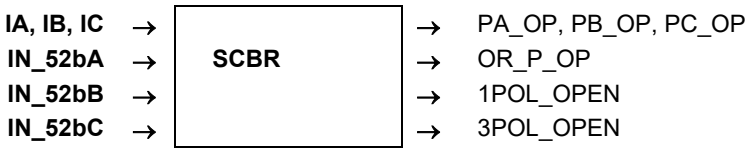
8.5 Open Pole Detector

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8.5.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Open Pole Detector	SCBR1		

8.5.2 General Block



8.5.3 Operation Principles and Block Diagram

Depending on the model, the equipment can be provided with an Open Pole Detector per breaker. This unit detects the opening of any pole of the breaker, generating the corresponding outputs (**Pole A Open**, **Pole B Open** and **Pole C Open**).

For the IED working on a Breaker-and-a-Half Bay configuration and one CT in the line (**DLF-B**), the algorithm takes in account the condition of the breaker position contacts. For the IED working on a single breaker bay configuration it also takes in account the output of the three undercurrent detectors, one for each pole, whose levels are given by the settings of each pole: ***X Pole Open Current***. With the aperture indication outputs of each pole, the open pole detector also generates the following outputs: **One Pole Open**, **Three Poles Open** or **Any Pole Open**.

The outputs of this unit are used by other units which carry out modifications in the operating logic to adapt to the new situation which causes the opening of any pole of the breaker.

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The Open Pole Detector can operate based on two operating logics, exclusive within themselves, each of which can be selected through the ***Num Brk Pos Inputs*** setting. If this setting takes the value **3 Inputs**, the operating logic will be the following:

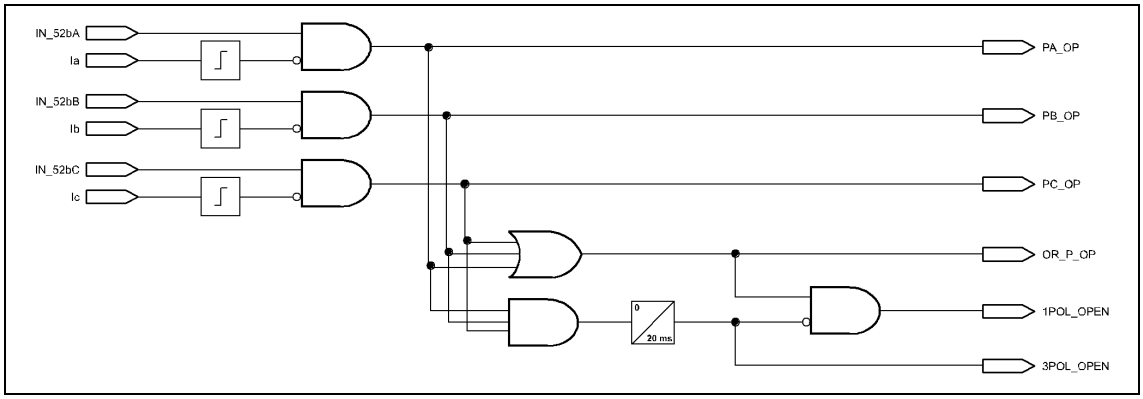


Figure 8.5.1 Logic Diagram of the Open Pole Detector with 3 Inputs (Models with Single Breaker Bay configuration capability).

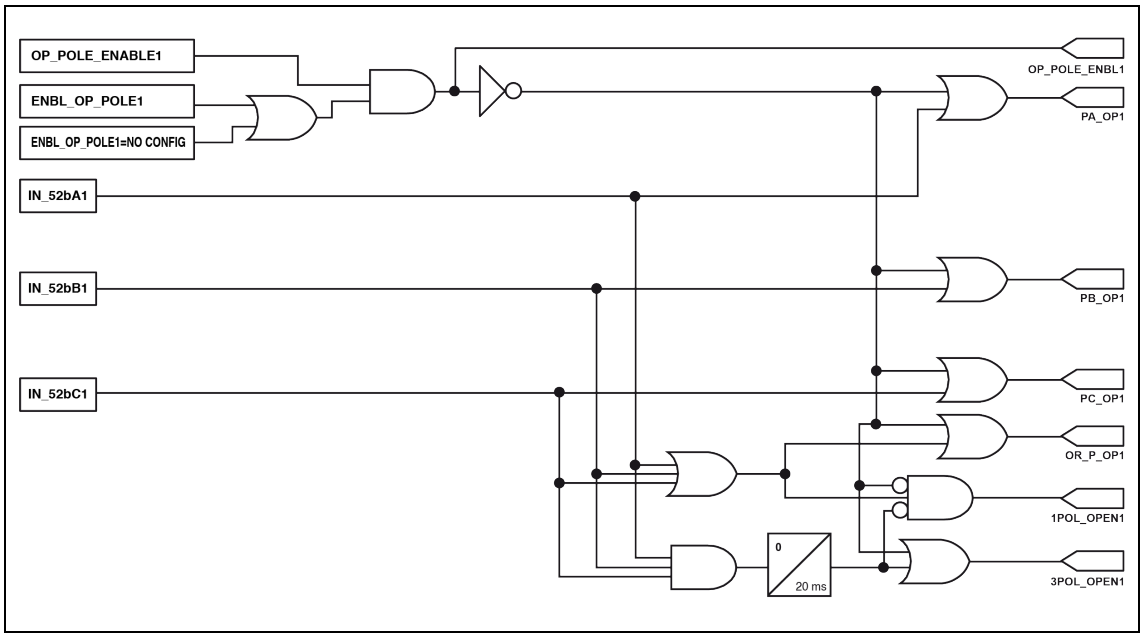


Figure 8.5.2 Logic Diagram of the Open Pole Detector with 3 Inputs (Models with Double Breaker or Breaker-and-a-Half Bay Configuration Capability).

Legend	
OP_POLE_ENABLE: Open Pole Enable Setting	PX_OP: Pole X Open.
ENBL_OP_POLE: Enable Open Pole Digital Input	OR_P_OP: Any Pole Open.
IN_52bX: Open X Pole Position Input.	1POL_OPEN: One Pole Open.
OP_POLE_ENLB: Open Pole Unit Enable	3POL_OPEN: Three Poles Open.

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IN_52bA, **IN_52bB** e **IN_52bC** inputs are designed to receive breaker **52b** normally closed contact state. However, using programmable logic, said logic inputs could receive breaker 52a contact (use operator NOT) or both **52b** and **52a** contacts (use operators NOT and AND) state.

The reset time of 20 ms associated with the **Three Poles Open** (**3POL_OPEN**) signal will be used to avoid transient activation of the **One Pole Open** (**1POL_OPEN**) signal in case of imbalances which arise in a three-phase reclose.

If the ***Num Brk Pos Inputs*** setting takes the value **2 Inputs** (only available in single breaker mode), the operating logic used becomes the following:

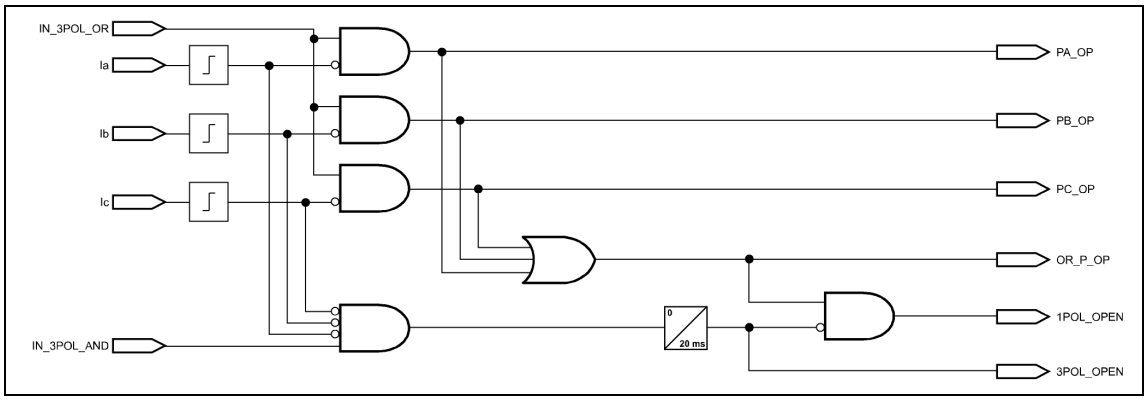


Figure 8.5.3 Logic Diagram of the Open Pole Detector with 2 Inputs (Models with Single Breaker Bay Configuration Capability).

Legend	
IN_3POL_OR: One Pole Open Input.	OR_P_OP: Any Pole Open.
IN_3POL_AND: Three Poles Open Input.	1POL_OPEN: One Pole Open.
PX_OP: Pole X Open.	3POL_OPEN: Three Poles Open.
OP_POLE_ENABLE: Open Pole Enable Setting	OP_POLE_ENLB: Open Pole Unit Enable
ENBL_OP_POLE: Enable Open Pole Digital Input	PX_OP: Pole X Open.

This logic allows using one less input than the logic above. Inputs **IN_3POL_OR** and **IN_3POL_AND** are designed to receive one **OR** and one **AND,** respectively, from the breaker **52b** normally closed contacts. However, using programmable logic, one OR and one AND from the **52 a** normally open contacts or both **52b** and **52a** contacts can also be assigned.

The reset time of 20 ms associated with the **Three Poles Open** (**3POL_OPEN**) signal is used, as in the previous logic, to avoid transient activation of the **One Pole Open** (**1POL_OPEN**) signal in case of imbalances which occur in a three-phase reclose.

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In models with double breaker or breaker-and-a-half bay configuration capability, Open Pole Logic Diagrams are applicable to both Circuit Breaker 1 and Circuit Breaker 2. The output of both Open Pole Units altogether that are used by other units is calculated according to the following logic:

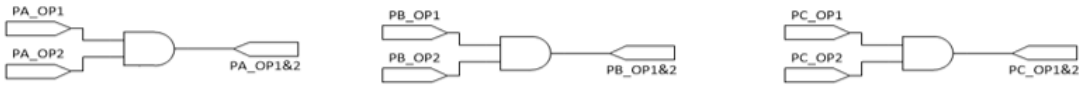


Figure 8.5.4 Pole A, B, C Open Output. (For models with Double Breaker or Breaker-and-a-Half Bay Configuration Capability).

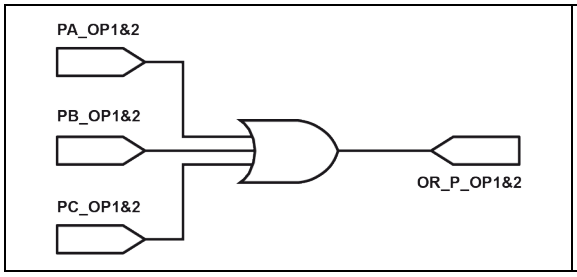


Figure 8.5.5 Any Pole Open Output (Models with Double Breaker or Breaker-and-a-Half Bay Configuration Capability).

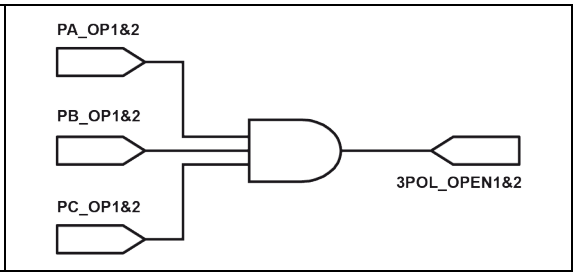


Figure 8.5.6 Three Pole Open Output (Models with Double Breaker or Breaker-and-a-Half Bay Configuration Capability).

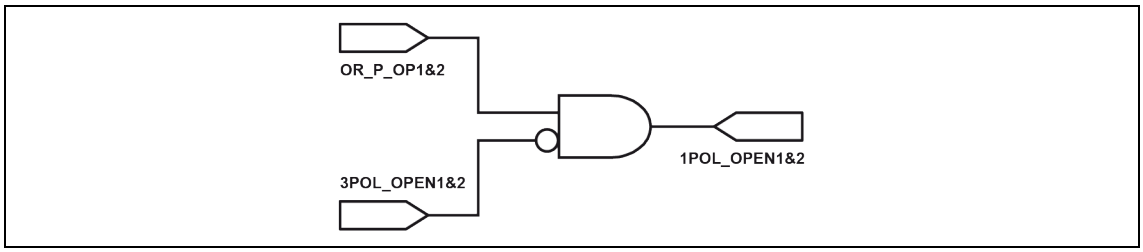


Figure 8.5.7 One Pole Open Output (Models with Double Breaker or Breaker-and-a-Half Bay Configuration Capability).

In the case of double breaker or breaker-and-a-half bay configuration models, Any Pole Open Output signal used by the close-onto-fault unit is activated by the opening of any pole of one breaker and activated again with the opening of any pole of the second breaker.

8.5.4 Remote Open Poles

The open pole current of the remote equipment must be configured so that the External Fault Detector can correctly determine if the pre-fault current can be used in the directional comparison and what type of magnitudes should be used (positive sequence or negative sequence).

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8.5.5 Setting Ranges

Protection / Open Pole Logic					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Breaker 1					
Num Brk Pos Inputs	Open Pole Selection	SCBR1.NumIn	3 INPUTS 2 INPUTS		3 INPUTS
Pole Open Current	Pole Open Current	SCBR1.OpnCur	0.04 - 0.8 A	0.01 A	0.04
Enable Open Pole*	Enable Open Pole	SCBR1.OpnPoleSvc	NO/YES		YES
Breaker 2					
Num Brk Pos Inputs	Open Pole Selection	SCBR2.NumIn	3 INPUTS 2 INPUTS		3 INPUTS
Pole Open Current	Pole Open Current	SCBR2.OpnCur	0.04 - 0.8 A	0.01 A	0.04
Enable Open Pole*	Enable Open Pole	SCBR2.OpnPoleSvc	NO/YES		YES
Pole Open Current Remote 2		SCBR1.OpnCurR1	0.04 - 0.8 A	0.01 A	0.04
Pole Open Current Remote 3		SCBR1.OpnCurR2	0.04 - 0.8 A	0.01 A	0.04

*Option available in models with Double Breaker of Breaker-and-a-Half bay configuration capability.

8.5.6 Analog Inputs to the Unit

Table 8.5-1: Analog Inputs to the Open Pole Module		
Name	**Description**	**IEC 61850**
IA1	Phase A Current 1	A1MMXU.A.phsA
IB1	Phase B Current 1	A1MMXU.A.phsB
IC1	Phase C Current 1	A1MMXU.A.phsC

Only for single Breaker models.

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8.5.7 Digital Inputs to the Open Pole Module

Table 8.5-2: Digital Inputs to the Open Pole Module

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_OP_POLE1	Enabling Commands	SCBR1.OpnPoleEna	Enable Open Pole Detector Unit 1	I	Function enabling Commands.
ENBL_OP_POLE2		SCBR2.OpnPoleEna	Enable Open Pole Detector Unit 2	I	
IN_52bA1	Breaker Control	SCBR1.CBInp1	Pole A1 Open Input	I	Activation of this input indicates that the 52b contact of (A/B/C) pole position of the breaker is closed.
IN_52bB1		SCBR1.CBInp2	Pole B1 Open Input	I	
IN_52bC1		SCBR1.CBInp3	Pole C1 Open Input	I	
IN_52bA2		SCBR2.CBInp1	Pole A2 Open Input	I	
IN_52bB2		SCBR2.CBInp2	Pole B2 Open Input	I	
IN_52bC2		SCBR2.CBInp3	Pole C2 Open Input	I	
IN_3POL_OR1		SCBR1.CBInOR	Any Pole Open Input circuit breaker 1	I	The activation of this input indicates that any 52b contact of the pole position of the breaker is closed.
IN_3POL_OR2		SCBR2.CBInOR	Any Pole Open Input circuit breaker 2	I	
IN_3POL_AND1		SCBR1.CBInAND	Three Poles 1 Open Input	I	The activation of this input indicates that the three 52b contacts of the pole position of the breaker are closed.
IN_3POL_AND2		SCBR2.CBInAND	Three Poles 2 Open Input	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.5.8 Auxiliary Outputs and Events of the Open Pole Module

Table 8.5-3: Auxiliary Outputs and Events of the Open Pole Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
OP_POLE_ ENBL1	Breaker Control	SCBR1.OpnPoleEna	Open Pole Detector Unit 1 Enabled	I	Unit enabled.
OP_POLE_ ENBL2		SCBR2.OpnPoleEna	Open Pole Detector Unit 2 Enabled	I	
PA_OP1		SCBR1.AnyPoleOpn	Pole A1 Open	I	Open (A / B / C) pole indication.
PB_OP1		SCBR1.AnyPoleOpn	Pole B1 Open	I	
PC_OP1		SCBR1.AnyPoleOpn	Pole C1 Open	I	
PA_OP2		SCBR2.AnyPoleOpn	Pole A2 Open	I	
PB_OP2		SCBR2.AnyPoleOpn	Pole B2 Open	I	
PC_OP2		SCBR2.AnyPoleOpn	Pole C2 Open	I	
OR_P_OP1		SCBR1.AnyPoleOpn	Any Pole Open circuit breaker 1	I	Any pole open indication.
OR_P_OP2		SCBR2.AnyPoleOpn	Any Pole Open circuit breaker 2	I	
3POL_OPEN1		SCBR1.AllPoleOpn	Three Poles Open circuit breaker 1	I	Three poles open indication.
3POL_OPEN2		SCBR2.AllPoleOpn	Three Poles Open circuit breaker 2	I	
1POL_OPEN1		SCBR1.OnePoleOpn	One Pole Open circuit breaker 1	I	One pole open indication. It is also activated when 2 poles open.
1POL_OPEN2		SCBR2.OnePoleOpn	One Pole Open circuit breaker 2	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.5.9 IEC 61850 Logical Node

CLASS DLFSCBR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
SumSwARs1	BCR	Accumulative KA2 phase A
SumSwARs2	BCR	Accumulative KA2 phase B
SumSwARs3	BCR	Accumulative KA2 phase C
OpCntRs1	INC	Number of pole A closing operations
OpCntRs2	INC	Number of pole B closing operations
OpCntRs3	INC	Number of pole C closing operations
OpCntRs4	INC	Number of pole 3 phase closing operations
SwA1	MV	Current opened phase A
SwA2	MV	Current opened phase B
SwA3	MV	Current opened phase C
Status information		
ArcStrIn1	SPS	Pole A arc initiation input
ArcStrIn2	SPS	Pole B arc initiation input
ArcStrIn3	SPS	Pole C arc initiation input
NumTrAlm	SPS	Alarm excessive number of trips
SwAAlm1	SPS	Alarm KA2 phase A
SwAAlm2	SPS	Alarm KA2 phase B
SwAAlm3	SPS	Alarm KA2 phase C
SwARsCmd1	SPC	Reposition command KA2 phase A
SwARsCmd2	SPC	Reposition command KA2 phase B
SwARsCmd3	SPC	Reposition command KA2 phase C
SwABlkIn	SPS	Accumulative kA2 block input
OpCntRs1	INC	Reposition command open current phase A
OpCntRs2	INC	Reposition command open current phase B
OpCntRs3	INC	Reposition command open current phase C
CBInA	SPS	Breaker pole A open input
CBInB	SPS	Breaker pole B open input
CBInC	SPS	Breaker pole C open input
CBInOR	SPS	Breaker any pole open input
CBInAND	SPS	Breaker all pole open input
AnyPoleOpn	ACT	Breaker any pole open
OnePoleOpn	SPS	Breaker one pole open
AllPoleOpn	SPS	Breaker all pole open
OpnFail	SPS	Breaker open command failure
ClsFail	SPS	Breaker close command failure
ColOpn	SPS	Breaker open command executed
ColCls	SPS	Breaker close command executed
ClsOpIntr	SPS	Breaker close command canceled

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Status information (Cont.)		
OpnCmdIn	SPC	Breaker open command
ClsCmdIn	SPC	Breaker close command
ClsBlkIn	SPS	Breaker close command block input
Settings		
MaxTrEna	SPG	Enable maximum number of trips
MaxNumTr	ING	Maximum number of trips value
MaxSwA	ASG	Value for KA2 alarm
SwARsVal1	ASG	Reposition value for KA2 phase A
SwARsVal2	ASG	Reposition value for KA2 phase B
SwARsVal3	ASG	Reposition value for KA2 phase C
SwAExp	ASG	KA2 index
ArcDlTmCyc	ASG	Arc initiation delay
ArcEvTmCyc	ING	Arc calculation window
NumIn	ENG	Open Pole number of breaker inputs
OpnCurA	ASG	Open Pole current pole A open
OpnCurB	ASG	Open Pole current pole B open
OpnCurC	ASG	Open Pole current pole C open
TrSeal	SPG	Sealed enable
OpnPlsTmms	ING	Minimum open command time
ClsPlsTmms	ING	Open command failure
ClsFlTmms	ING	Minimum close command time
ClsPlsTmms	ING	Close command failure
StrInf	SPG	Fault report with pickups
MagVisMod	ENG	Primary/secondary values in fault report
ManClsChk	SPG	Synchrocheck for closing
LodShedMsk	SPG	Load shedding close command enable

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8.6 Pole Discordance Detector

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8.6.5 Digital Inputs to the Pole Discordance Detector Module 8.6-3
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8.6.8 Protection Element Test 8.6-5

8.6.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Pole Discordance Detector	PPDS1		2

8.6.2 General Block



8.6.3 Operating Principles and Block Diagram

This unit is for the purpose of detecting a discordance in the position of the three breaker poles. If this condition is maintained during the **T_PD** (***Pole Discrep Delay***) time setting, the **TRIP_PD** (**Pole Discordance Detector Trip**) trip signal is generated. Given that the single-phase reclose cycles will produce a pole discordance condition, the **T_PD** time setting should be longer than the single-phase reclose time.

Figure shows the operation diagram of the Pole Discordance Detector.

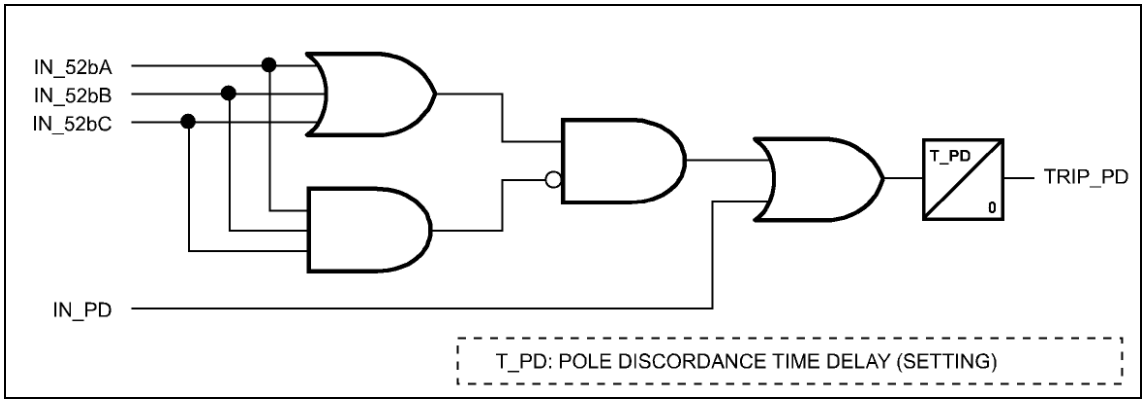


Figure 8.6.1 Diagram of the Pole Discordance Detector.

It will be possible to detect the existence of pole discordance from the status of the three digital inputs associated with the status of the three poles of the breaker (activated if the corresponding pole is open). Notwithstanding, many breakers incorporate a wiring logic in their control cabinets, which detects the pole discordance (based on the status of the **52aA/B/C** and **52bA/B/C** contacts), generating a signal in this case. For this reason, the IED incorporates a digital input, **IN_PD** (Pole Discordance Input), to receive this signal, which will directly activate the **TRIP_PD** output.

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8.6.4 Setting Ranges

Protection / Pole Discrepancy					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable Pole Discrep	Pole Discr Enable	PPDS1.LNInSvc	YES / NO		3 NO
Pole Discrep Delay	Pole discrep. Delay	PPDS1.OpDITmms	0 - 50 s	0.01 s	2 s

8.6.5 Digital Inputs to the Pole Discordance Detector Module

Table 8.6-1: Digital Inputs to the Pole Discordance Detector Module

Name	Group	IEC 61850	Description	Vis.	Function
IN_52bA	Breaker Control	SCBR1.CBInA	Pole A Open Input	I	Activation of this input indicates that the 52b contact of (A/B/C) pole position of the breaker is closed.
IN_52bB		SCBR1.CBInB	Pole B Open Input	I	
IN_52bC		SCBR1.CBInC	Pole C Open Input	I	
IN_PD		PPDS1.PoleDscIn	Pole Discordance Input	I	Activation of this input directly generates the startup of the timer associated with the pole discordance detector.
ENBL_PD	Enabling Commands	PPDS1.Mod	Pole Discrepancy Enable Input	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.6.6 Auxiliary Outputs and Events of the Pole Discordance Detector Module

Table 8.6-2: Auxiliary Outputs and Events of the Pole Discordance Detector Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
TRIP_PD	Breaker Control	PPDS1.Op	Pole Discrepancy Trip	I, F	Trip of the Unit.
PD_ENBLD		PPDS1.Mod	Pole Discrepancy Enabled	I	Indication of enabled or disabled status of the unit.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.6.7 IEC 61850 Logical Node

CLASS IRLPPSD		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status		
Op	ACT	Operation
PoleDscIn	SPS	Pole Discrepancy Input
Settings		
LnInSvc	SPG	In service
OpDlTmms	ING	Time delay

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8.6.8 Protection Element Test

The following indicators will be monitored during the test:

In the display on the **Information** - **Status** - **Measuring elements** - **Pole Discordance** screen, or on the status screen of the ***ZIV e-NET tool***® (**Status** - **Elements** - **Pole Discordance**).

The Pole Discordance Detector will be enabled and the remaining elements disabled.

Adjust the timing to 10 s.

Activate the **Pole A Open Input**, without the **Pole B Open Input** and **Pole C Open Input** inputs being active. Verify that a three-phase trip due to pole discordance is produced after 10 s.

Repeat the test with the **Pole A Open Input** and **Pole B Open Input** active without the **Pole C Open Input** active. Verify that a three-phase trip due to pole discordance is produced after 10 s.

Activate the **Pole Discordance Input** and verify that a three-phase trip due to pole discordance is produced after 10 s.

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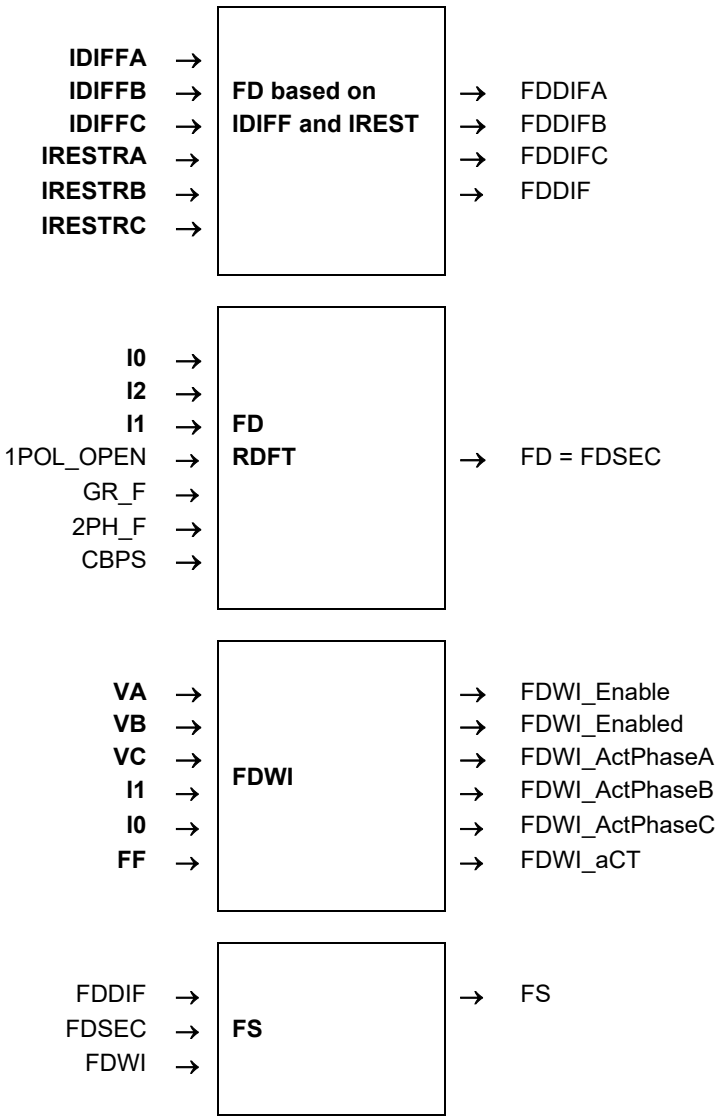
8.7 Fault Detector

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8.7.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Fault Detector based on differential and restraint currents			FDDIF
Fault Detector based on sequence currents	RDFT1	-	FD=FDSEC
Fault Detector in weak infeed conditions			FDWI
Fault start			FS

8.7.2 General Block



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LEGEND
1POL_OPEN = An open pole condition.
GR_F = Ground Fault.
2PH_F= Two-Phase Fault.
CBPS = Power Swing Conditions (when the relay has the suitable unit).
FDSEC = Fault Detector based on sequence currents.
FDDIF = Fault Detector based on differential and restraint currents.
FDWI = Fault Detector in weak infeed conditions
FF = Fuse Failure
FS = Fault start.

8.7.3 Fault Detector

The Fault Detector of the **DLF** equipment consists of three algorithms:

- - Fault Detector based on Sequence Currents.
- - Fault detector based on Differential and Restraint currents.
- - Weak Infeed Fault Detector.

8.7.3.a Fault Starts

Fault starts indicate the occurrence of a fault and define the pre-fault and post-fault instance for those units that need it, such as those that use pure fault measures such as the External Fault Detector, the Positive Sequence Differential Unit, etc. Due to the communication with the remote ends and the fact that the DLF equipment allows the operation of the local units that do not need remote measurements when there is no communication, several fault starts must be distinguished.

On the one hand, there will be fault start depending on the activation of the Fault Detector based on Sequence Currents and the Fault Detector on Weak Infeed, when enabled.

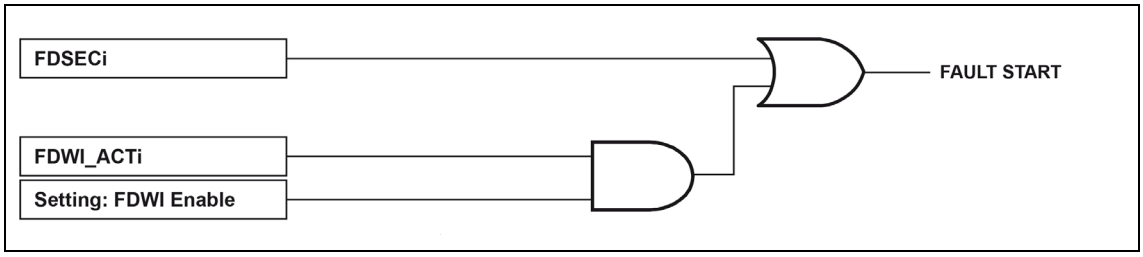


Figure 8.7.1 Block Diagram of the Fault Start Detector with Local Magnitudes.

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For the capture of the pre-fault instances for 87L differential units, two different fault starts are distinguished: for differential units without pre-fault and for differential units with pre-fault. The fault starts of the differential units take into account both the fault start previously described and that generated from the **Fault Detector based on Differential and Restraint Currents**. This latter unit needs to operate the measurement of said currents two cycles earlier, so it must be ensured that said measurements are correct. To do this, it is verified that during the last three cycles no fault has occurred (by activating the **Fault Start** signal) and no communications blocking has occurred, that is, no communications failure that invalidates the measurement of differential and restraint currents. This avoids taking erroneous pre-fault values.

The differential units that do not use pre-fault will consider the previous condition, the state of the **Fault Start** signal and the state of the **Differential Units Blocked by Communications** signal to determine the **Fault Start 87L Units without Prefault**.

On the other hand, the differential units using pre-fault will consider the activation of the **Fault Detector based on Differential and Restraint Currents**, the state of the of **Fault Start** signal, and the state of the signal **Prefault based Units Blocked by Communications** to determine the **Fault Start 87L Units with Prefault**.

8.7.3.b Trip Supervision by Fault Detector

- **Differential Units 87L**

The activation of the Fault Detector based on Sequence Currents or the activation of the Weak Infeed Detector, when enabled, will be responsible for supervising the 87L differential units (phase differential with and without restraint, neutral, positive sequence and negative sequence), provided that the ***Fault Detector Supervision 87L*** setting in the Trip Logic is set to YES. The Fault Detector based on differential and restraint currents is not considered to immunize the operation of the 87L differential units against undetected communication failures.

- **Rest of the units**

The activation of the Fault Detector based on Sequence Currents will be responsible for supervising the activation or tripping of the rest of the units (Saturation Detector, Distance Units, Fault Locator based on local measurements and the rest of the auxiliary units). To do this, the ***Fault Detector Supervision*** setting in the Trip Logic section must be set to YES.

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8.7.4 Fault Detector Based on Differential and Restraint Currents

8.7.4.a Operating Principles and Block Diagram

The Differential Unit of the **DLF** models features a Fault Detector for the supervision of their operation. The conditions which activate the Fault Detector for phase n (n=A, B and C) are the following:

- A per cent increase of the **restraint current of said phase**, with respect to two previous cycles above 20%, provided that said phase restraint current exceeds the differential element ***Sensitivity*** setting.
- A per cent increase of the **differential current of said phase**, with respect to two previous cycles above 20%, provided that said phase differential current exceeds the differential element ***Sensitivity*** setting.

The fault detector resets when the above conditions remain deactivated for two cycles and the differential current is below the 80% of the ***Sensitivity*** setting.

The logic of the fault detector associated to the differential unit for phase A is shown in the following logic diagram:

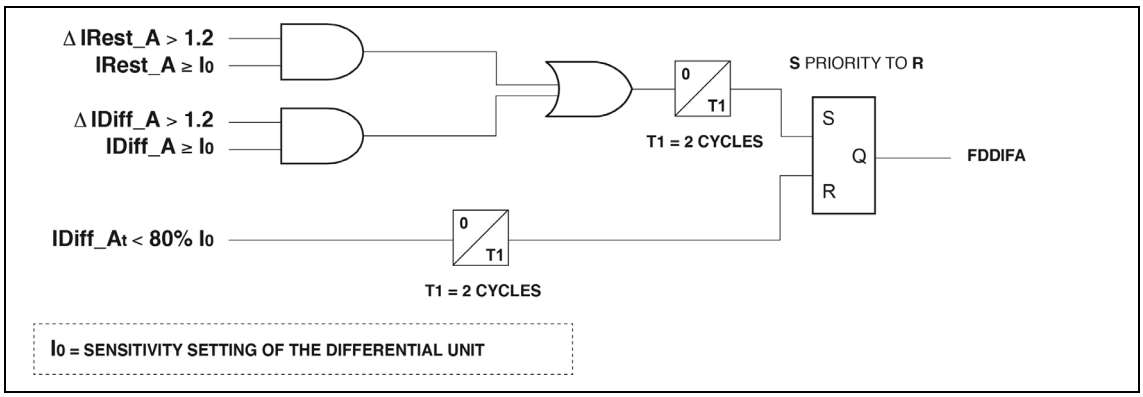


Figure 8.7.2 Fault Detector for Phase A Differential Unit Diagram.

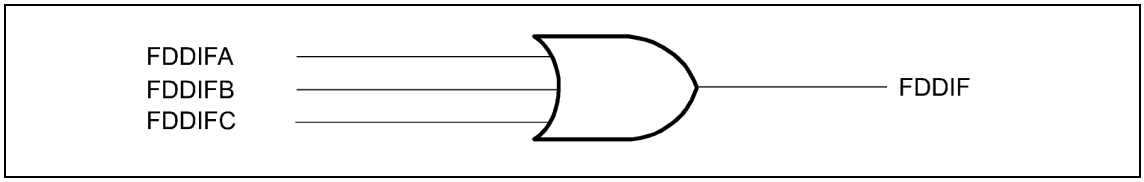


Figure 8.7.3 Fault Detector for Differential Unit Diagram.

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8.7.4.b Setting Ranges

The Fault Detector Based on Differential and Restraint Currents does not present any setting (it is only influenced by differential element sensitivity setting).

8.7.4.c Analog Inputs to the Unit

Table 8.7-1: Analog Inputs to the Fault Detector (based on Differential and Restraint Currents)

Name	Description	IEC 61850
IDIFFA	Differential Current Phase A	PDIF1.DifAClc
IDIFFB	Differential Current Phase B	PDIF1.DifAClc
IDIFFC	Differential Current Phase C	PDIF1.DifAClc
IRESTRA	Restraint Current Phase A	PDIF1.RstA
IRESTRB	Restraint Current Phase B	PDIF1.RstA
IRESTRC	Restraint Current Phase C	PDIF1.RstA

8.7.5 Fault Detector based on Sequence Currents

8.7.5.a Correlation between Analog Channels

Generic	DLF
IA	IA1
IB	IB1
IC	IC1

8.7.5.b Operating Principles and Block Diagram

The operation of this element is based on two types of algorithms:

- **Detection of Increases in the Sequence Currents**

The conditions which activate the Fault Detector are the following:

- **ΔI0:** An increase in the effective value of the **Zero Sequence Current** with respect to the value of two cycles previously higher than ***Delta I0*** setting (ground fault indicative).
- **ΔI2:** An increase in the effective value of the **Negative Sequence Current** with respect to the two cycle value previously higher than ***Delta I2*** setting (phase fault indicative).
- **ΔI1:** A percentual increase in the effective value of the **Positive Sequence Current** with respect to the two-cycle value previously higher than 25% (indicative of any fault).

The elements **ΔI0, ΔI2** y **ΔI1** activate at 1.05 times (105%) the pickup setting and they reset at 1 time (100%) the pickup setting.

Only when the relay has the suitable unit: Under Power Swing Conditions (CBPS = 1), ***Delta I0 Power Swing*** setting *and* ***Delta I2 Power Swing*** setting are used instead of ***Delta I0*** *and* ***Delta I2*** setting respectively. In addition, the Fault Detector activation based on the increase of positive sequence currents (**ΔI1)** is disabled.

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This algorithm further need at least one of the following conditions to be met:

- Positive sequence current above I1_MIN = 0.02*In A.
- Zero sequence current above I0_MIN= ***I0_LEVEL*** (***Phase Selector*** setting).

Zero sequence threshold current supervision allows the Fault Detector to be operative upon faults associated to mainly zero sequence current flow.

The activation of the Fault Detector based on previously mentioned increases will remain sealed for the duration of two cycles, given that the comparison is made with magnitudes memorized two cycles previously. Notwithstanding, an additional reset time T1 is included (T1 is 30 ms, and **only when the relay has the suitable** unit, under Power Swing Conditions (CBPS = 1), T1 is replaced by a time equal to the ***Memory Duration*** setting).

- **Detection of Levels Exceeded in the Sequence Current**

The following are the conditions which activate the Fault Detector:

- **Ground Fault** output activation (GR_F) originating from the Phase Selector.
- **Two-Phase Fault** output activation (2PH_F) originating from the Phase Selector.

An open pole condition (1POL_OPEN) excludes the **Ground Fault** and **Two Phase Fault** signals from the fault detector. Otherwise, this situation would activate the detector as long as the pole remains open.

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- **Sealed Algorithms**

The activation of the Fault Detector generated by either of the two previously-mentioned algorithms is kept sealed with the activation of any of the next units:

- **Overcurrent Units** (**OC_PU**): any instantaneous or temporized overcurrent unit associated with the suitable analog channels of the relay (see 8.3.5.a, Correlation between analog channels).
- **Distance zones** (**DIST_PU**): any distance zone activation (only when the relay has the suitable unit).
- **Closing on to fault Pickup** (**COF_PU**): Any activation of the closing on to fault unit (only when the relay has the suitable unit).

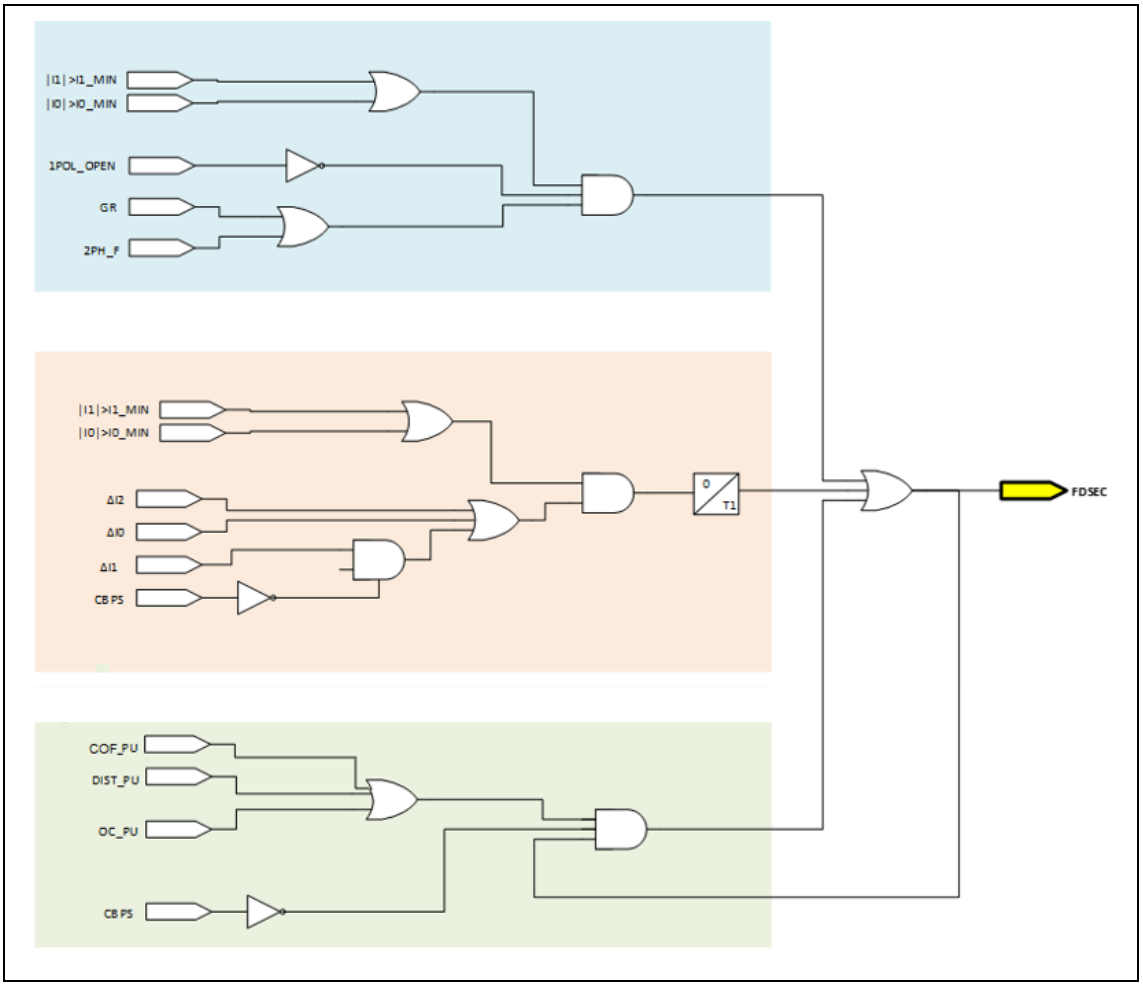


Figure 8.7.4 Fault Detector Block Diagram.

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8.7.5.c Setting Ranges

Protection / Fault Detector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Delta I0	Delta I0	RFDT1.Incrl0	0.02-5.00 A	0.01 A	0.05 A
Delta I2	Delta I2	RFDT1.Incrl2	0.02-5.00 A	0.01 A	0.05 A
Delta I0 Power Swing (*)	Delta I0 P. Swing		0.02-5.00 A	0.01 A	0.05 A
Delta I2 Power Swing (*)	Delta I2 P. Swing		0.02-5.00 A	0.01 A	0.05 A

(*) Only when the relay has the suitable unit.

8.7.5.d Analog Inputs to the Unit

Table 8.7-2: Analog Inputs to the Fault Detector Module		
Name	**Description**	**IEC 61850**
I1	Positive Sequence Current	MSQI1.SeqA.c1
I2	Negative Sequence Current	MSQI1.SeqA.c2
I0	Zero Sequence Current	MSQI1.SeqA.c3

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

$I_0 = I_N / 3$

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

$$|I_1| = \left| \frac{I_A + I_C \cdot 1\angle 240° + I_B \cdot 1\angle 120°}{3} \right|$$

8.7.6 Fault Detector in Weak Infeed Conditions

In weak infeed conditions, the Fault Detector described above may be disabled because the positive and zero sequence current level will be lower than the minimum operating level of the fault detector (0.02*In and Level_I0 respectively). Therefore, a new module called Weak Infeed Fault Detector will be implemented, which will be enabled by the corresponding ***Enable*** setting. In addition to the setting, this module will only work when the following conditions are met (both at the same time):

- The positive sequence current is less than level 0.02*In.
- The zero sequence current is lower than the setting ***Level_I0*** (Phase Selector setting).

If both conditions are met, supervision will be based on the activation of three undervoltage units (one per phase), whose starting level is given by the ***WI Undervoltage Level*** setting (Phase Selector settings). If any of the three phases has a voltage level lower than the setting, the FDWI_ACT signal will be activated, as long as the phase or phases with undervoltage do not have their corresponding open poles or there is no blocking due to a fuse failure. These undervoltage units shall be reset when the voltage level of the phase(s) is 1.05 times higher than the ***WI Undervoltage Level*** setting.

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On the other hand, the signals **FDWI_ActPhaseA**, **FDWI_ActPhaseB** and **FDWI_ActPhaseC** will be used as phase selector, in case of weak infeed, for the neutral, positive and negative sequence differential units .

This fault-detection by weak infeed will only affect the differential units *and in no case will it affect the distance units.*

8.7.6.a Setting Ranges

Table 8.7-3: Analog inputs to the Fault Detector (based on differential and restraint currents)		
Name	**Description**	**IEC 61850**
IAJS_ENBL_FDWI	Enable	

8.7.6.b Analog Inputs to the Unit

Table 8.7-4: Analog inputs to the Fault Detector (based on differential and restraint currents)		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	
VB	Phase B Voltage	
VC	Phase C Voltage	

8.7.7 Digital Inputs of the Fault Detector

The Fault Detector does not present any digital input, not even enable, remaining always in operation.

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8.7.8 Auxiliary Outputs and Events of the of the Fault Detector

Table 8.7-5:Auxiliary Outputs and Events of the Fault Detector (based on Differential and Restraint Currents)

Name	Group	IEC 61850	Description	Vis.	Function
FDDIFA	Pickup Protection Outputs Generic Outputs of Protection		Fault Detector Differential Unit Phase A"	I	Activation of Fault Detector based on differential and restraint currents phase A.
FDDIFB			Fault Detector Differential Unit Phase B	I	Activation of Fault Detector based on differential and restraint currents phase B.
FDDIFC			Fault Detector Differential Unit Phase C	I	Activation of Fault Detector based on differential and restraint currents phase C.
FDDIF			Fault Detector Differential Unit	I	Activation of Fault Detector based on differential and restraint currents (OR for activation in three phases).
FDWI_ENBLD			Weak Infeed fault detector enabled		Indicates that the weak infeed fault detector is enabled.
FDWI_ACTFASEA			Phase A weak infeed fault detector activation		Indicates activation of weak infeed phase A.
FDWI_ACTFASEB			Phase B weak infeed fault detector activation		Indicates activation of weak infeed phase B.
FDWI_ACTFASEC			Phase C weak infeed fault detector activation		Indicates activation of weak infeed phase C.
FDWI_Act			Weak infeed fault detector activation		Indicates activation of weak infeed.
FS_PREF			Fault Start 87L units with prefault		Fault start signal for 87L units using pre-fault magnitudes.
FS_SINPREF			Fault Start 87L units without prefault		Fault start signal for 87L units not using pre-fault magnitudes.
FD	Generic Outputs of Protection	RFDT1.FltInd	Fault Detector Activation by Sequence Currents	I	Detection of the existence of a fault by the Fault Detector by sequence currents.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.7.9 IEC 61850 Logical Node

CLASS IRLRDFT		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
FtlInd	SPS	Fault detector activated
Settings		
IncrI0	ASG	Minimum value to detect increments of I0
IncrI2	ASG	Minimum value to detect increments of I2

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8.8 Phase Selector

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8.8.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Phase Selector	RPSL1	-	-

8.8.2 General Block



LEGEND
FD = Fault Detector
1POL_OPEN = An open pole condition
CBPS = Power Swing Conditions (when the relay has the suitable unit)

8.8.3 Operation Principles

The function of the Phase Selector unit is to determine the type of failure to generate the outputs which include this information.

The selection of the faulted consists basically of two algorithms. The first algorithm determines that a three-phase (**3PH_F**) fault is generated if the following conditions are met:

1. **Low Negative Sequence Current**: the presence of a negative sequence current not greater than the setting ***I2 Level*** and a ratio of negative sequence current / positive sequence current no greater than the setting ***I2/I1 Factor***.
2. **Low Zero Sequence Current**: the presence of a zero sequence current no greater than the setting ***I0 Level*** and a ratio of zero sequence current / positive sequence current no greater than the setting ***I0/I1 Factor***.

The percentages of negative and zero sequence current with respect to the positive sequence current avoid erroneous phase selections due to imbalance deriving from a different degree of saturation presented by the current transformers in case of three-phase faults.

It is important to point out that the three-phase indication is associated with a balanced condition, for which it would also arise in a load situation. The Fault Detector will be in charge of distinguishing the fault condition of a load.

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When the detected fault does not satisfy the conditions to be considered a three-phase fault, the second algorithm of the Phase Selector will be executed, based on the comparison between positive and negative sequence current angles.

When the fault is not three-phase, but the second condition for three-phase faults is satisfied (low zero sequence current component), the fault involves two phases (**2PH_F**). If the second condition for three-phase faults is not met (high zero sequence current component), a ground fault has occurred, which could be single-phase or two phases to ground (**GR_F**).

To determine the phases involved, the angle will be examined:

$$\phi = \arg\left(Ia2\right) - \arg\left(Ia1_f\right)$$

Where:

$Ia2$	Phase A negative sequence current.
$Ia1_f$	Phase A positive sequence fault current (without the load component).

The angle diagrams, used to determine the phases under fault as a function of the angle ϕ, are represented in next Figures.

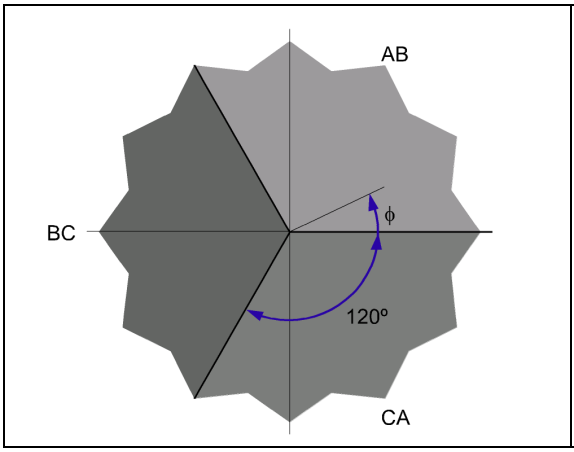


Figure 8.8.1 Two-Phase Fault Angle Diagram.

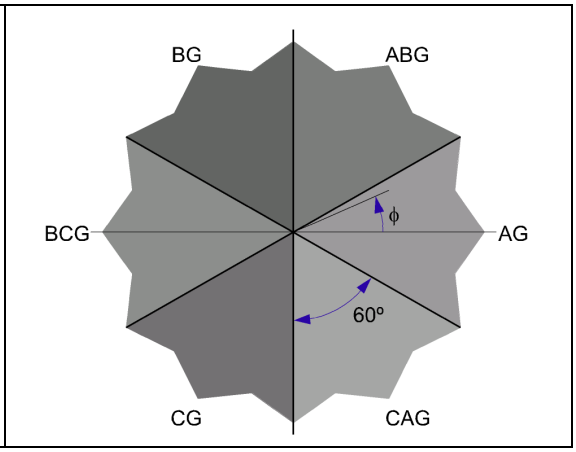


Figure 8.8.2 Single-Phase and Two-Phase- to-Ground Fault Angle Diagram.

The phase selector will not operate if the following two conditions are simultaneously complied with:

1. Presence of positive sequence current component not above 0.02*In A.
2. Presence of zero sequence current component not above 0.05*In A.

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8.8.3.a Phase Selection upon Faults with Mainly Zero Sequence Current Flow

The presence of power transformers with grounded wye connected windings, generate, upon weak infeed faults, mainly zero sequence fault current flow. In this case, the positive sequence current can be below 0.02*In A, whereas the zero sequence current will be above the setting ***Level I0***. If these conditions are met, the Phase Selector will consider it a ground fault but will not determine the faulted phases from the angle between positive and negative sequence currents but based on the activation of three undervoltage elements (one per phase), the pickup level of which is given by the ***WI Undervoltage Level*** setting, also used by the Weak Infeed Logic (when the relay has the suitable unit).

8.8.3.b Phase Selection in Open-Pole or Power Oscillation Conditions

The opening of a breaker pole, detected through the Open-Pole Detector, creates an imbalance which generates negative and zero sequence components in load conditions. The Phase Selector will remove pre-fault currents in order to operate with fundamental fault currents.

To determine the fault phases the following angle is studied:

$$\phi = \arg\left(Ia2_f\right) - \arg\left(Ia0_f\right)$$

Where:

$Ia2_f$	Phase A Negative Sequence fault current (load component removed).
$Ia0_f$	Phase A Zero Sequence fault current (load component removed).

The figure shows the angle diagrams used for the determination of the fault phases as a function of the ϕ angle.

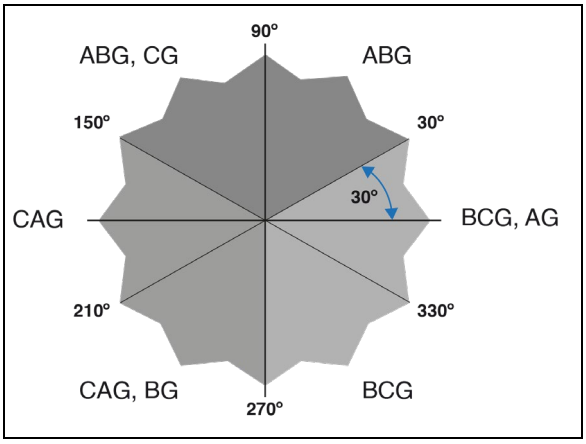


Figure 8.8.3 Angle Diagram for Single-Phase and Two-Phase to Ground Faults.

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To differentiate the faults AG and BCG, CG and ABG, BG and CAG, the I0/I2 quotient is used:

If Ia0_f / Ia2_f > **K**, we will have a single-phase fault (AG, BG or CG).
If Ia0_f / Ia2_f < **K**, we will have a two-phase to ground fault (BCG, ABG and CAG).

Where **K** is an internal parameter.

In Power Swing conditions (CBPS = 1) and during the 500 ms after its deactivation this same criterion is also used.

8.8.4 Setting Ranges

Protection / Phase Selector					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
I0 Level	I0 Level	RPSL1.I0Lev	0.02-5.00 A	0.01 A	0.05 A
I2 Level	I2 Level	RPSL1.I2Lev	0.02-5.00 A	0.01 A	0.05 A
I0/I1 Factor	I0/I1 Factor	RPSL1.I0I1Fact	1 - 100 %	0.1 %	8%
I2/I1 Factor	I2/I1 Factor	RPSL1.I2I1Fact	1 - 100 %	0.1 %	10%
I0/I1 Factor Pow. Swing (*)	I0/I1 Fact Pow Swi		1 - 100 %	0.1 %	20%
I2/I1 Factor Pow. Swing (*)	I0/I1 Fact Pow Swi		1 - 100 %	0.1 %	20%
WI Undervoltage Level	WI Undervolt Level	PSCH1.PhGndVal	15.00-70.00 V	0.01 V	45 V

(*) Only when the relay has the suitable unit.

8.8.5 Analog Inputs to the Unit

Table 8.8-1: Analog Inputs to the Fault Detector Module		
Name	**Description**	**IEC 61850**
I1	Positive Sequence Current	MSQI1.SeqA.c1
I2	Negative Sequence Current	MSQI1.SeqA.c2
I0	Zero Sequence Current	MSQI1.SeqA.c3

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

$I_0 = I_N / 3$

$$|I_2| = \left| \frac{I_A + I_B \cdot 1\angle 240° + I_C \cdot 1\angle 120°}{3} \right|$$

$$|I_1| = \left| \frac{I_A + I_C \cdot 1\angle 240° + I_B \cdot 1\angle 120°}{3} \right|$$

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8.8.6 Digital Inputs to the Phase Selector

The Phase Selector does not present any digital input, not even enable, remaining always in operation.

8.8.7 Auxiliary Outputs and Events of the Phase Selector

Table 8.8-2: Auxiliary Outputs and Events of the Phase Selector

Name	Group	IEC 61850	Description	Vis.	Function
AG_F	Generic Outputs of Protection	RPSL1.FltAG	AG Fault	I, F	Indication of type of fault.
BG_F		RPSL1.FltBG	BG Fault	I, F	
CG_F		RPSL1.FltCG	CG Fault	I, F	
AB_F		RPSL1.FltAB	AB Fault	I, F	
BC_F		RPSL1.FltBC	BC Fault	I, F	
CA_F		RPSL1.FltCA	CA Fault	I, F	
ABG_F		RPSL1.FltABG	ABG Fault	I, F	
BCG_F		RPSL1.FltBCG	BCG Fault	I, F	
CAG_F		RPSL1.FltCAG	CAG Fault	I, F	
ABC_F		RPSL1.Flt3Ph	ABC Fault	I, F	
GR_F		RPSL1.FltGnd	Ground Fault	I, F	
2PH_F		RPSL1.Flt2Ph	Two Phase Fault	I, F	
MULTIPH_F		RPSL1.FltMltPh	Multi Phase Fault	I, F	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.8.8 IEC 61850 Logical Node

CLASS IRLRPSL		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
FltAG	SPS	AG type fault
FltBG	SPS	BG type fault
FltCG	SPS	CG type fault
FltAB	SPS	AB type fault
FltBC	SPS	BC type fault
FltCA	SPS	CA type fault
FltABG	SPS	ABG type fault
FltBCG	SPS	BCG type fault
FltCAG	SPS	CAG type fault
Flt3Ph	SPS	3 phase type fault
FltGnd	SPS	Ground type fault
Flt2Ph	SPS	2 phase type fault
FltMltPh	SPS	Multy phase type fault
Settings		
I0Lev	ASG	Minimum value to detect increments of I0
I2Lev	ASG	Minimum value to detect increments of I2
I0I1Fact	ASG	
I2I1Fact	ASG	

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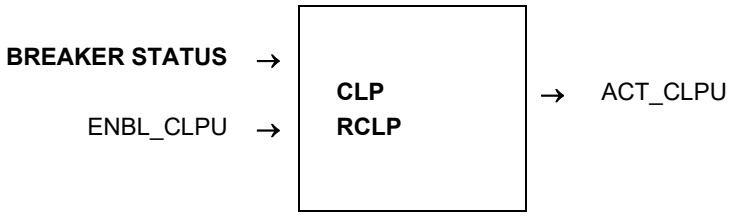
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8.9.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Cold Load Element	RCLP1	-	CLP

8.9.2 General Block



8.9.3 Operation Principles

If a breaker has been open for a long time after line recloser failure, problems may occur when closing. When breaker is closed, large motors may start demanding high current peaks. Overcurrent protection may activate as a result of this. Pickup levels must be increased to prevent the above, and last active table can be used to this end as a second group with higher calibration settings.

By definition of their application, IEDs operate on more than one breaker. When applying the “cold load” function, it is necessary to select, via a setting (***Cold Load Breaker***), which breaker position will be supervised, i.e. which winding it corresponds to.

Assuming the relay works using Table 1 and the supervised breaker opens, a timer starts timing and if breaker remains open after time-out, settings in ”last active table” apply. Last active table will be the active table while breaker remains open.

When breaker closes, the IED will be working with higher settings, and trips caused by starting motors will not take place.

A timer starts timing after closing, and if breaker remains closed after time-out, Table 1 activates. If this function is disabled, last active table can be used in the same way as other tables.

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It could happen that with the Cold Load Unit enabled, the breaker changes state while the equipment is switched off. In this case, the unit works as follows:

- **If equipment is switched off when breaker is closed and breaker is open when switched on**, Cold Load Unit activates 100 milliseconds after equipment is switched on, and last active table will apply.
- **If equipment is switched off with Cold Load Unit activated (Table 4 applies after breaker trips) and breaker is closed when switched on**, Cold Load Unit remains activated during 100 milliseconds (Last active table) after pickup. When time expires the unit resets and the last relay operate table before activation of Cold Load Unit will apply.
- **If equipment is switched off with Cold Load Unit activated and unit disable digital signal is active when switched on**, unit output remains active during 100 milliseconds after pickup. When time expires output resets and the original table will apply.
- **If equipment is switched on with Cold Load Unit deactivated and breaker opens within 100 milliseconds wait time for unit pickup**, unit output will activate instantaneously after said time.
- **If equipment is switched off with Cold Load Unit activated and breaker remains open when switched on**, unit continuous its normal operation as if nothing had happened.

8.9.4 Setting Ranges

Protection / Cold Load					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Cold Load Enable	Cold Load Enable		YES / NO		NO
Cold Load Breaker	Cold Load Breaker		1 - 3	1	1
Activation Time for last active table	Last Grp Act Time		0 - 1800 s	0.1 s	120 s
Timer for Previous Group Activation after Closing	Prev Grp Act Time		0 - 1800 s	0.1 s	120 s

8.9.5 Digital Inputs to the Cold Load Module

Table 8.9-1: Digital Inputs to the Cold Load Module

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_CLPU			Cold Load Enable Input	I	Activation of this input puts the element into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.9.6 Auxiliary Outputs and Events of the Cold Load Module

Table 8.9-2: Auxiliary Outputs and Events of the Cold Load Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ACT_CLPU			Cold Load activation (Table 4)	I	This signal indicates that cold load logic is activated so that settings in Table 4 apply. Or is deactivated so that settings in the original Table apply.
CLPU_ENBLD			Cold Load enabled	I	Indication of enabled or disabled status of the element.
ENBL_CLPU			Cold Load enable input	I	The same as for the Digital Inputs.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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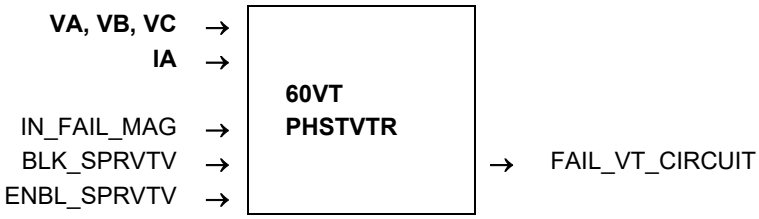
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8.10.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Voltage Measurement Circuit Supervision	PHSTVTR1	MCS 3V	60VT

8.10.2 General Block



8.10.3 Operation Principles and Block Diagram

In order to avoid incorrect operations issued by the units that use voltage measurements, the equipment has a function to check if a drop in the measurement is produced by a failure in the analog voltage measurement reception circuit.

This supervision unit blocks inputs from protection elements when the protection magnetic-thermal circuit breaker of the voltage measuring transformer has previously tripped. The logic related to the detection of the thermal-magnetic circuit breaker trip conditions must be carried out before the functions it blocks. The logic associated to the element is indicated in the following figure.

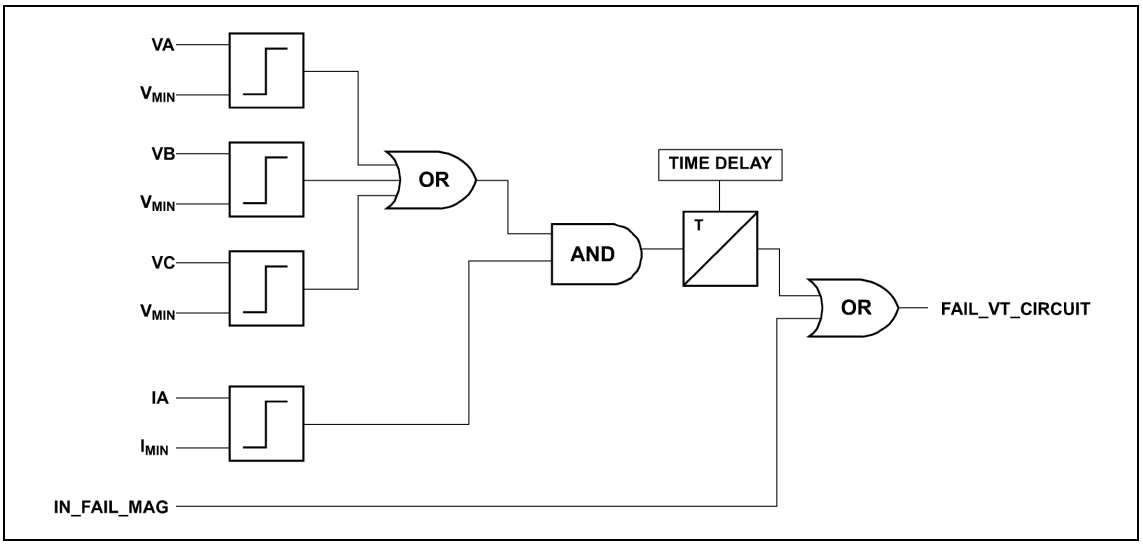


Figure 8.10.1 Voltage Circuit Failure Detection Element Scheme.

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Current on phase A (IA) is compared with the setting value ***C Min VT Supervision***. If IA is higher all phase voltages will be compared with the corresponding setting value ***V Min VT Supervision***. In this case, if those phase voltages are lower than the set voltage value, the relay will activate the signal **Failure on Voltage Measuring Circuit** after a certain time delay (***VT Supervision Timer*** setting). The blocking of those protection units affected by the voltage measurement unbalance will have to be duly programmed in the logic module through the communication program ***ZIV e-NET tool***®.

8.10.4 Setting Ranges

Protection / Voltage Transformer Supervision					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
VT Supervision Enable	VT Superv Enable	PHSTVTR1.SupSvc	YES / NO		NO
C Min VT Supervision	C min VT Superv	PHSTVTR1.SupMinA	0.2-2 A	0.01A	0.5 A
V Min VT Supervision	V min VT Superv	PHSTVTR1.SupMinV	2-100 V	0.01 V	30 V
VT Supervision Timer	VT Superv Time	PHSTVTR1.SupTmms	0.01-5 s	0.01 s	0.05 s

8.10.5 Digital Inputs to the Voltage Measurement Circuit Supervision Module

Table 8.10-1: Digital Inputs to the Voltage Measurement Circuit Supervision Module

Name	Group	IEC 61850	Description	Vis.	Function
IN_FAIL_MAG	Logic Inputs to Protection	PHSTVTR1.SupFailIn	Voltage Circuit Supervision Fail Input	I	The activation of this input means direct activation of voltage circuit failure Detector signal.
BLK_SPRVTV		PHSTVTR1.SupBlk	Block VT Supervision Unit	I	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_SPRVTV	Enabling Commands	PHSTVTR1.SupEna	Enable VT Supervision Unit	I	Activation of this input puts the unit into service. It can be assigned to status contact inputs by level or to a command from the communications protocol or from the HMI. The default value of this logic input signal is a “1.”

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.10.6 Auxiliary Outputs and Events of the Voltage Measurement Circuit Supervision Module

Table 8.10-2: Auxiliary Outputs and Events of the Voltage Measurement Circuit Supervision Module

Name	Group	IEC 61850	Description	Vis.	Function
FAIL_VT_CIRCUIT	Trip Protection Outputs	PHSTVTR1.SupFail	VT Supervision Unit Active	I	It shows that although voltage measurement does not reach the equipment, there actually is voltage. So that no trip on lack of voltage shall be performed.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.10.7 IEC 61850 Logical Node

CLASS IRLPHSTVTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
Vol	SAV	Voltage
Status information		
FuFail	ACD	TVTR fuse failure
Settings		
VRtg	ASG	Rated Voltage
Rat	ASG	Winding ratio of external voltage transformer
Extended Data		
SupEna	EXT_SPC	TVTR supervision enable command
SupBlk	EXT_SPC	TVTR supervision block command
SupFailIn	EXT_SPS	Supervision failure input
SupFail	EXT_SPS	Supervision failure signal
SupSvc	EXT_SPG	Supervision in service
SupTmms	EXT_ING	Supervision delay time
SupMinA	EXT_ASG	Supervision minimum current
SupMinV	EXT_ASG	Supervision minimum voltage
FuFailIn	EXT_SPS	Fuse failure input
FuFailBlk	EXT_SPS	Fuse failure block
FuFailSvc	EXT_SPG	Fuse failure in service
FuFailBlkE	EXT_SPG	Enable fuse failure block
FuInRsTmms	EXT_ING	Fuse failure delay time
FuFailMinV	EXT_ASG	Fuse failure minimum operating voltage

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8.10.8 Voltage Measurement Circuit Supervision Test

Without the injection of any magnitude, activate the **Voltage Circuit Supervision Fail Input** signal, which will have been configured in a DI or allocated in a control logic. Check that the **Voltage Circuit Failure** activates without any time delay. Carry out the same check applying voltage above the minimum voltage setting value and current below the minimum current setting, a similar behavior being observed when the **Voltage Circuit Supervision Fail Input** signal is activated.

Beginning with the injection of IA above the minimum current setting and the three phase voltages above the minimum voltage setting, keep the voltages VB and VC above this value and decrease VA until it is below the setting. Check that the element output activates when **VA** < ***V Min VT Supervision*** and deactivates when **VA** ≥ ***V Min VT Supervision***. Namely, there is no hysteresis between pickup and reset, this value being approximately 50mV.

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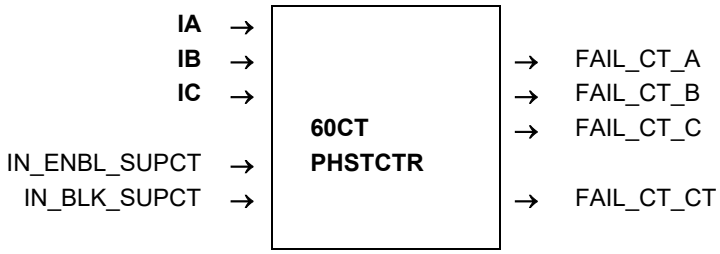
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8.11.1 Current Measurement Circuit Supervision

8.11.1.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Current Measurement Circuit Supervision	PHSTCTR	MCS 3I	60CT

8.11.1.b General Block



8.11.1.c Operation Principles and Block Diagram

All models count on a supervision system for the set of elements that make up the phase current measurement system, from external current transformers, to copper cables that connect them to the relay, up to the internal magnetic modules on the IED itself.

This supervision function is exclusively based on the measurement of phase currents. Measurement of the three phase currents is required for its application. Otherwise, it must be disabled.

Due to the unlikely simultaneous failure of more than one phase, a simple algorithm is used to enable the detection of failures in a single phase each time. Simultaneous failures are not detected.

When a phase current (phase **X**) below 2% of its rated value is detected, other phase currents are checked (phases **Y** and **Z**) to see if they exceed 5% and are below 120% of their rated value. The angular difference between these currents is also calculated, which, under normal operating conditions, must be within the 120º±10º range.

If “normal” operating conditions are detected in phases **Y** and **Z**, the phase **X** current circuit failure alarm is activated.

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Figure shows the supervision algorithm used for current measurement in phase A.

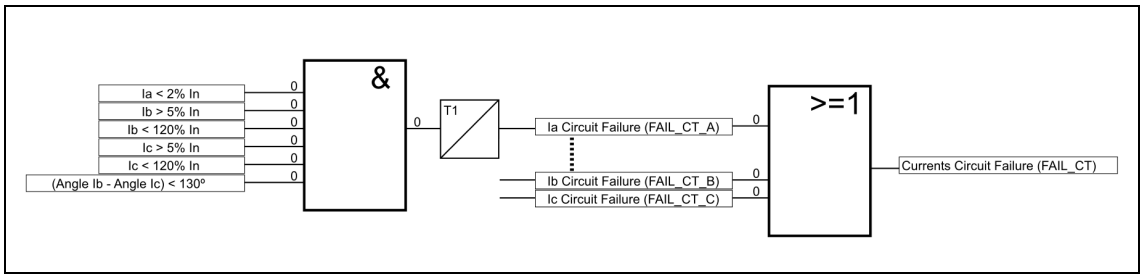


Figure 8.11.1 Supervision Algorithm for Current Measurement in Phase A.

Failure detection in any of the measuring circuits only generates the activation of the **CT Supervision Unit Phase A, B and C Active** (**FAIL_CT_A**, **FAIL_CT_B**, **FAIL_CT_C**) and **CT Supervision Unit Active** (**FAIL_CT**) signals. Blocking the operation of protection elements that are affected by measurement unbalance of phase currents must be programmed in ***ZIV e-NET tool***® logic.

8.11.1.d Setting Ranges

Protection / Current Transformer Supervision					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
CT Supervision Enable	CT Superv Enable	PHSTCTR1.SupSvc	YES / NO		NO
CT Supervision Timer	CT Superv Time	PHSTCTR1.SupTmms	0.05-300 s	0.01 s	0.05 s

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8.11.1.e Digital Inputs to the Current Measurement Circuit Supervision Module

Table 8.11-1: Digital Inputs to the Current Measurement Circuit Supervision Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_ENBL_SUPCT	Enabling Commands	PHSTCTR1.SupEna	Enable CT Supervision Unit	I	Activation of this input brings the element into operation. It can be assigned to a digital input by level or to a command from the communications protocol, or from the HMI: The default value for this logic input is “1”.
IN_BLK_SUPCT	Logic Inputs to Protection	PHSTCTR1.SupBlk	Block CT Supervision Unit	I	Activation of this input generates the blocking of the supervision.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.11.1.f Auxiliary Outputs and Events of the Current Measurement Circuit Supervision Module

Table 8.11-2: Auxiliary Outputs and Events of the Current Measurement Circuit Supervision Module

Name	Group	IEC 61850	Description	Vis.	Function
FAIL_CT_A	Trip Protection Outputs	PHSTCTR1.SupFail	CT Supervision Unit Phase A Active	I	Its activation indicates the existence of a failure in the measuring system of one of the phases
FAIL_CT_B		PHSTCTR1.SupFail	CT Supervision Unit Phase B Active	I	
FAIL_CT_C		PHSTCTR1.SupFail	CT Supervision Unit Phase C Active	I	
FAIL_CT		PHSTCTR1.SupFail	CT Supervision Unit Active	I	
ENBL_SUPCT	Enabled Units Protection Outputs	PHSTCTR1.SupEna	CT Supervision Unit Enabled	I	Block output due to condition of fuse failure detected by the element in question.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.11.1.g IEC 61850 Logical Node

CLASS IRLPHSTCTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
Amp	SAV	Current
Settings		
ARtg	ASG	Rated Current
Rat	ASG	Winding ratio of external current transformer
Extended Data		
SupEna	EXT_SPC	TCTR supervision enable command
SupBlk	EXT_SPC	TCTR supervision block command
SupSvc	EXT_SPG	Supervision in service
SupTmms	EXT_ING	Supervision delay time
SupFail	EXT_ACT	TCTR supervision failure

8.11.1.h Current Measurement Circuit Supervision Test

Inject a system of balanced currents of a value 5% above In. Reduce the current value by injecting current into a phase until a value 2% below In is reached. Assign a lag between 110º and 130º to phases B and C. Under these conditions, the element will operate.

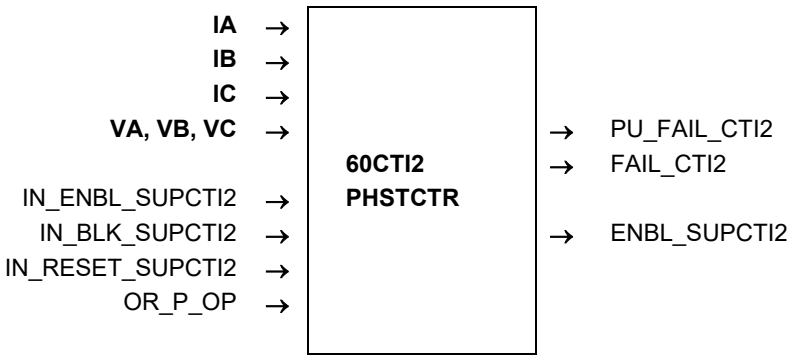
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8.11.2 Current Measurement Supervision by Negative Sequence Current

8.11.2.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Current Measurement Circuit Supervision by Negative Sequence Current	PHSTCTR1	MCS 3I	60CTI2

8.11.2.b General Block



8.11.2.c Operation Principles and Block Diagram

This supervision function of the phase CTs is based on the measurement of the phase currents to calculate the negative sequence current, and on the measurement of the phase voltages to calculate the negative sequence voltage of the system.

In case of failure of one or two CTs, the equipment will detect the presence of negative sequence current (I2 ≠ 0) without presence of negative sequence voltage (V2 = 0), detecting the failure in the supervised phase CTs group.

In order to make the negative sequence value (I2) generated by the IT failure independent of the load level existing in the system (I1), the unit works with the I2/I1 ratio (activation at 100% of the setting and reset at 95%). For this reason, for the unit to operate, a load value (positive sequence current I1) equal to or greater than the set value (***Minimum Load*** setting) must be present. This prevents the unit from operating at very low loads that would generate a high negative sequence level (I2/I1) due to the measurement error of the CTs themselves. As a note, it should be mentioned that the unit considers no load when the positive sequence is less than or equal to 95% of the setting.

The absence of phase voltage will generate a null negative sequence voltage level (V2=0), so the unit could indicate CT failure in case of single or two-phase fault in the system. To avoid this, the unit is blocked by activation of the **Frequency Disabled by Lack of Voltage** signal (**BLK_MIN_V**) when the voltage does not meet the minimum stability conditions (see Chapter 3.2, Frequency Units).

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The unit is also blocked if any of the following conditions are met:

- The negative sequence voltage is equal to or greater than 100% of the maximum residual voltage of the system (***Maximum residual Voltage*** setting). The blocking is reset when the negative sequence voltage is equal to or less than 95% of the setting.
- The positive sequence current is equal to or higher than the positive sequence current that existed two cycles before. In case of CT failure, the positive sequence current is never increased.
- The current of one of the phases is equal or higher than the set ***Maximum Current*** value. The CTs group supervision is assumed to be in load condition, so the unit should be blocked in fault condition. The value of the Maximum Current setting should be adjusted to the maximum system load. The blocking is reset when the current is equal to or less than 95% of the setting for more than 3 cycles.
- The activation of the **Block CT Supervision Unit** input signal (**IN_BLK_ENER**). The breaker closing may cause a negative sequence voltage transient (when the CT is on the line side) and energization situations where the negative sequence voltage may be lower than the maximum residual voltage. To avoid CT fault activation in these cases, the unit can be blocked by connecting in the user logic the breaker closing command to the **IN_BLK_ENER** signal using the ***ZIV e-NET tool***® program. It should be noted that the unit will be blocked with the activation of the **IN_BLK_ENER** signal and will remain blocked until the ***Closing Block Time*** has elapsed after the deactivation of the **IN_BLK_ENER** signal.
- Activation of the signal **Block input CT Supervision Unit I2** (**IN_BLK_SUPCTI2**).

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The figure shows the CT supervision algorithm based on negative sequence:

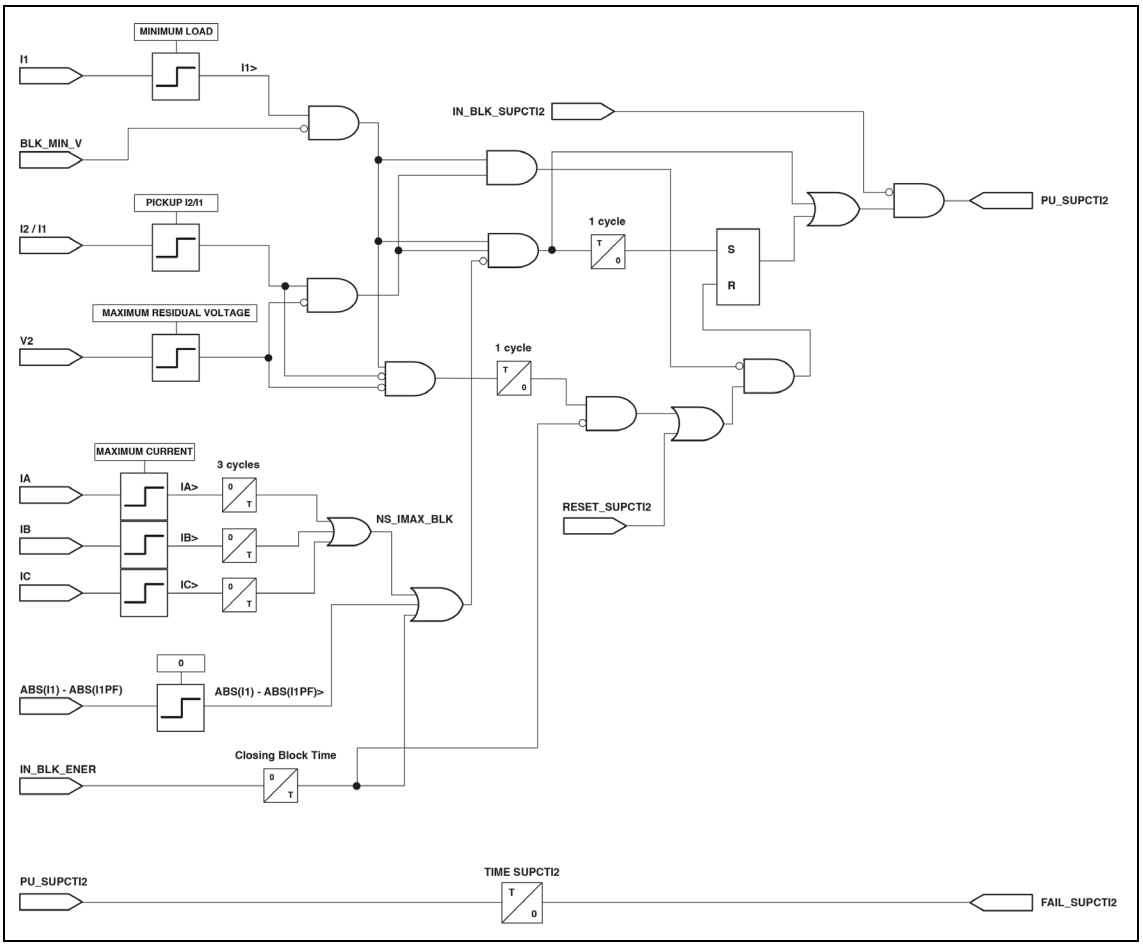


Figure 8.11.2 CT Supervision Algorithm based on Negative Sequence.

The detection of a fault in any of the measurement circuits generates the activation of the unit pickup (**PU_SUPCTI2**). Once a signal cycle has elapsed with the pickup activated, it is sealed, producing the activation of the unit (**FAIL_SUPCTI2**) at the end of the time adjusted as supervision time (***CT Supervision Timer***).

Once the fault detected in the CT group has been corrected, the user can reset the unit by activating the **Reset input CT Supervision Unit I2** signal (**RESET_SUPCTI2**) which will reset the CT fault indication whenever the fault conditions have disappeared. The unit has an automatic reset, which occurs when the CT fault conditions have disappeared and the unit detects stable load and voltage conditions in the system for one cycle.

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8.11.2.d Application

The CT Supervision by Negative Sequence unit has real application in cases where the detection of the CT failure must be performed very quickly, for example, to block the activation of the Phase Differential unit when the system load is higher than the sensitivity of the differential unit and thus prevent the tripping of the unit due to the false differential current caused by the CT failure.

As possible CT failures, the following cases may occur:

- Failure of one CT (secondary open). In this case I2/I1 = 0.5
- Failure of two CTs (secondaries open). In this case I2/I1 = 1
- Secondary short-circuit, in which case I2/I1 < 0.5

When a CT fails, a false negative sequence current (I2) is produced at the same time as a false differential current (**I_DIF**) is produced. The false differential current **I_DIF** will trip the equipment if the load current (**I_LOAD**) is higher than the sensitivity (Io) x tap setting.

The CT monitoring unit can block the Differential Unit if the CT fault activation signal (**PU_SUPCTI2** or **FAIL_SUPCTI2**) is connected to the differential unit blocking input through the programmable logic (use the maximum priority logic which is executed every 2 ms). In this case, to avoid tripping, I2/I1 must reach the value of the ***Pickup I2/I1*** setting before **I_DIF** reaches the value of the sensitivity Io x tap.

The false differential current **(I_DIF**) due to the CT failure starts with a value of 0 A to reach steady state in 1 cycle. During 1 cycle the differential current experiences a transient (due to the measurement algorithm) whose curve is similar to the transient that experiences I2/I1, so the following approximation can be made:

$$I_DIF / I_LOAD = 2 \times I2/I1$$

That is, for a maximum load value and a given differential unit sensitivity setting (**Io**), the CT fault unit pickup setting (***Pickup I2/I1***) should comply with the following expression:

$$Pickup\ I2/I1 < 0.5 \times (Io \times tap / I_LOAD)$$

This condition is not sufficient to completely define the pickup setting of the CT fault unit, since, even if the CT fault unit picks up before the phase differential unit, the activation of the blocking signal could occur during the following 2 ms, enough time for the differential unit to detect its pickup level and trip.

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Although the theoretical curve for setting the CT fault unit can be determined based on the sensitivity setting of the differential unit, load, etc., it is most practical to perform a small laboratory test.

The following are the most representative setting values for this application in the worst-case scenario (maximum load = 1.2 x rated current):

Phase Differential Unit Sensitivity Setting (Io)	CT Supervision Unit Pickup I2/I1 Setting
0.05	0.04
0.1	0.06
0.2	0.09
0.3	0.09

As a note for this application, the unit has sufficient stability against transformer energization, so it is not necessary to configure any blocking of the unit due to harmonic detection. Doing so would blocking the unit during the transient that occurs on CT failure preventing the blocking of the differential unit.

In addition to the special application discussed above, the behavior of the unit in some application cases is described below:

CT Failure Detection on Load

As previously described, the different load cases that can occur are as follows:

- Failure of one CT (secondary open). In this case I2/I1 = 0.5
- Failure of two CTs (secondaries open). In this case I2/I1 = 1
- Secondary short-circuit, in which case I2/I1 < 0.5

CT Failure Detection after Breaker Closing (Load or Transformer Energization)

The unit remains stable (no activation) to the negative sequence voltage transient due to the closing, both by **Energization Blocking** (**IN_BLK_ENER**) and by positive sequence increment blocking. It is not necessary to configure any blocking by harmonic detection.

The CT failure will be detected after the minimum ***Closing Block Time*** has elapsed, and when the algorithm conditions (negative sequence voltage, positive sequence current decrease, etc.) are met.

CT Failure Detection in Fault Conditions

The unit never detects CT failure under fault conditions.

The unit remains stable in single-phase and two-phase faults due to negative sequence voltage blocking and maximum current blocking. In three-phase faults, the positive sequence increment blocking and the maximum current blocking will act.

When clearing single and two-phase faults on a line downstream of the transformer, a positive current decrease occurs at the same time as the negative sequence current drops, which could result in the activation of the unit if the negative sequence voltage is lower than the adjusted residual voltage. To avoid this type of untimely activations, the blocking due to the increase of the positive sequence current does not reset as long as there is a decrease of the negative sequence current.

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When a three-phase fault is cleared, there is an increase in the negative sequence current (at breaker opening) and a decrease in the positive sequence current at the same time. To maintain unit stability in this case, the maximum current blocking has a 3-cycle timer that maintains the blocking long enough to prevent unit activation.

In case of three-phase faults that generate saturation in any of the CTs, the positive sequence current increase blocking will initially block the unit long enough for the maximum current blocking to activate.

CT Failure Detection in Open-Phase (Conductor Down) or Open-Pole Conditions

The unit never detects CT failure under such conditions due to the negative sequence voltage presence blocking, which in turn remains the stability of the unit.

8.11.2.e Recommended Settings

The ***Maximum Residual Voltage*** setting should be greater than the negative sequence residual voltage that the system has at maximum load and should be less than the negative sequence minimum voltage during transformer energization.

If the negative sequence voltage (V2) during transformer energization is lower than the negative sequence residual voltage of the system at maximum load, then the ***Maximum Residual Voltage*** setting should be greater than the negative sequence residual voltage of the system at maximum load, and the ***Closing Block Time*** setting should have a value greater than the duration of the transformer energizing current.

The ***Pickup I2/I1*** setting should be higher than the maximum residual negative sequence current due to load unbalance, CT errors, and so on. On the other hand, this setting should be lower than the sensitivity setting of the phase differential unit, and lower than 0.5 (to detect CT failure by 1 CT open).

If there is no large load unbalance, a 9% adjustment of the load current (I2/I1=0.09) is recommended. For CTs with a maximum measurement error of 5%, the maximum theoretical error of I2/I1 would be:

$$Error_I2/I1 = [(I + 0.05*I - I + 0.05I) / 3] / (I - 0.05*I) = 0.035$$

assuming negligible the angle error between the three phases, so the recommended setting value (0.09) can be reduced if necessary.

The ***Minimum Load*** setting should be adjusted to the minimum value of the load current to avoid activation of the CT failure in case of unbalances due to the CTs own errors, which would be amplified at very low load (I2/I1>>0).

The ***Maximum Current*** value should be adjusted with the maximum operating current the user wants to detect the CT failure. The recommended value is 1.2 x rated current.

The minimum ***Closing Block Time*** setting should have a value higher than 1 cycle, to avoid activation of the unit due to the V2 transient (negative sequence voltage) during breaker closing. The recommended value is 25 ms.

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If the negative sequence voltage (V2) during transformer energizing is lower than the ***Maximum Residual Voltage***, the minimum ***Closing Block Time*** setting should be higher than the duration of the energizing current.

The timing of the unit (***CT Supervision Timer***) depends on the application of the unit. As alarm signaling it can be set to several seconds.

The ***Inhibit Voltage*** (see Chapter 3.2, Frequency Units) ensures that the phase voltage transformers are connected to the equipment so that the equipment can calculate the negative sequence voltage (V2). If the equipment does not detect the presence of voltage, the CT Supervision unit will be blocked.

8.11.2.f Setting Ranges

Protection / Current Transformer Supervision / Common Settings					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Minimum Load	Min. Load	PHSCTR1.MinValPsA (ASG)	0.04 - 1 A	0.01	0.1
Maximum Current	Max. Current	PHSCTR1.BlkValA (ASG)	0.05 - 10 A	0.01	6

Protection / Current Transformer Supervision / Current Transformer Supervision by Negative Sequence					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
CT Supervision Enable	CT Superv Enable	PHSCTR1.NsSupSvc (SPG)	NO / YES		NO
Pickup I2/I1	Pickup I2/I1	PHSCTR1.NsStrVal (ASG)	0.01 - 0.4	0.001	0.1
Maximum Residual Voltage	Max residual Volt.	PHSCTR1.MaxResNsV (ASG)	0.01 - 20 V	0.01	1
CT Supervision Timer	CT Superv Time	PHSTCTR1.SupTmms	0.05 - 300 s	0.01 s	0.05 s
Closing Block Time	Closing Block Time	PHSCTR1.ClsBlkTmms (ING)	0 - 3 s	0.001	0.025

8.11.2.g Analog Inputs to the Unit

Table 8.11-3: Analog Inputs to the CT Supervision Modules		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
I2	Negative Sequence Current	MSQI1.SeqA.c2
I1	Positive Sequence Current	MSQI1.SeqA.c1
V2	Negative Sequence Voltage	MSQI1.SeqV.c2

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8.11.2.h Digital Inputs to the CT Supervision by Negative Sequence Module

Table 8.11-4: Digital Inputs to the CT Supervision by Negative Sequence Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_ENB_SUPCTI2	Enabling Commands	PHSTCTR1.NsSupEna (SPC (ctlVal))	Enable input CT Supervision Unit I2		Activation of this input brings the element into operation. It can be assigned to a digital input by level or to a command from the communications protocol, or from the HMI: The default value for this logic input is “1”.
IN_BLK_SUPCTI2	Logic Inputs to Protection	PHSTCTR1.NsSupBlk (SPC)	Block input CT Supervision Unit I2		Activation of this input generates the blocking of the supervision.
IN_BLK_ENER		PHSTCTR1.EnerBlkIn (SPC)	Block CT Supervision Unit		
IN_RESET_SUPCTI2	Reposition Commands	PHSTCTR1.ResNsSup (SPC)	Reset input CT Supervision Unit I2		Activation of this input generates the reset of the unit activation signal and the pickup signal.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.11.2.i Auxiliary Outputs and Events of the CT Supervision by Negative Sequence Module

Table 8.11-5: Auxiliary Outputs and Events of the CT Supervision by Negative Sequence Module

Name	Group	IEC 61850	Description	Vis.	Function
PU_FAIL_CTI2	Trip Protection Outputs	PHSCTR1.NsSupStr (ACD)	CT Supervision Unit I2 Pickup	I	Its activation indicates the existence of a fault in the measurement system of one of the phases.
FAIL_CTI2		PHSCTR1.NsSupFail (ACT)	CT Supervision Unit I2 Alarm	I	
ENB_SUPCTI2	Enabled Units Protection Outputs	PHSCTR1.NsSupEna (SPC (stVal))	CT Supervision Unit I2 Enabled	I	Blocking output due to fuse failure condition detected by the unit itself.
NS_IMAX_BLK	Generic Outputs of Protection	PHSCTR1.NsMaxABlk (SPS)	CT Supervision Unit I2 Blocked by Maximum Current	I	Blocking output by maximum current condition.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.11.2.j IEC 61850 Logical Node

CLASS PHSTCTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
Amp	SAV	Current
Settings		
ARtg	ASG	Rated Current
Rat	ASG	Winding ratio of external current transformer

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CLASS PHSTCTR		
Extended Data		
SupEna	EXT_SPC	TCTR supervision enable command
SupBlk	EXT_SPC	TCTR supervision block command
SupSvc	EXT_SPG	Supervision in service
SupTmms	EXT_ING	Supervision delay time
SupFail	EXT_ACT	TCTR supervision failure
NsSupSvc	EXT_SPG	CT SUP I2 Enable
MinValPsA	EXT_ASG	Min. LOAD
NsStrVal	EXT_ASG	I2/I1 PICKUP
MaxResNsV	EXT_ASG	Max. RESIDUAL VOLTAGE
BlkValA	EXT_ASG	Max. CURRENT
OpDelTmms	EXT_ING	SUPCTI2 TIME DELAY
ClsBlkTmms	EXT_ING	Min. CLOSE BLOCK TIME
NsSupEna	EXT_SPC	Enable of CT Supervision unit based on I2
NsSupBlk	EXT_SPC	Block input of CT Supervision unit based on I2
ResNsSup	EXT_SPC	Reset Input of CT Supervision unit based on I2
NsSupStr	EXT_ACD	CT Supervision based on I2 picked up
NsSupFail	EXT_ACT	CT Failure based on I2
NSupSvc	EXT_SPG	CT SUP IDIFN Enable
NStrVal	EXT_ASG	IDIFN PICKUP
RstPct	EXT_ASG	Restraint Slope
GndMaxValA	EXT_ASG	Maximum IG Current
NOpDelTmms	EXT_ING	SUPCTIN TIME DELAY
NSupEna	EXT_SPC	Enable input of CT Supervision unit based on IDIFN
NSupBlk	EXT_SPC	Block input of CT Supervision unit based on IDIFN
ResNSup	EXT_SPC	Reset Input of CT Supervision unit based on IDIFN
EnerBlkIn	EXT_SPC	Energization Blocking Input
NSupStr	EXT_ACD	CT Supervision based on IDIFN picked up
NSupFail	EXT_ACT	CT Failure based on IDIFN
NMaxABlk	EXT_SPS	Maximum Current Blocking of CT Supervision based on IDIFN
NOpBlk	EXT_SPS	Blocked Operation

8.11.2.k CT Supervision by Negative Sequence Unit Test

Inject a system of balanced currents and voltages with nominal value. Drastically reduce the current value injected in one of the phases to zero (simulating the opening of the CT secondary). Under these conditions, the unit will operate.

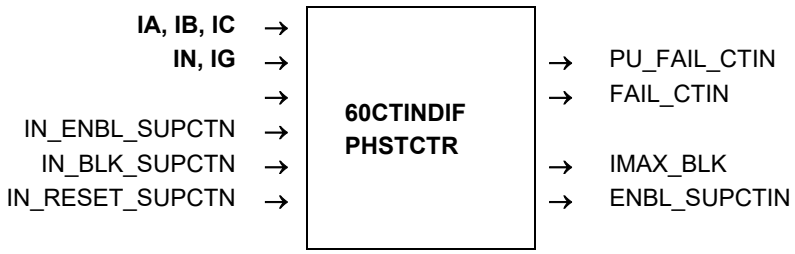
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8.11.3 Current Measurement Supervision by Neutral Differential Current

8.11.3.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Current Measurement Circuit Supervision by Neutral Differential Current	PHSTCTR1	MCS 3I	60CTINDIF

8.11.3.b General Block



8.11.3.c Operation Principles and Block Diagram

This supervision function of the phase CTs is based on the measurement of the phase currents to calculate the neutral current and compare it with the neutral current measured in a ground channel of the equipment. Its main application is for CTs with two secondaries, so that on the supervised secondary the neutral current is calculated, which is compared with the current measured in the ground channel connected to the star return of the second secondary.

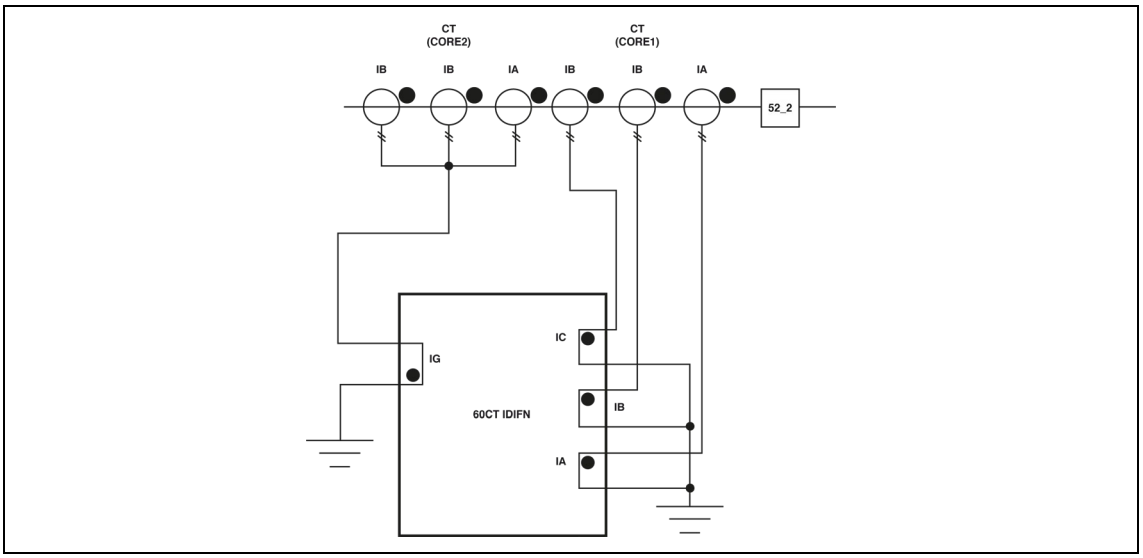


Figure 8.11.3 Supervision of a CT with Two Secondaries.

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In case of failure of one or two CTs the equipment will detect the presence of neutral current **(IN ≠ 0**) without presence of current in the ground channel (**IG = 0**), so that the neutral differential current will be different from zero (**IDIFN = (IN / tN) + IG ≠ 0**), detecting the failure in the group of supervised phase CTs.

This unit can also be used to detect phase CT failure by comparing the neutral current (**IN**) with the current through the transformer grounding measured in the equipment ground channel (**IG**). In this case if **IN ≠ 0** and **IG = 0** it means that a fault has occurred in some phase CT.

This application should only be used as a time alarm, since it is very complicated to coordinate the value of the ***Maximum IG*** current with the value of the IDIFN pickup setting (***CT Supervision Pickup***) for instantaneous triggers (you will have to wait a certain time to check that **IG** does not exceed the setting before considering **IG=0**).

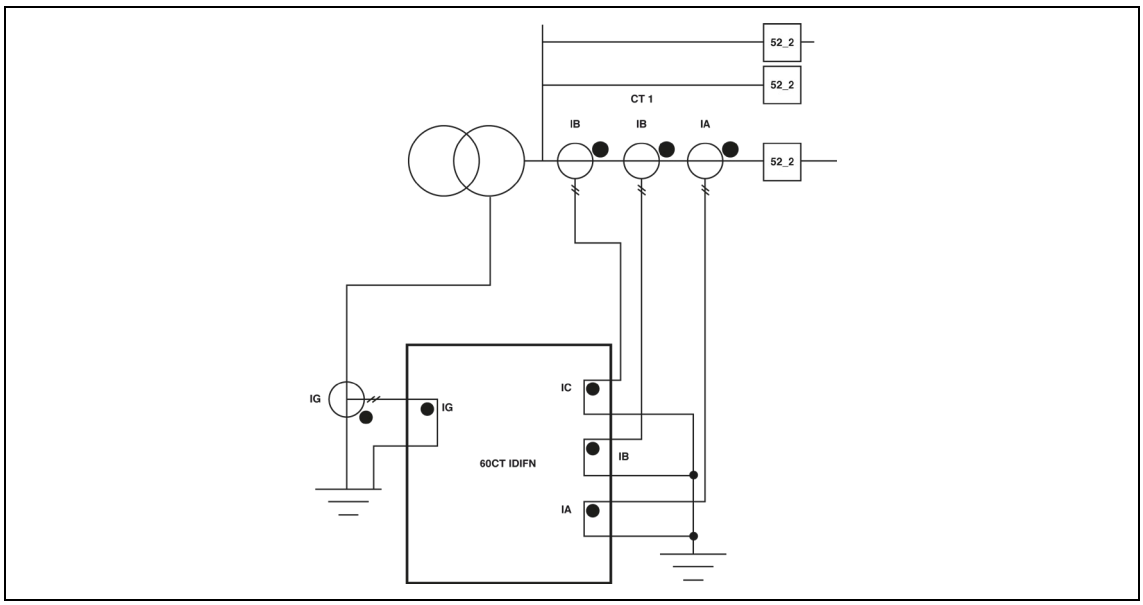


Figure 8.11.4 CT Supervision using Power Transformer Grounding Current.

Regardless of the application for which the supervision unit works, the operation principle is the same.

The unit calculates the neutral current as the sum of the supervised phase currents (**IN = IA + IB + IC**) and the reference to the ground channel current **IG**, with which it will calculate the neutral differential current using the tap value ***tn = CTIG / CTPhase***.

Therefore, the neutral differential current is calculated as follows:

$$IDIFN = IG + IN / tn.$$

The restraint current is the higher current of the phases being supervised:

$$IrestN = Max (IA, IB, IC) / tn$$

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From the RMS value of the restraint current magnitude and the RMS value of the neutral differential current, the corresponding slope is obtained:

$$P_N = \frac{I_{diffN}}{\frac{I_{restN}}{t_N}} \times 100$$

Where *IdiffN_Setting* is the sensitivity of the characteristic (IDIFN Pickup setting: ***CT Supervision Pickup***), and *Slope_Setting* is the slope of the characteristic (***CT Supervision Slope*** setting).

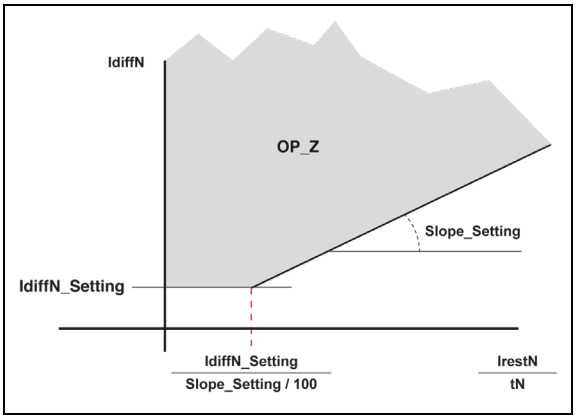


Figure 8.11.5 Differential Characteristic with Percentage Restraint.

LEGEND:	
IdiffN: NEUTRAL DIFFERENTIAL CURRENT	**IrestN**: NEUTRAL RESTRAINT CURRENT
IdiffN_Setting: NEUTRAL DIFFERENTIAL CURRENT SETTING	**tN**: RATIO BETWEEN GROUNDING CHANNEL CT RATIO AND ITS ASSIGNED WINDING CHANNEL CT RATIO
OP_Z: OPERATE ZONE.	
Slope_Setting: RESTRAINT SLOPE SETTING	

The pickup of the characteristic (**PU_IDIFN**) is performed at 100% of the corresponding value from the operating characteristic and the reset is to be performed at 80% of the same value.

The pickup of the unit (**PU_FAIL_CTIN**) requires that, in addition to the characteristic pickup (**PU_IDIFN**), the calculated neutral current (IN) is equal to or higher than 100% of the characteristic sensitivity setting (**IDIFN Pickup**). Reset occurs at 80%.

The unit is blocked if any of the following conditions are met:

- The **IG** current is equal to or higher than 100% of the ***Maximum IG*** current setting. Blocking is reset when **IG** is equal to or lower than 95% of the setting.
- The current of one of the phases is equal or higher than the ***Maximum Current*** adjusted value (activation of **N_IMAX_BLK**). The supervision of the CTs group is assumed in load situation, so the unit should be blocked in fault condition. The value of the maximum current setting should be set to the maximum system load. The blocking is reset when the current is equal to or lower than 95% of the setting for more than 1.5 cycles.
- Activation of the CT supervision unit blocking due to differential neutral current input signal (**IN_BLK_SUPCTN**).

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The figure shows the CT supervision by differential neutral current algorithm:

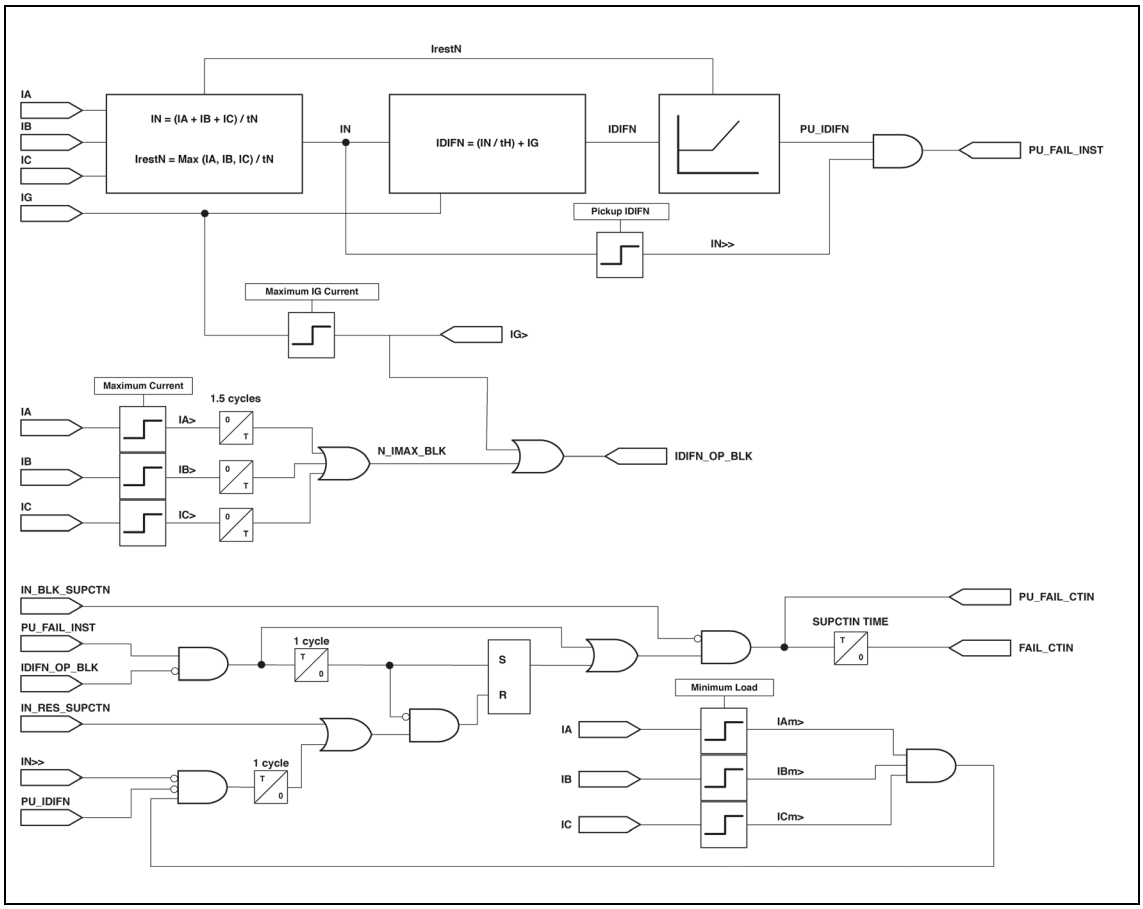


Figure 8.11.6 CT Supervision Algorithm based on Differential Neutral Current.

Fault detection in any of the measurement circuits generates the unit pickup activation (**PU_FAIL_CTIN**). Once a signal cycle has elapsed with the pickup activated, it is sealed, resulting in the activation of the unit (**FAIL_CTIN**) when the time adjusted as CT supervision time (**SUPCTIN TIME**) has elapsed.

Once the fault detected in the CT group has been fixed, the user can reset the unit by activation of the **CT Supervision Unit IDIFN Reset Input** signal (**IN_RES_SUPCTN**) which will reset the CT fault indication whenever the fault conditions have disappeared. The unit has an automatic reset, which occurs when the CT fault conditions have disappeared and the unit detects load conditions in the system during a cycle.

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8.11.3.d Application

The CT supervision unit by neutral differential current can be applied in cases where the CT failure detection must be performed instantaneously, for example, to block the activation of the phase differential unit when the system load is higher than the sensitivity of the differential unit and, thus, avoid tripping of the unit due to the false differential current caused by the CT failure. In this case, the CT failure activation signal (**PU_FAIL_CTIN** or **FAIL_CTIN**) must be connected to the blocking input of the differential unit through the programmable logic (the maximum priority logic running every 2 ms will be used).

This application (instantaneous CT failure detection) requires that the **IG** channel associated to the group of supervised CTs be exclusively dedicated to the CT supervision unit, i.e. that it be the channel exclusively dedicated to the measurement of the neutral current of the "second" secondary of the CT group, and not the channel dedicated to the measurement of the transformer grounding current, since, in the latter case, the unit will not behave correctly in the event of internal faults in the power transformer and external faults in windings with breaker and a half (in both cases, as the CT current contribution is different from the **IG** current contribution, there will be differential neutral current, so it is likely that CT faults will be detected before being blocked due to reaching the maximum **IG** current).

In any case, this unit can be used to detect the CT failure of the phases by comparing the neutral current with the current of the power transformer grounding, provided it is used on a timed mode.

Returning to the application of CTs with two secondaries supervision (supervision of the first secondary of the three phases by calculating **IN** and comparing it with the **IG** measurement of the star return of the second secondary of the CTs), we will now analyze the behavior of the unit in the different cases in which it can operate:

CT Failure Detection on Load

In any failure case (one or two CTs with secondary open, or secondary short-circuit), the neutral differential current (**IDIFN**) will be equal to the calculated neutral current (**IN / tn**), since **IG = 0**. On the other hand, the phase differential current (**IDIF**) generated by the CT failure is also equal to the neutral current (**IN**), so it is fulfilled:

$$IDIFN = IN / tn = IDIF / tn$$

When the CT failure occurs, a false neutral current (**IN**) appears at the same time as a false phase differential current (**IDIF**), which will cause the unit tripping if the load current (**I_LOAD**) is higher than the sensitivity adjusted in the differential unit (Io x tap). The CT supervision unit can be configured for blocking the phase differential unit to prevent untimely tripping of the equipment (the activation of the CT failure, **PU_FAIL_CTIN** or **FAIL_CTIN**, should be connected to the phase differential unit blocking input through the high priority programmable logic).

In this case, to avoid tripping, **IDIFN** must reach the **IDIFN** Pickup value before IDIF reaches the value **Io x tap**.

At primary values, **IDIFN = IDIF**. So, at secondary values:

$$Pickup\ IDIFN < Io \times tap / tn$$

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CT Failure Detection after Breaker Closing (Load or Transformer Energization)

Unit detects CT failure (**IDIFN ≠ 0**).

In addition, the unit always remains stable (no activation) since no neutral differential current (**IDIFN=0**) is ever generated if there is no CT failure.

It is not necessary to configure a blocking due to harmonic detection. Doing so would blocking the unit during the transient that occurs on CT failure preventing the blocking of the differential unit.

CT Failure Detection in Fault Conditions

The unit would detect the CT failure under fault conditions as long as there is no saturation in any of the CTs (the CT supervision unit does not implement any blocking by directional comparison).

Regarding stability, in all types of faults, if there is no CT failure and no saturation of any of the CTs is reached, the neutral differential current (**IDIFN**) will be null because **IN / tn = IG**.

In case of faults that generate saturation in one of the CTs, the neutral differential current due to CT saturation could activate the unit. To avoid this, the maximum current blocking (**N_IMAX_BLK**) should block the unit as soon as possible, so it is recommended to set the maximum current to the maximum load value (**1.2 x nominal**).

As a note, it is worth mentioning that the saturation detector (in the programmable logic) should not be used for blocking the CT supervision unit, because CT saturation generates the same neutral differential current as CT failure, so the saturation detector would block the unit in case of CT failure, preventing the CT supervision unit from blocking the differential unit (obviously, if this application has been configured).

CT Failure Detection in Open-Phase (Conductor Down) or Open-Pole Conditions

The unit detects CT failure in all cases. In isolated neutral systems **IN** and **IG** will always be zero, so CT failure will cause an **IDIFN ≠ 0** detecting CT failure. In grounded neutral systems, unbalance in open phase or open pole situation will generate an **IN = - IG**, so **IDIFN = 0** if there is no CT failure. If the CT failure occurs, there will be an increase in **IN** causing an **IDIFN ≠ 0**, allowing the unit to indicate the CT failure.

8.11.3.e Recommended Settings

The **IDIFN** pickup setting (***CT Supervision Pickup***) should be lower than the sensitivity of the phase differential unit, i.e., ***IDIFN Pickup < Io x tap / tn***. In any case, in order to provide the CT monitoring unit with a longer time to block the differential unit in case of CT failure, the setting: ***IDIFN Pickup < 0.33 x Io x tap / tn*** is recommended.

The ***Minimum Load*** setting should be set to the minimum load current value.

The ***Maximum Current*** value should be set to the maximum operating current at which the user wants to detect the CT failure. The recommended value is **1.2 x rated current**.

The timing of the unit (***SUPCTIN Time***) depends on the application of the unit. As alarm signaling it can be set to several seconds.

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8.11.3.f Setting Ranges

Protection / Current Transformer Supervision / Common Settings					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Minimum Load	Min. Load	PHSCTR1.MinValPsA (ASG)	0.04 - 1 A	0.01	0.1
Maximum Current	Max. Current	PHSCTR1.BlkValA (ASG)	0.05 - 10 A	0,01	6

Protection / Current Transformer Supervision / Current Transformer Supervision by Neutral Differential Current					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
CT Supervision Enable	CT Superv Enable	PHSCTR1.NSupSvc (SPG)	NO / YES		NO
CT Supervision Pickup	CT Superv pickup	PHSCTR1.NStrVal (ASG)	0.05 - 50 A	0.01	0.05
CT Supervision Slope	CT Superv slope	PHSCTR1.RstPct (ASG)	0 - 100 %	1	0
CT Supervision Timer	CT Superv Time	PHSTCTR1.SupTmms	0 - 300 s	0.01 s	1 s
Maximum IG	Max. IG	PHSCTR1.GndMaxValA (ASG)	0.02 - 10 A	0.01	6

8.11.3.g Analog Inputs to the Unit

Table 8.11-6:Analog Inputs to the CT Supervision Modules		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC
IN	Neutral Current	MMXU1.A.res
IG	Ground Current	MMXU1.A.neut

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8.11.3.h Digital Inputs to the CT Supervision by Neutral Differential Current Module

Table 8.11-7: Digital Inputs to the CT Supervision by Neutral Differential Current Module

Name	Group	IEC 61850	Description	Vis.	Function
IN_ENB_SUPCTN	Enabling Commands	PHSCTR1.NSupEna (SPC (cálvale))	Enable input CT Supervision Unit IDIFN		Activation of this input brings the element into operation. It can be assigned to a digital input by level or to a command from the communications protocol, or from the HMI: The default value for this logic input is “1”.
IN_BLK_SUPCTN	Logic Inputs to Protection	PHSCTR1.NsSupBlk (SPC)	Block input CT Supervision Unit IDIFN		Activation of this input generates the blocking of the supervision.
IN_RES_SUPCTN	Reposition Commands	PHSCTR1.ResNsSup (SPC)	Reset input CT Supervision Unit IDIFN		L Activation of this input generates the reset of the unit activation signal and the pickup signal.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.11.3.i Auxiliary Outputs and Events of the CT Supervision by Neutral Differential Current Module

Table 8.11-8: Auxiliary Outputs and Events of the CT Supervision by Neutral Differential Current Module

Name	Group	IEC 61850	Description	Vis.	Function
PU_FAIL_CTN	Trip Protection Outputs	PHSTCTR1.NSupStr (ACD)	CT Supervision Unit IDIFN Pickup	I	Its activation indicates the existence of a fault in the measurement system of one of the phases.
FAIL_CTIN		PHSTCTR1.NSupFail (ACT)	CT Supervision Unit IDIFN Alarm	I	
ENB_SUPCTIN	Enabled Units Protection Outputs	PHSTCTR1.NSupEna (SPC (stVal))	CT Supervision Unit IDIFN Enabled	I	Blocking output due to fuse failure condition detected by the unit itself.
NS_IMAX_BLK	Generic Outputs of Protection	PHSTCTR1.NMaxABlk (SPS)	CT Supervision Unit IDIFN Blocked by Maximum Current	I	Blocking output by maximum current condition.
IDIFN_OP_BLK		PHSTCTR1.NOpBlk (SPS)	CT Supervision Unit IDIFN Blocked	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.11.3.j IEC 61850 Logical Node

CLASS PHSTCTR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
Amp	SAV	Current
Settings		
ARtg	ASG	Rated Current
Rat	ASG	Winding ratio of external current transformer

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CLASS PHSTCTR		
Extended Data		
SupEna	EXT_SPC	TCTR supervision enable command
SupBlk	EXT_SPC	TCTR supervision block command
SupSvc	EXT_SPG	Supervision in service
SupTmms	EXT_ING	Supervision delay time
SupFail	EXT_ACT	TCTR supervision failure
NsSupSvc	EXT_SPG	CT SUP I2 Enable
MinValPsA	EXT_ASG	Min. LOAD
NsStrVal	EXT_ASG	I2/I1 PICKUP
MaxResNsV	EXT_ASG	Max. RESIDUAL VOLTAGE
BlkValA	EXT_ASG	Max. CURRENT
OpDelTmms	EXT_ING	SUPCTI2 TIME DELAY
ClsBlkTmms	EXT_ING	Min. CLOSE BLOCK TIME
NsSupEna	EXT_SPC	Enable of CT Supervision unit based on I2
NsSupBlk	EXT_SPC	Block input of CT Supervision unit based on I2
ResNsSup	EXT_SPC	Reset Input of CT Supervision unit based on I2
NsSupStr	EXT_ACD	CT Supervision based on I2 picked up
NsSupFail	EXT_ACT	CT Failure based on I2
NSupSvc	EXT_SPG	CT SUP IDIFN Enable
NStrVal	EXT_ASG	IDIFN PICKUP
RstPct	EXT_ASG	Restraint Slope
GndMaxValA	EXT_ASG	Maximum IG Current
NOpDelTmms	EXT_ING	SUPCTIN TIME DELAY
NSupEna	EXT_SPC	Enable input of CT Supervision unit based on IDIFN
NSupBlk	EXT_SPC	Block input of CT Supervision unit based on IDIFN
ResNSup	EXT_SPC	Reset Input of CT Supervision unit based on IDIFN
EnerBlkIn	EXT_SPC	Energization Blocking Input
NSupStr	EXT_ACD	CT Supervision based on IDIFN picked up
NSupFail	EXT_ACT	CT Failure based on IDIFN
NMaxABlk	EXT_SPS	Maximum Current Blocking of CT Supervision based on IDIFN
NOpBlk	EXT_SPS	Blocked Operation

8.11.3.k CT Supervision by Neutral Differential Current Unit Test

Inject a system of balanced currents with nominal value. Drastically reduce the current value injected in one of the phases to zero (simulating the opening of the CT secondary). Under these conditions, the unit will operate.

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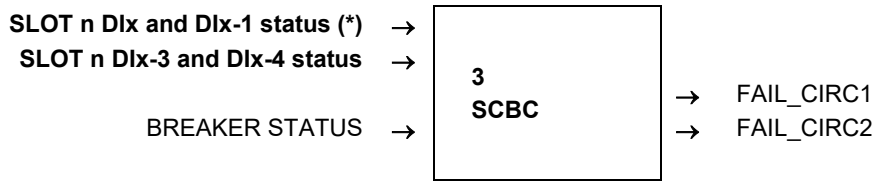
8.12 Trip and Close Coil Circuit Supervision

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8.12.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Trip and Close Coil Circuit Supervision	SCBC1	TCS	3

8.12.2 General Block



(*) Where n goes from "A" to "J", and x is the number of the last digital input on the card.
The slots of digital inputs that have Coil Circuit Supervision inputs always have 2 sets of 3 inputs for the supervision of 2 circuits (coils).

8.12.3 Operation Principles and Block Diagram

This Supervision function permits an alarm when an anomalous situation occurs in the breaker's switching circuits: losses of the auxiliary switching power supply voltage or openings in the open and close circuits themselves.

The number of circuits on which supervision can be carried out depends on the cards selected in the model (see Chapters1.2, Model Selection and 1.9, Schemes and Drawings), being adjustable for each circuit, whether supervision is carried out in both positions of the breaker (open and closed), by means of 3 digital inputs, or only in one of them (by means of 2 digital inputs, the third being free for other applications).

The supervision function generates 2 outputs for each supervised circuit, so that with the 2 possible circuits to be monitored in each slot enabled, the outputs would be the following: **Slot n Circuit 1 Power Failure**, **Slot n Circuit 1 Failure**, **Slot n Circuit 2 Power Failure**, **Slot n Circuit 2 Failure**.

The two supervision circuits, in each slot, are treated as independent functions that can be independently set to enabled by means of a setting.

The coils to be monitored may be trip or closing; therefore, the denomination of the unit is generic. Each of the coils has an associated pair of configurable digital inputs for monitoring. They can be paired to **Supervision in 2 States**, which is explained next, or individually to **Supervision in 1 State**. In any case, both modes can be combined for different coils (for example, to monitor the trip coil in open and closed, and coil two only in open).

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Table 8.12-1 identifies the status contact inputs that must be used to monitor each of the circuits.

Table 8.12-1: Configuration of Digital Inputs for Supervision by SLOTS

Monitored Circuit	Supervision in 2 states	Supervision in one state
SLOT n Coil 1	IN(x-4)	IN(x-4)
	IN(x-3)	-
SLOT n Coil 2	IN(x-1)	IN(x-1)
	INx	-

Where x is the number of the last digital input on the card.

To monitor the Coil 1, a positive must be entered through terminal IN(x-5) of the SLOT n, and to monitor Coil 2, a positive must be entered through terminal IN(x-2) of the SLOT n. For details, see Chapter 1.9, Schemes and Drawings.

These digital inputs do not need to be configured in advance to perform the coils supervision function. By enabling any of the coils supervision, each pair of digital inputs will be automatically configured as per the table above, this is, the IED needs no physical intervention to be able to assign status contact inputs for the Supervision function; they simply need to be set for this purpose. Each of the coils can be configured as:

1. **No supervision**: The supervision algorithm is not executed and the status contact inputs associated with the supervision of each of the coils are treated as standard status contact inputs.
2. **Supervision in 2 states**: The algorithm is the one indicated by way of example in figure 5.7.1. Basically, an XOR algorithm supervises the state of the switching circuit in open as well as in closed.
3. **Supervision in 1 state**: The algorithm only takes into account the supervision of the coil in the breaker's position configured in the input. It does not monitor in the other position and therefore can never detect a fault in the coil.

For each of the monitored coils, it is possible to set a time after which, if there is discordance, the Failure is activated.

The supervision system of the coil circuits is not very sensitive to the impedance of the circuits as seen from the relay, basing its principle of operation on an injection of current pulses that allow to detect continuity in this circuit. Current pulses of 100ms are injected every second and it is checked whether this current circulates or not. In case of not circulating, the reason could be that it is being supervised by the open auxiliary contact or that the coil is open.

Under the conditions of the following figure (breaker open), current pulses are injected through inputs **IN12** and **IN13**.

Because **IN12** is connected to the 52/b contact that is closed, current flows through it. This current flow implies that the voltage at (+) of **IN12** will be that corresponding to the voltage drop at the coil and therefore insufficient to activate it. Therefore, **IN12** will be deactivated.

There is no current flowing through **IN13** because contact 52/a is open. As a consequence of this, the voltage drop in the (+) of this digital input will be practically the supply voltage of the Opening Circuit. Therefore, **IN13** will be activated.

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Since the supervision has been programmed for **Supervision in 2 states**, the μController in charge of managing this supervision function will send a logic "0" to the main μProcessor and this will set the **SLOTn_FAIL_CIR1** (**Circuit 1 Failure**) signal to a logical "0". In this situation, it will be detected that digital input **IN12** is deactivated and **IN13** is activated.

If an operating coil is opened, the input that was deactivated (**IN12**) will be activated, remaining **IN13** activated and, after the configured time, the **Circuit 1 Failure** (**SLOTn_FAIL_CIR1**) signal will be activated.

If, with the control circuit in good condition, a closing or reclosing takes place, once the command has been executed, the status of the breaker and its contacts **52/a** and **52/b** changes resulting in that the situation of the **IN12** and **IN13** input activation is reversed and **SLOTn_FAIL_CIR1** output will remain deactivated.

The function of the reset time is to absorb the possible time race between the closure of the **52/a** contact and the opening of the **52/b** contact. In general, the **IN12** and **IN13** digital inputs will not change status simultaneously and, therefore, there will be a discordance between the two contacts. This does not change the **SLOTn_FAIL_CIR1** output status, provided its duration is less than the set time.

If the operating voltage disappears, the energized inputs will deenergize and this will cause the activation of circuit failure outputs (**SLOTn_FAIL_CIR1** and **SLOTn_FAIL_CIR2**).

In order for the supervision function of a trip coil (**SLOTn_FAIL_CIR1**, **SLOTn_FAIL_CIR2**) to avoid the closing of the supervised breaker, this logic must be configured in the programmable logic.

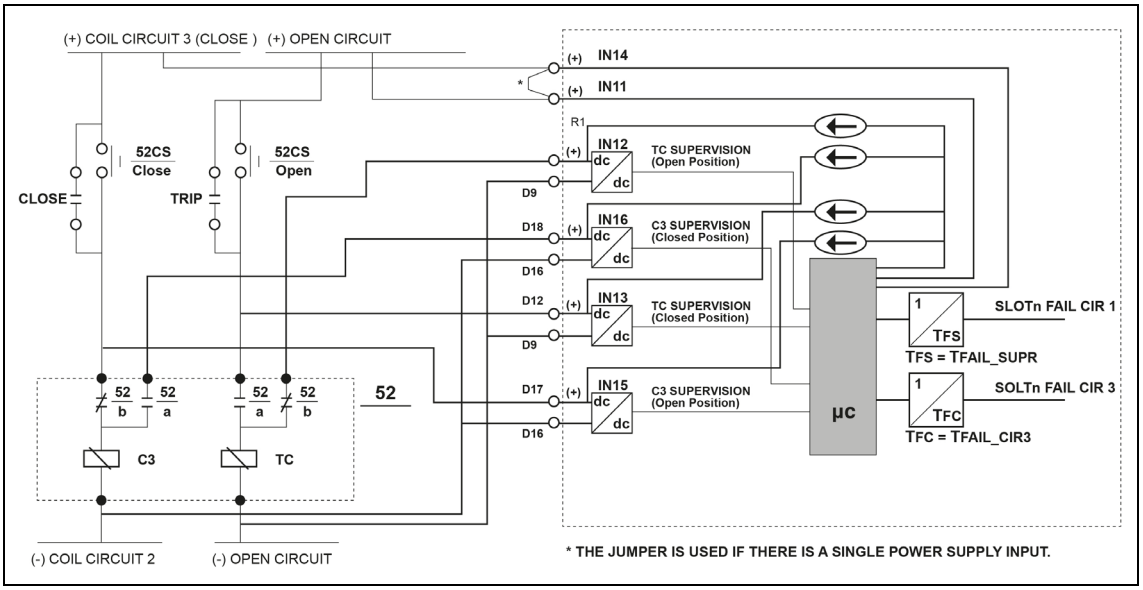


Figure 8.12.1 Trip/Close Coil Circuit Supervision Block Diagram.

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8.12.3.a Circuit 1 Supervision in One State

Under the conditions in previous Figure (open breaker), when carrying out the supervision in a given status, open or closed breaker supervision must be selected. In any case, the first group input (**IN12** or **IN15**) will be used.

The **IN12** or **IN15** input will therefore be hard wired to the open or closed breaker status, the one to be supervised. In case of Figure 8.12.1, the **IN12** input would be supervising the breaker closed status and therefore the supervision will not be operative since the breaker is open.

With the breaker closed, the **IN12** input is deenergized, because when current is injected into the circuit, the voltage at the positive terminal is below its activation threshold. In this situation, the **Circuit 1 Failure** (**SLOTn_FAIL_CIR1**) output is inactive.

If an operating coil anomaly occurs (breakage), the deactivated input will be activated and once the set timing times out, the **Trip Circuit 1 Failure** (**SLOTn_FAIL_CIR1**) signal will be sent.

8.12.3.b Supervision of Coil Circuit 2

The explanation given for Circuit 1 supervision is valid for the control circuit 2 and for any of the SLOTS, both for the supervision in two states and the supervision in a single status. Also, there must be taken into account that reset times for the activation of the failure output are independent from that of Circuit 1. In this case, the control circuit failure signal is designated as **SLOTn_FAIL_CIR2**.

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8.12.4 Setting Ranges

Coil Circuit Supervision					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
SLOT A. Circuit 1					
Supervision Mode	Supervision Mode	SCBC1.ColChk1	NO TWO STATES ONE STATE (52 OPEN 1) ONE STATE (52 CLOSE 1) ONE STATE (52 OPEN 2) ONE STATE (52 CLOSE 2) ONE STATE (52 OPEN 3) ONE STATE (52 CLOSE 3) ONE STATE (52 OPEN 4) ONE STATE (52 CLOSE 4)		NO
Failure Delay	Fail Delay	SCBC1.ColAlmTms1	1 - 60 s	1 s	5 s
SLOT A. Circuit 2					
Supervision Mode	Supervision Mode	SCBC1. ColChk2	NO TWO STATES ONE STATE (52 OPEN 1) ONE STATE (52 CLOSE 1) ONE STATE (52 OPEN 2) ONE STATE (52 CLOSE 2) ONE STATE (52 OPEN 3) ONE STATE (52 CLOSE 3) ONE STATE (52 OPEN 4) ONE STATE (52 CLOSE 4)		NO
Failure Delay	Fail Delay	SCBC1.ColAlmTms2	1 - 60 s	1 s	5 s

8.12.5 Auxiliary Outputs and Events of the Coil Circuit Supervision Module

Table 8.12-2: Auxiliary Outputs and Events of the Coil Circuit Supervision Module

Name	Group	IEC 61850	Description	Vis.	Function
SLOTn_FAIL_CIR1	Generic Outputs of Protection	SCBCn.ColAlm1	Coil Circuit 1 Failure Slot n	I	They activate when an anomaly is detected in any of the switching circuits.
SLOTn_FAIL_CIR2		SCBCn.ColAlm2	Coil Circuit 2 Failure Slot n	I	
SLOTA_FAIL_ALMCIR1		SCBCn.ColPwrAlm1	Coil Circuit 1 Power Failure Slot n	I	Alarm signals that indicate an anomaly of the internal supervision circuit power supply.
SLOTA_FAIL_ALMCIR2		SCBCn.ColPwrAlm2	Coil Circuit 2 Power Failure Slot n	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.12.6 IEC 61850 Logical Node

CLASS IRLSCBCn		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
ColAlm1	SPS	Slotn_Circuit 1 alarm indication
ColAlm2	SPS	Slotn_Circuit 2 alarm indication
ColPwrAlm1	SPS	Slotn_Circuit 1 internal supply failure indication
ColPwrAlm2	SPS	Slotn_Circuit 2 internal supply failure indication
Settings		
ColChk1	ENG	Slotn_Circuit 1 supervision mode
ColAlmTmms1	ING	Slotn_Circuit 1 time delay
ColChk2	ENG	Slotn_Circuit 2 supervision mode
ColAlmTmms2	ING	Slotn_Circuit 2 time delay

8.12.7 Coil Circuit Supervision Test

Hard wire the relay with the **IN12** and **IN13**, **IN15** and **IN16** inputs, corresponding to Slot A, connected to a resistor simulating a breaker coil, with a contact in series that can be opened and closed (simulating the breaker status contact) to close the ground connection circuit.

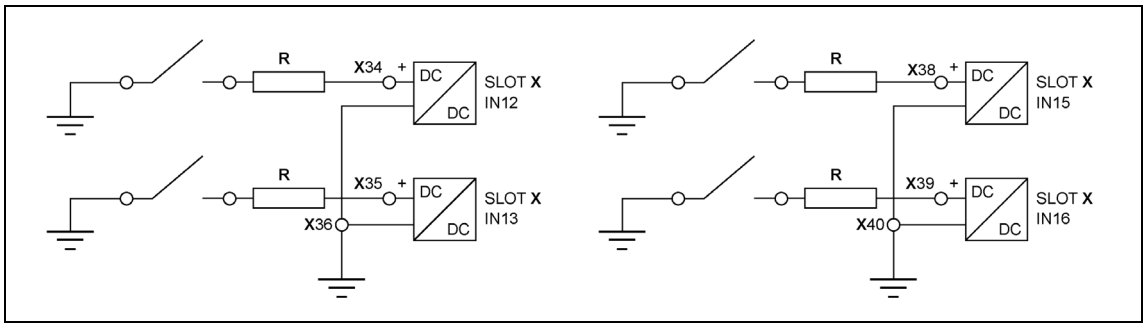


Figure 8.12.2 Hard Wiring for the Control Circuit Supervision Test of the SLOT X (A and/or B).

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Set the circuit 1 and 2 element to **Double Status** checking that:

- Circuit anomaly signal is generated when both contacts simulating the breaker status are open or both closed.
- The alarm of each of the supervision circuits disappears when one and only one contact is in closed status, whereas the other remains open (always referring to the pairs of contacts relative to the supervision circuit inputs, **IN12**-**IN13** and **IN15**-**IN16**).

Set the element to close breaker status, such that the inputs used for supervision will be **IN12** (Circuit 1) and **IN15** (Circuit 2).

- In the closed breaker status, leave the contact simulating open breaker and check that alarms are generated.
- In the closed breaker status, close the contact simulating the breaker and check that alarms disappear.
- In the open breaker status, check that no alarms are ever generated regardless the status of the contact simulating the breaker status.

Set the element to open breaker status, such that the inputs used for supervision will be **IN12** (Circuit 1) and **IN15** (Circuit 2).

- In the open breaker status, leave the contact simulating open breaker and check that alarms are generated.
- In the open breaker status, close the contact simulating the breaker and check that alarms disappear.
- In the close breaker status, check that no alarms are ever generated regardless the status of the contact simulating the breaker status.

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8.13 Tripping Logic

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8.13.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Trip Logic	PTRC		

8.13.2 General Block



8.13.3 Operation Principles and Block Diagram

Relays are provided with a Trip Logic that generates the protection trip signal as a function of the activities of the protection elements, digital blocking inputs, element operation masks, recloser status, etc. The trip is therefore generated by the trip logic.

Relays are provided with a single or three-phase Tripping Logic. Trip commands are generated for phase A, B, and C according to activation of protection elements, blocking status contact inputs, element masks, recloser status, etc. The Tripping Logic comprises the following sub-logics:

1. **Trip Command Generation Logic**, in charge of processing the activation of the different protection elements responsible for trips to generate a general trip command.
2. **Three-Phase Trip Logic**, in charge of indicating to the phase trip logic if the trip must be a three-phase trip.
3. **Phase Trip Logic**, in charge of generating independent tripping signals for phases A, B, and C (outputs **TRIP_A**, **TRIP_B** and **TRIP_C**), which will be used by the Command Module to generate the open outputs of each pole.

The block diagram of Figure 8.13.2 shows the Single / Three-Phase Tripping Logic for the Distance and Auxiliary elements. In Figure 8.13.3 the block diagram of the Single / Three-Phase Tripping Logic for the Differential Units is shown. Trip Reset Time is applied to **TRIP_A**, **TRIP_B**, **TRIP_C** generated from both logic diagrams.

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8.13.4 Trip Command Generation Logic

This logic generates a trip command according to activation of the protection elements. The settings to enable or the elements involved are (depending on model):

- Differential Elements.
- Distance Elements.
- Protection Schemes (Distance and Overcurrent).
- Auxiliary Units:
  - Close-Onto-Fault Detector.
  - Power-Swing Detector (power-swing trip enabled).
  - Remote Breaker Open Detector.
  - Phase Instantaneous Overcurrent Elements.
  - Ground Instantaneous Overcurrent Elements.
  - Negative Sequence Instantaneous Overcurrent Elements.
  - Phase Time Overcurrent Elements.
  - Ground Time Overcurrent Elements.
  - Negative Sequence Time Overcurrent Elements.
  - Thermal Image Protection.
  - Open Phase Detector.
  - Phase Undervoltage Elements.
  - Phase Overvoltage Elements.
  - Ground Overvoltage Elements.
  - Underfrequency Elements.
  - Overfrequency Elements.
  - Rate Of Change Elements.
  - Pole Discordance Detector.
  - Programmable Trip.
  - External Trip.

Enabling the **Step Distance** scheme (signal **TRIP_STP**) activates the protection elements for ground fault and phase-to-phase faults in Zones 1, 2, 3, 4, 5, 6, 7 and 8. The **Zone Trip Mask** setting allows the user to independently enable or disable tripping by each of these elements.

Distance trips (by step or by channel) can be blocked by using the Status Contact Input **Distance Protection Blocking** (**INBLK_DIST**), which presents an adjustable reset time (**Distance Blocking Time**).

Trips by auxiliary units and trips by ground and phase elements for Zones 1 to 8 can be independently enabled or disabled in the **Auxiliary Units Mask** setting. Setting any of these elements to **0** (disabled) will disable the element from tripping.

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As shown in Figure 8.13.2, the Trip Command will be generated if any of the following occurs:

1. A trip by Differential Units or Direct Transfer Trip received form remote end.
2. A trip by Step Distance (**TRIP_STP**) or by Distance Protection Scheme (**TRIP_SCHM_D**) not blocked by digital input (**INBLK_DIST**).
3. A trip by an Overcurrent Protection Scheme (**TRIP_SCHM_OC**).
4. A trip of any of the auxiliary units.
5. Activation of **Programmable Trip** (**INPROGTRIP**).
6. The activation of the input **Three-Phase External Trip (IN_EXT_3PH)** or the inputs **Pole A External Trip (IN_EXT_A)**, **Pole B External Trip B (IN_EXT_B)** and **Pole C External Trip (IN_EXT_C)**.

In addition, the **Trip Blocking** (**INBLK_TRIP**) digital input should not be activated and the **Fault Detector** (**FD**) should be activated, provided that there are no conditions of power swing and the trip does not originate from Voltage, Frequency, Thermal Image, Pole Discordance and Power Swing Detector (trip by power swing: **TRIP_PS**), or due to Weak Infeed Logic (either distance or overcurrent) or **Programmable trip** input or **External Three-Phase Trip** input **(IN_EXT_3PH)**. The activation of **Three-phase Trip Preparation Block** input (**INBLK_3PHPREP)** will disable any three-phase-only trip (see conditions in following paragraph). Thus, there are two supervisions per Fault Detector depending on the type of unit. For line differential units, they will be monitored when the ***Fault Det. Supervision 87L*** setting is set to **YES**. The rest of the units will be supervised if the ***Fault Det. Supervision*** setting is activated.

Also, trip blocking inputs for each pole (**INBLK_TRIP_A**, **INBLK_TRIP_B**, **INBLK_TRIP_C**) will cancel the trip of the corresponding pole, except if the trip is produced through the inputs **Pole A External Trip (IN_EXT_A), Pole B External Trip (IN_EXT_B)** and **Pole C External Trip (IN_EXT_C)**. Trip blocking inputs per pole are applied to enable single phase trips by two-phase elements on “cross-country” faults.

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8.13.5 Three-Phase Trip Logic

The Three-Phase Trip Logic function detects if the trip generated by the previous logic will be a three-phase trip. In the case of a three-phase trip, the logic will generate the **Three-Phase Trip Ready** signal (**3PH_PREP**).

Whenever the detected fault is a fault between phases (two or three phases, signals **PU_ZIPH**, **PU_ZIIPH**, **PU_ZIIIPH**, **PU_ZIVPH**, **PU_ZVPH**, **PU_ZVIPH**, **PU_ZVIIPH**, **PU_ZVIIIPH**), the trip will be a three-phase trip. Also, there are a series of conditions where a three-phase trip will be generated independent of the fault detected. These conditions are:

1. The **Three-Phase Trip** setting is set to **YES**.
2. The status contact input **Three-Phase Trip Enable** is activated (signal **3POL_OPEN**).
3. If the Recloser is in **Blocking Command** (**RCLS_CMD_LO** signal activated) or in **Internal Blocking** (**RCLS_LO** signal activated).
4. The Recloser is set to three-phase mode (**3P Mode**).
5. The **Recloser Sequence** is activated (signal **RECLOSING**). (Therefore, a three-phase trip will always follow any reclosing operation).
6. The trip of the Ground, Positive Sequence or Negative Sequence Differential Units while the setting ***Monophasic Trip 87SEC*** is set to **NO**.
7. If Zone 2, 3, 4, 5, 6, 7 or 8 is activated, that is, if in the Step Distance scheme the **Fault in Zone 2** (**Z_II**), **Fault in Zone 3** (**Z_III**), **Fault in Zone 4** (**Z_IV**), **Fault in Zone 5** (**Z_V**, **Fault in Zone 6** (**Z_VI**), **Fault in Zone 7** (**Z_VII**) or **Fault in Zone 8** (**Z_VIII**) outputs are activated, as long as **Zone 2 Three-Phase Trip Blocking** (**INBLK_3PH_ZII**), **Zone 3 Three-Phase Trip Blocking** (**INBLK_3PH_ZIII**), **Zone 4 Three-Phase Trip Blocking** (**INBLK_3PH_ZIV**), **Zone 5 Three-Phase Trip Blocking** (**INBLK_3PH_ZV**), **Zone 6 Three-Phase Trip Blocking** (**INBLK_3PH_ZVI**), **Zone 7 Three-Phase Trip Blocking** (**INBLK_3PH_ZVII**) or **Zone 8 Three-Phase Trip Blocking** (**INBLK_3PH_ZVIII**) outputs remain deactivated, respectively.
8. If the trip of any of the auxiliary units is produced, except in case of unit 1 of ground or negative sequence overcurrent and the **Single-Phase Trip 67G** (**1P_67G_ON**) setting is at **YES** and the fault is single phase (**AG_F**, **BG_F** and **CG_F**).
9. If the **Programmable Trip** (**INPROGTRIP**) input has been activated.
10. If the input **Three-Phase External Trip (IN_EXT_3PH)** has been activated.
11. If at least two breaker poles have tripped (**3PH_PREP_TRIP** signal).
12. If the phase selector indicates two-phase to ground fault and the two single-phase units associated with this fault are picked up (**PREP_3PH_PH-PH-G** signal).

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No matter the above conditions, activating the **Three-phase Trip Preparation Block** input (**INBLK_3PHPREP)** disables all three-phase trip preparations.

Under any of the above conditions, the trip will be three-phase, even if a single-phase fault is detected. Consequently, single-phase trips can only occur when the following trip:

1. The trip of the Differential Units (with or without restraint) or the trip of the Ground, Positive Sequence or Negative Sequence Differential Units while the setting ***Monophasic Trip 87SEC*** is set to **YES** and the fault is single phase (**AG**, **BG** and **CG**).
2. **Zone 1** units and the fault is single phase (**AG_F**, **BG_F** and **CG_F**).
3. The distance protection scheme in operation, with the fault also being single phase (**AG_F**, **BG_F** and **CG_F** outputs or **TRIP_WI_D_A**, **TRIP_WI_D_B** and **TRIP_WI_D_C** outputs), provided this is carried out prior to the timing of the units of Zone 2 and none of the above conditions are fulfilled.
4. **Unit 1** of **Ground** or **Negative Sequence Overcurrent** provided that the **Single-Phase Trip 67G** (**1P_67G_ON**) setting is set at **YES** and the fault is single phase (**AG**, **BG** and **CG**).
5. The overcurrent protection scheme is in operation, with the fault also being single phase (**AG_F**, **BG_F** and **CG_F** outputs or **TRIP_WI_I_A**, **TRIP_WI_I_B** and **TRIP_WI_I_C** outputs), provided this is carried out prior to the timing of unit 2 of ground or negative sequence overcurrent.
6. When zone 1 to 6 distance elements, ground overcurrent or negative sequence element 1 pickup or **Overreach Element Pickup** input is activated, provided it is a single-phase fault and **Three-phase Trip Preparation Block** input (**INBLK_3PHPREP)** activates or **pole trip block** inputs (**INBLK_TRIP_A, INBLK_TRIP_B, INBLK_TRIP_C)** associated to unfaulted phases activate**.** In this way, single-phase time delayed trips would be allowed.
7. When only one of the inputs **Pole A External Trip (IN_EXT_A)**, **Pole B External Trip (IN_EXT_B)** or **Pole C External Trip (IN_EXT_C)** has been activated.

All provided that the above-mentioned **Three-Phase Trip Ready** signal has not been activated, except for the case of external trip inputs per pole **(IN_EXT_A, IN_EXT_B** and **IN_EXT_C)**.

8.13.6 Phase Trip Logic

The phase trip logic function generates the independent trip command for each of the phases (signals **TRIP_A**, **TRIP_B** and **TRIP_C**), the **Trip** signal (**TRIP**) and the **Three-Phase Trip** signal (**TRIP_3PH**). To generate these signals, the logic uses the **Trip Command** signal and the **Three-Phase Trip Ready** signal (**3PH_PREP**), described in the previous sections.

The tripping logic of the poles is formed of three single-phase sub-logics corresponding to phases A, B and C. The trip command is common to the three logics. However, in case that three-phase trip conditions present themselves (for example, if the recloser is blocked), on activating the **3PH_PREP** signal, the trip is produced in the three phases even though the single-phase sub-logics indicate otherwise. On the other side, pole trips can be disabled by means of **INBLK_TRIP_A**, **INBLK_TRIP_B**, **INBLK_TRIP_C** inputs.

When the trip is produced by one of the external trip inputs per pole **(IN_EXT_A, IN_EXT_B** and **IN_EXT_C)**, it will be released when the corresponding input is deactivated.

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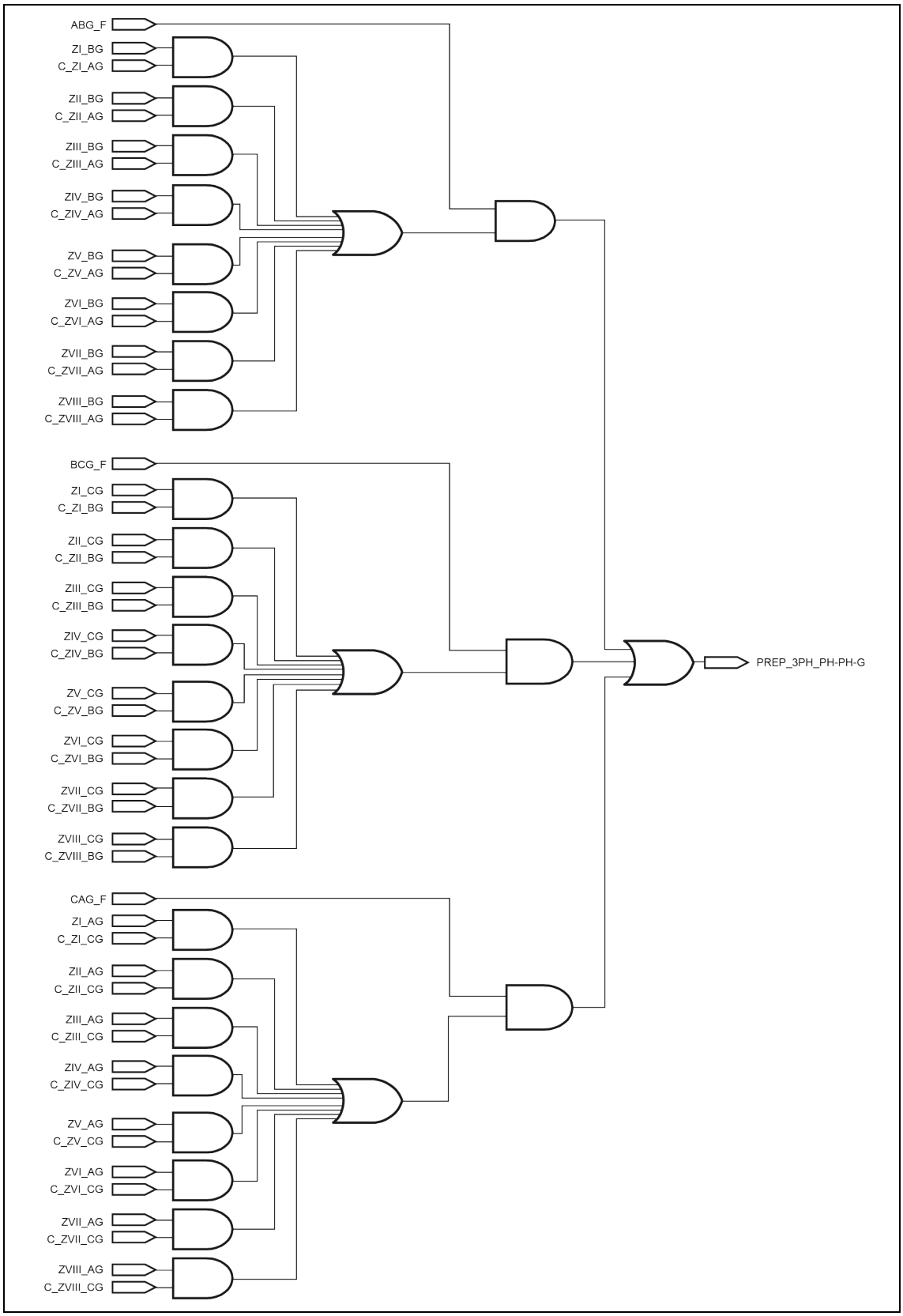


Figure 8.13.1 Generation Logic of the Three-Phase Trip Ready Signal in Case of a Two-Phase Fault to Ground.

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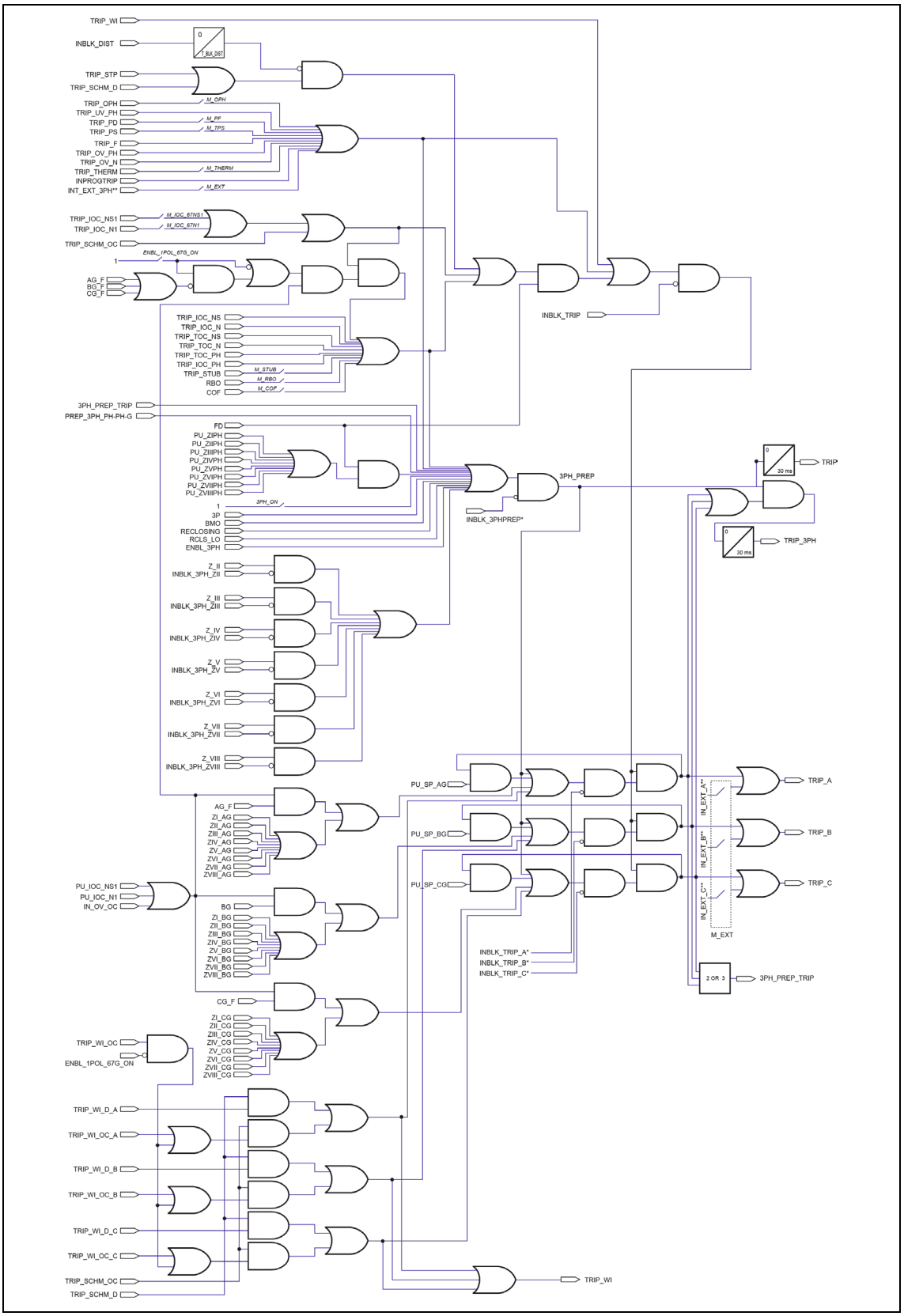


Figure 8.13.2 Block Diagram of the Single-Three-Phase Trip Logic.

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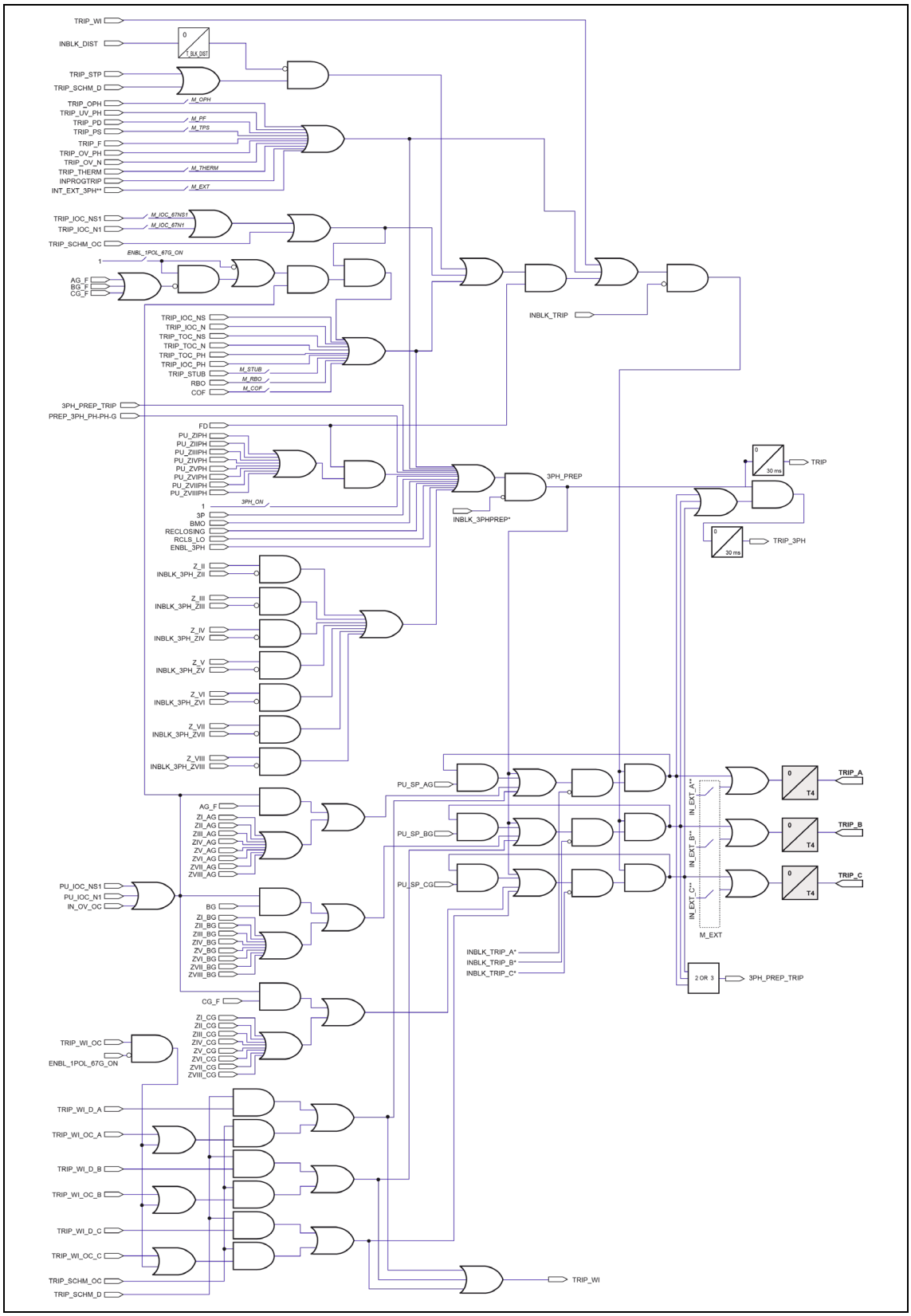


Figure 8.13.3 Block Diagram of the Differential Units Single-Three-Phase Trip Logic.

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Legend
T_BLK_DIST: Distance Blocking Input Reset Time Delay (setting).
M_OPH: Open Phase Element Trip Mask (setting).
M_PF: Pole Discordance Element Trip Mask (setting).
M_TPS: Power Swing Element Trip Mask (setting).
M_THERM: Thermal Image Element Trip Mask (setting).
M_IOC_67NS1: Negative Sequence IOC Element 1 Trip Mask (setting).
M_IOC_67N1: Ground IOC Element 1 Trip Mask.
ENBL_1POL_67G_ON: Ground Overcurrent Single-Phase Trip Enable (setting).
M_RBO: Remote Breaker Open Element Trip Mask (setting).
M_COF: Close-onto-Fault Element Trip Mask (setting).
M_EXT: Mask for External Trip (setting).
MR=3POL: Recloser 3-P Mode (setting).
DTT: Direct Transfer Trip.
87R: Phase Differential Unit with restraint.
87U: Phase Differential Unit without restraint.
87N: Neutral Differential Unit.
87P: Positive Sequence Differential Unit.
78Q: Negative Sequence Differential Unit.
T4: Trip Reset Time.

For models with Double Breaker of Breaker-and-a-half bay configuration capability:

- Signal **TRIP_PD** (Pole Discrepancy Trip) will be an OR of the Pole Discrepancy Trip signals for each breaker.
- Signal **RECLOSING** will be an OR of the signals **RECLOSING1** and **RECLOSING2**.
- Signal **RCLS_LO** will follow the logic included in Figure 8.13.4.
- Signal **BMO** will follow the logic included in Figure 8.13.5.

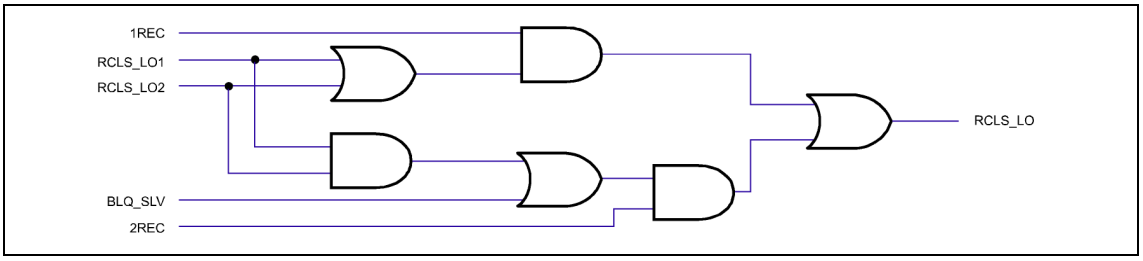


Figure 8.13.4 Logic of Recloser Internal Block Signal Generation.

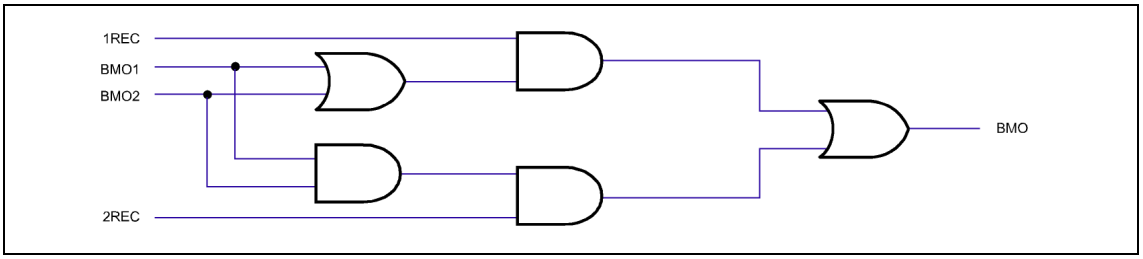


Figure 8.13.5 Logic of Recloser Command Block Signal Generation.

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Legend	
1REC: 1 Recloser in Operation.	BLK_SLV: Slave Recloser Lockout.
RCLS_LO: Recloser Lockout.	2REC: 2 Reclosers in Operation.

The trip signals of the protection elements are within the Trip Logic. Once the corresponding mask has been applied, the masked signal is generated, which is used for final trip signalling.

Depending on the element, these masks will be single and generic or will be subject to the recloser status and therefore the available mask will be a function of the recloser status.

In case of masked signals dependent on the recloser status, masks for overcurrent elements, programmable protection and trip schemes will be generated, based on the recloser status:

Stand By Recloser Trip.
Lock Out Recloser Trip.
Shot 1 Reset Time Trip.
Shot 2 Reset Time Trip.
Shot 3 Reset Time Trip.
Shot 4 Reset Time Trip.
External or Manual Close Reset Time Trip.
Manual Close through Recloser Reset Time Trip.

Below is the list of masked elements dependent on the recloser status.

Table 8.13-1: Protection Elements dependent on the Recloser Status

Description	Communications Program	Range	Default
Direct Transfer Trip	DTT	YES/NO	YES
Phase Differential with Restraint	87PH	YES/NO	YES
Phase Differential without Restraint	87I	YES/NO	YES
Neutral Differential with Restraint	87N	YES/NO	YES
Positive Sequence Differential	87P	YES/NO	YES
Negative Sequence Differential	87Q	YES/NO	YES
Phase Instantaneous O/C Unit 1	IOC PH1	YES/NO	YES
Phase Instantaneous O/C Unit 2	IOC PH2	YES/NO	YES
Phase Instantaneous O/C Unit 3	IOC PH3	YES/NO	YES
Neutral Instantaneous O/C Unit 1	IOC N1	YES/NO	YES
Neutral Instantaneous O/C Unit 2	IOC N2	YES/NO	YES
Neutral Instantaneous O/C Unit 3	IOC N3	YES/NO	YES
Negative Sequence Instantaneous O/C Unit 1	IOC NEG SEQ1	YES/NO	YES
Negative Sequence Instantaneous O/C Unit 2	IOC NEG SEQ2	YES/NO	YES
Negative Sequence Instantaneous O/C Unit 3	IOC NEG SEQ3	YES/NO	YES
Phase Time-delayed O/C Unit 1	TOC PH1	YES/NO	YES
Phase Time-delayed O/C Unit 2	TOC PH2	YES/NO	YES
Phase Time-delayed O/C Unit 3	TOC PH3	YES/NO	YES
Neutral Time-delayed O/C Unit 1	TOC N1	YES/NO	YES
Neutral Time-delayed O/C Unit 2	TOC N2	YES/NO	YES
Neutral Time-delayed O/C Unit 3	TOC N3	YES/NO	YES

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Table 8.13-1: Protection Elements dependent on the Recloser Status			
Description	**Communications Program**	**Range**	**Default**
Negative Sequence Time-delayed O/C Unit 1	TOC NEG SEQ1	YES/NO	YES
Negative Sequence Time-delayed O/C Unit 2	TOC NEG SEQ2	YES/NO	YES
Negative Sequence Time-delayed O/C Unit 3	TOC NEG SEQ3	YES/NO	YES
O/C Teleprotection Trip	CHANNEL TRIP	YES/NO	YES
Ground Instantaneous Overcurrent Unit 1	IOC GND1	YES/NO	YES
Ground Instantaneous Overcurrent Unit 2	IOC GND2	YES/NO	YES
Ground Instantaneous Overcurrent Unit 3	IOC GND3	YES/NO	YES
Ground Time-delayed Overcurrent Unit 1	TOC GND1	YES/NO	YES
Ground Time-delayed Overcurrent Unit 2	TOC GND2	YES/NO	YES
Ground Time-delayed Overcurrent Unit 3	TOC GND3	YES/NO	YES
Programmable Trip	3PH_PR_TRIP	YES/NO	YES
Programmable Trip without Fault Detector	3PH_PR_TRPFDS	YES/NO	YES

Trip mask availability depends on model selected.

While elements with a single and general mask will be as follows

Table 8.13-2: Protection Elements independent on the Recloser Status			
Description	**Communications Program**	**Range**	**Default**
Phase O/V Unit 1	OVERVOLT PH1	YES / NO	YES
Phase O/V Unit 2	OVERVOLT PH2	YES / NO	YES
Phase O/V Unit 3	OVERVOLT PH3	YES / NO	YES
Phase U/V Unit 1	UNDVOLT PH1	YES / NO	YES
Phase U/V Unit 2	UNDVOLT PH2	YES / NO	YES
Phase U/V Unit 3	UNDVOLT PH3	YES / NO	YES
Neutral O/V Unit 1	OVERVOLT G1	YES / NO	YES
Neutral O/V Unit 2	OVERVOLT G2	YES / NO	YES
Neutral O/V Unit 3	OVERVOLT G3	YES / NO	YES
Ground O/V Unit 1	OVERVOLT G1	YES / NO	YES
Ground O/V Unit 2	OVERVOLT G2	YES / NO	YES
Ground O/V Unit 3	OVERVOLT G3	YES / NO	YES
Overfrequency Unit 1	OVERFREQ1	YES / NO	YES
Overfrequency Unit 2	OVERFREQ2	YES / NO	YES
Overfrequency Unit 3	OVERFREQ3	YES / NO	YES
Overfrequency Unit 4	OVERFREQ4	YES / NO	YES
Underfrequency Unit 1	UNDERFREQ1	YES / NO	YES
Underfrequency Unit 2	UNDERFREQ2	YES / NO	YES
Underfrequency Unit 3	UNDERFREQ3	YES / NO	YES
Underfrequency Unit 4	UNDERFREQ4	YES / NO	YES
Frequency Rate-of-Change Unit 1	ROC FREQ1	YES / NO	YES
Frequency Rate-of-Change Unit 2	ROC FREQ2	YES / NO	YES
Frequency Rate-of-Change Unit 3	ROC FREQ3	YES / NO	YES
Frequency Rate-of-Change Unit 4	ROC FREQ4	YES / NO	YES
External Trip	EXT TRIP	YES / NO	YES
Negative Sequence O/V	OVERVOLT NS	YES / NO	YES
Pole Discrepancy	POLE DISCREP	YES / NO	YES
Open Phase	OPEN PHASE	YES / NO	YES
Thermal Image	THERMAL IMG	YES / NO	YES

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Trip mask availability depends on model selected.

In short, elements subject to the recloser status are all the overcurrent elements (phase, ground, neutral, negative sequence, voltage dependent), programmable protection and trip schemes whereas the rest of protection elements will have a single mask common for any Recloser status.

The trips produced by the equipment can be configured as three-phase or single-phase (default). If the ***Three Phase Trip*** setting is set to YES, then only three phase trips will be allowed. If, on the contrary, it is set to NO, single-phase tripping will be allowed for those units that allow it. In addition, there is the possibility for single-phase tripping of three-phase units such as the neutral, positive sequence and negative sequence differentials by activating the ***Monophasic Trip 87SEC*** setting or the directional neutral or negative sequence overcurrent units or the overcurrent protection scheme by activating the ***1 Phase Trip 87G*** setting. In both cases, the selection of the pole to be tripped will depend on the phase selector.

8.13.7 Setting Ranges

Protection / Tripping Logic					
Programa de comunicaciones	**HMI**	**IEC 61850**	**Rango**	**Paso**	**Defecto**
Fault Det Supervision	Fault Det. Sup.	PTRC1.FltDetEna	YES / NO		YES
Fault Det Supervision 87L	Fault Det. Sup 87L		YES / NO		YES
Three Phase Trip	Three Phase Trip		YES / NO		NO
1 Phase Trip 67G	1 Phase Trip 67G		YES / NO		NO
1 Phase Trip 87sec	Pos Seq Differenti		YES / NO		NO
Distance Block Timer	Distance Block Timer		0 - 1000	50	150 ms
Shot Reposition Time	Shot Repos. Time	PTRC1.RsDlTmms	0 - 5 s	0.01s	0.02s

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8.13.8 Digital Inputs to the Tripping Logic

Table 8.13-3: Digital Inputs to the Tripping Logic					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INPROGTRIP_3P	Trip Protection Outputs	PTRC1.TrProg1	Three Phase Programmable Trip	I	Activating this input causes a direct three-phase trip.
INPROGTRIP_A		PTRCx.TrProg1	A pole Programmable Trip	I	Activating this input causes a direct (A/B/C) pole trip.
INPROGTRIP_B		PTRCx.TrProg1	B pole Programmable Trip	I	
INPROGTRIP_C		PTRCx.TrProg1	C pole Programmable Trip	I	
INPROGTRIP_3P_FD		PTRC1.TrProg2	Three Phase Programmable Trip with Fault Detector Supervision	I	The activation of this input generates a three phase trip subject to the compliance with the fault detector conditions.
INPROGTRIP_A_FD		PTRC1.TrProg2	A pole Programmable Trip with Fault Detector Supervision	I	The activation of this input generates a A pole trip subject to the compliance with the fault detector conditions.
INPROGTRIP_B_FD		PTRC1.TrProg2	B pole Programmable Trip with Fault Detector Supervision	I	The activation of this input generates a B pole trip subject to the compliance with the fault detector conditions.
INPROGTRIP_C_FD		PTRC1.TrProg2	C pole Programmable Trip with Fault Detector Supervision	I	The activation of this input generates a C pole trip subject to the compliance with the fault detector conditions.
INBLK_TRIP	Logic Inputs to Protection	PTRC1.BlkTr	Trip Blocking Input	I	Activation of this input produces a block of any trip.
IN_EXT_3PH		PTRC1.TrEx	External Three Phase Trip Input	I	The activation of this input indicates the existence of a three-phase trip of the breaker caused by an external protection.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.13.9 Auxiliary Outputs and Events of the Tripping Logic

Table 8.13-4: Auxiliary Outputs and Events of the Tripping Logic					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
M_ALGUNARR	Pickup Protection Outputs	PTRC1.Str	Any Unit Picked Up	I	OR of the pickup of all the protection units.
TRIP	Trip Protection Outputs	PTRC1.Tr	Trip	I	Trip of the unit.
TRIP1		PTRC1.TrCB1	Trip 1	I	
TRIP_A1			Trip A 1		
TRIP_B1			Trip B 1		
TRIP_C1			Trip C 1		
TRIP_3PH1			Trip 3PH 1		
TRIP2		PTRC2.TrCB2	Trip 2	I	
TRIP_A2			Trip A 2		
TRIP_B2			Trip B 2		
TRIP_C2			Trip C 2		
TRIP_3PH2			Trip 3PH 2		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.13.10 IEC 61850 Logical Node

CLASS IDFPTRC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACT	Trip
Tr	ACT	Operate
Extended Data		
FltDetEna	EXT_SPG	Fault detector supervision enable
RsDlTmms	EXT_ING	Time to reset the trip
PHIOC1TrY	EXT_SPG	Phase inst unit 1 mask trip X
PHIOC2TrY	EXT_SPG	Phase inst unit 2 mask trip X
PHIOC3TrY	EXT_SPG	Phase inst unit 3 mask trip X
NIOC1TrY	EXT_SPG	Neutral inst unit 1 mask trip X
NIOC2TrY	EXT_SPG	Neutral inst unit 2 mask trip X
NIOC3TrY	EXT_SPG	Neutral inst unit 3 mask trip X
GIOC1TrY	EXT_SPG	Ground inst unit 1 mask trip X
GIOC2TrY	EXT_SPG	Ground inst unit 2 mask trip X
GIOC3TrY	EXT_SPG	Ground inst unit 3 mask trip X
NSIOC1TrY	EXT_SPG	Negative sequence inst unit 1 mask trip X
NSIOC2TrY	EXT_SPG	Negative sequence inst unit 2 mask trip X
NSIOC3TrY	EXT_SPG	Negative sequence inst unit 3 mask trip X
PHTOC1TrY	EXT_SPG	Phase time unit 1 mask trip X
PHTOC2TrY	EXT_SPG	Phase time unit 2 mask trip X
PHTOC3TrY	EXT_SPG	Phase time unit 3 mask trip X
NTOC1TrY	EXT_SPG	Neutral time unit 1 mask trip X
NTOC2TrY	EXT_SPG	Neutral time unit 2 mask trip X
NTOC3TrY	EXT_SPG	Neutral time unit 3 mask trip X
GTOC1TrY	EXT_SPG	Ground time unit 1 mask trip X
GTOC2TrY	EXT_SPG	Ground time unit 2 mask trip X
GTOC3TrY	EXT_SPG	Ground time unit 3 mask trip X
NSTOC1TrY	EXT_SPG	Negative sequence time unit 1 mask trip X
NSTOC2TrY	EXT_SPG	Negative sequence time unit 2 mask trip X
NSTOC3TrY	EXT_SPG	Negative sequence time unit 3 mask trip X
PSCH1TrY	EXT_SPG	Protection schema mask trip X
ProgTrTrY	EXT_SPG	Programmable trip mask trip X
PHTOV1Tr	EXT_SPG	Overvoltage unit 1 trip mask
PHTOV2Tr	EXT_SPG	Overvoltage unit 2 trip mask
PHTOV3Tr	EXT_SPG	Overvoltage unit 3 trip mask
PHTUV1Tr	EXT_SPG	Undervoltage unit 1 trip mask
PHTUV2Tr	EXT_SPG	Undervoltage unit 2 trip mask
PHTUV3Tr	EXT_SPG	Undervoltage unit 3 trip mask

Extended Data (Cont.)		
GNDTOV1Tr	EXT_SPG	Ground overvoltage unit 1 trip mask
GNDTOV2Tr	EXT_SPG	Ground overvoltage unit 2 trip mask
GNDTOV3Tr	EXT_SPG	Ground overvoltage unit 3 trip mask
PTOF1Tr	EXT_SPG	Overfrequency unit 1 trip mask
PTOF2Tr	EXT_SPG	Overfrequency unit 2 trip mask
PTOF3Tr	EXT_SPG	Overfrequency unit 3 trip mask
PTOF4Tr	EXT_SPG	Overfrequency unit 4 trip mask
PTUF1Tr	EXT_SPG	Underfrequency unit 1 trip mask
PTUF2Tr	EXT_SPG	Underfrequency unit 2 trip mask
PTUF3Tr	EXT_SPG	Underfrequency unit 3 trip mask
PTUF4Tr	EXT_SPG	Underfrequency unit 4 trip mask
PFRC1Tr	EXT_SPG	ROCOF unit 1 trip mask
PFRC2Tr	EXT_SPG	ROCOF unit 2 trip mask
PFRC3Tr	EXT_SPG	ROCOF unit 3 trip mask
PFRC4Tr	EXT_SPG	ROCOF unit 4 trip mask
ExProTr	EXT_SPG	External protection trip mask
NSTOV1Tr	EXT_SPG	Negative sequence overvoltage trip mask
PPDS1Tr	EXT_SPG	Pole discrepancy trip mask
OPHTOC1Tr	EXT_SPG	Open phase trip mask
PTTR1Tr	EXT_SPG	Thermal image trip mask

Data depends on model selected.

Note: Y is X+1.

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8.14 Command / Logic

8.14.1	Operation Principles	8.14-2
8.14.1.a	Trip Seal-In	8.14-2
8.14.1.b	Manual Open Sealing Command	8.14-2
8.14.1.c	Breaker Open and Close Failure Time	8.14-3
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8.14.1 Operation Principles

Following functions exist within the Command / Logic group:

Trip Seal-In.
Manual Open Seal.
Minimum Open Command Reset Time.
Minimum Close Command Reset Time.
Fail to Open / Close Time.
Manual Closing through Recloser.
Manual Close Synchrocheck Supervision 1.
Manual Close Synchrocheck Supervision 2.

8.14.1.a Trip Seal-In

To enable the Seal-In function the setting ***Trip Seal-In*** must be set to **YES**. Under these circumstances, the trip command over a pole of the breaker (**Pole A Trip**, **Pole B Trip**, **Pole C Trip**) will be kept activated as long as the opening of this is not detected (PA_OP, PB_OP and PC_OP open pole detector outputs). If setting ***Trip Seal-In*** is set to **NO**, the trip command resets when protection measuring elements or logic signals that generated trip activation reset.

This setting is of application when the breaker associated to the protection fails or is very slow (very slow auxiliary contacts 52/a for breaking the current of the trip circuit), and an upstream breaker clears the fault, the trip contact would be compelled to open the trip circuit causing its destruction.

The failed or slow breaker, once the function that caused the trip is reset, makes the relay contact to open before the breaker auxiliary contact 52/a, even after the overrun time of the first. An active trip command prevents the relay contact from breaking the current of the trip circuit (mainly inductive and high), and related damage to same circuit as normally these currents exceed circuit rated current breaking capability.

8.14.1.b Manual Open Sealing Command

To enable the Manual Opening Command Sealing function the setting ***Manual Open Seal*** must be set to **YES**. Under these circumstances, once an opening and the corresponding breaker operate command has been generated; the command is active until open breaker is detected through the auxiliary contact.

If setting ***Manual Open Seal*** is set to **NO**, the opening command resets when protection the logic signals that generated trip activation reset, always respecting the minimum activation time of the adjusted opening command.

The application of this setting is the same as that of the trip sealing described in the previous section.

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8.14.1.c Breaker Open and Close Failure Time

Both for manual and protection element generated operations, a minimum open command activation time can be set. For this purpose the setting ***Minimum Open Command Reset Time*** is used the range of which is from 100ms to 5s.

If open command is generated by the activation of any protection element, the open command is active during the setting value; in case elements are active during a longer period of time, the open command will be active until elements deactivate.

If open command is manual, duration is always the setting value.

The open command (by trip) will be active until an open breaker is confirmed if setting ***Trip Seal-In*** is set to **YES**.

The open command will be active until an open breaker is confirmed if setting ***Manual Open Seal*** is set to **YES**.

A setting ***Minimum Close Command Reset Time*** is provided that allows setting the minimum time that close commands are active. Range is from 0s to 5s. The 0 value indicates that close commands will be active until closed breaker is detected or a close command failure is given.

Both for manual and protection element-generated or reclose-generated operations, if a breaker state change signal is not received, after an operate command is sent, within the operate failure time (settable separately for open and close operations), **Open Command Failure** or **Close Command Failure** signals are activated. If the **Close Command Failure** signal is produced before the breaker closes during a shot sequence, recloser will be blocked.

Nevertheless, open and close commands are active during the activation time setting even if Open or Close Command Failure is produced.

8.14.1.d Manual Closing through Recloser

Breakers can be closed using Recloser logic in order for the logic to decide to close the breaker. For this to happen, ***Manual Close by Recloser*** setting (Within the Recloser ***Cycle Control*** settings) must be set to **YES**.

8.14.1.e Manual Close Synchrocheck Supervision

As already mentioned in the corresponding Recloser paragraph, there is no need to use Recloser logic to close the breaker; this is the **External Manual Close**.

For these close commands to be synchronism check supervised, the setting ***Manual Close Synchrocheck Supervision*** must be set to **YES**.

8.14.1.f Close Blocking

Each coil supervision has an associated setting, ***Close Blocking***, that allows enabling the automatic blocking of breaker close commands, such that, if the close blocking setting ***SLOT X Coil 1 and 2*** (where X can be A and/or B) is enabled, when an anomaly of this coil occurs, the recloser close commands and the manual close command will be blocked.

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8.14.2 Setting Ranges

Control					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Trip Seal-In	Trip Seal-in	SCBR1.TrSeal	NO / YES		NO
Manual Open Seal	Manual Open Seal	PTRC1.OpnCmdSeal (SPG ext.)	NO / YES		NO
Minimum Open Command Reset Time	Min Opening Res T	SCBR1.OpnPlsTmms	0.1-5 s	0.1 s	0.2
Fail to Open Time	Fail to Open Time	SCBR1.OpnFlTmms	0.02-2 s	0.005 s	0.02 s
Minimum Close Command Reset Time	Min Closing Res T	SCBR1.ClsPlsTmms	0-5 s	0.1 s	0.2
Fail to Close Time	Fail to Close Time	SCBR1.ClsFlTmms	0.02-5 s	0.01 s	0.02 s
Manual Close Synchrocheck Supervision 1	Syncr. Supervision	SCBR1.ManClsChk	YES / NO		NO
Manual Close Synchrocheck Supervision 2*	Syncr. Supervision	SCBR2.ManClsChk	YES / NO		NO
Load Restoration Enable	Load Restorat.Ena				
REP DLS1**	LOAD REST1	SCBR1.LodShedMsk	YES / NO		NO
Close Blocking**					
Slot A Coil 1	Slot A Coil 1	SCBC1.CBBlkEna1	YES / NO		NO
Slot A Coil 2	Slot A Coil 2	SCBC1.CBBlkEna2	YES / NO		NO
Slot B Coil 1	Slot B Coil 1	SCBC2.CBBlkEna1	YES / NO		NO
Slot B Coil 2	Slot B Coil 2	SCBC2.CBBlkEna2	YES / NO		NO

(*) Only for models with Double Breaker of Breaker-and-a-half bay configuration capability.
(**) Not available in models with Double Breaker of Breaker-and-a-half bay configuration capability.

8.14.3 Digital Inputs to the Command / Logic Module

Table 8.14-1: Digital Inputs to the Command / Logic Module

Name	Group	IEC 61850	Description	Vis.	Function
M_OPN1	Breaker Control	SCBR1.OpnCmdIn	Breaker 1 Manual Open Command		Their activation generates manual open and close commands respectively; they can be allocated to the HMI, communications, digital inputs or any programmable logic signal. Their application is oriented to being allocated to COMMANDS.
M_OPN2		SCBR2.OpnCmdIn	Breaker 2 Manual Open Command		
M_CLS1		SCBR1.ClsCmdIn	Breaker 1 Manual Close Command		
M_CLS2		SCBR2.ClsCmdIn	Breaker 2 Manual Close Command		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.14.4 Auxiliary Outputs and Events of the Command / Logic Module

Table 8.14-2: Auxiliary Outputs and Events of the Command Failure Module						
Name		Group	IEC 61850	Description	Vis.	Function
DLF-A	DLF-B					
E_BLQ_CIERRE	IN_79_x	Breaker Control	SCBRx.ClsBlkIn	X Close Blocking Input		Close Blocking Input.
CIERRE	CLOSE_CMDx		SCBRx.ColCls	X Close Command		Close Command.
ORD_CIERRE	IN_CLOSE_CMD1		SCBRx.ClsCmdIn	X Manual Close Command		Manual Close Command.
OCAx	OCAx		SCBRx.ClsOpIntr	X Close Command Canceled		Close Command Canceled.
FOC	FAIL_CLOSEx		SCBRx.ClsFail	X Close Command Failure		Close Command Failure.
IN_CLS_EXCMD	IN_CLSx_EXCMD		SCBRx.ExClsCmd	X External Close Command Activation		External Close Command Activation.
APERTURA	OPEN_CMDx		SCBRx.ColOpn	X Open Command		Open Command.
ORD_APERTUA	IN_OPEN_CMDx		SCBRx.OpnCmdIn	X Manual Open Command		Manual Open Command.
APER_TR	OPEN_3PHx			Three Pole Open Command		Three Pole Open Command.
FOA	FAIL_OPENx		SCBRx.OpnFail	X Open Command Failure		Open Command Failure.
IN_OPN_EXCMD	IN_OPNx_EXCMD		SCBRx.ExOpnCmd	X External Open Command Activation		External Open Command Activation.
APER_A	OPEN_Ax			X Pole A Open Command		Pole A Open Command.
FOA_A	FAIL_OPEN_Ax			X Pole A Open Command Failure		Pole A Open Command Failure.
APER_B	OPEN_Bx			X Pole B Open Command		Pole B Open Command.
FOA_B	FAIL_OPEN_Bx			X Pole B Open Command Failure		Pole B Open Command Failure.
APER_C	OPEN_Cx			X Pole C Open Command		Pole C Open Command.
FOA_C	FAIL_OPEN_Cx			X Pole C Open Command Failure		Pole C Open Command Failure.

In Column **Description**: X= Breaker 1 or Breaker 2 for models with double breaker capability. For models with single breaker capability no suffix is added.
In column **Name**: x= 1,2 for models with double breaker capability. For models with single breaker capability no suffix is added.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.14.5 IEC 61850 Logical Node

CLASS DLFSCBR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
SumSwARs1	BCR	Accumulative KA2 phase A
SumSwARs2	BCR	Accumulative KA2 phase B
SumSwARs3	BCR	Accumulative KA2 phase C
OpCntRs1	INC	Number of pole A closing operations
OpCntRs2	INC	Number of pole B closing operations
OpCntRs3	INC	Number of pole C closing operations
OpCntRs4	INC	Number of pole 3 phase closing operations
SwA1	MV	Current opened phase A
SwA2	MV	Current opened phase B
SwA3	MV	Current opened phase C
Status information		
ArcStrIn1	SPS	Pole A arc initiation input
ArcStrIn2	SPS	Pole B arc initiation input
ArcStrIn3	SPS	Pole C arc initiation input
NumTrAlm	SPS	Alarm excessive number of trips
SwAAlm1	SPS	Alarm KA2 phase A
SwAAlm2	SPS	Alarm KA2 phase B
SwAAlm3	SPS	Alarm KA2 phase C
SwARsCmd1	SPC	Reposition command KA2 phase A
SwARsCmd2	SPC	Reposition command KA2 phase B
SwARsCmd3	SPC	Reposition command KA2 phase C
SwABlkIn	SPS	Accumulative kA2 block input
OpCntRs1	INC	Reposition command open current phase A
OpCntRs2	INC	Reposition command open current phase B
OpCntRs3	INC	Reposition command open current phase C
CBInA	SPS	Breaker pole A open input
CBInB	SPS	Breaker pole B open input
CBInC	SPS	Breaker pole C open input
CBInOR	SPS	Breaker any pole open input
CBInAND	SPS	Breaker all pole open input
AnyPoleOpn	ACT	Breaker any pole open
OnePoleOpn	SPS	Breaker one pole open
AllPoleOpn	SPS	Breaker all pole open
OpnFail	SPS	Breaker open command failure
ClsFail	SPS	Breaker close command failure
ColOpn	SPS	Breaker open command executed
ColCls	SPS	Breaker close command executed
ClsOpIntr	SPS	Breaker close command canceled

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Status information (cont.)		
OpnCmdIn	SPC	Breaker open command
ClsCmdIn	SPC	Breaker close command
ClsBlkIn	SPS	Breaker close command block input
Settings		
MaxTrEna	SPG	Enable maximum number of trips
MaxNumTr	ING	Maximum number of trips value
MaxSwA	ASG	Value for KA2 alarm
SwARsVal1	ASG	Reposition value for KA2 phase A
SwARsVal2	ASG	Reposition value for KA2 phase B
SwARsVal3	ASG	Reposition value for KA2 phase C
SwAExp	ASG	KA2 index
ArcDlTmCyc	ASG	Arc initiation delay
ArcEvTmCyc	ING	Arc calculation window
NumIn	ENG	Open Pole number of breaker inputs
OpnCurA	ASG	Open Pole current pole A open
OpnCurB	ASG	Open Pole current pole B open
OpnCurC	ASG	Open Pole current pole C open
OpnPlsTmms	ING	Minimum open command time
ClsPlsTmms	ING	Open command failure
ClsFlTmms	ING	Minimum close command time
ClsPlsTmms	ING	Close command failure
StrInf	SPG	Fault report with pickups
MagVisMod	ENG	Primary/secondary values in fault report
ManClsChk	SPG	Synchrocheck for closing
LodShedMsk	SPG	Load shedding close command enable
CBBlkEna1	SPG	Close command block enable due to circuit 1 alarm_SlotA
CBBlkEna2	SPG	Close command block enable due to circuit 2 alarm_SlotA
CBBlkEna1	SPG	Close command block enable due to circuit 1 alarm_SlotB
CBBlkEna2	SPG	Close command block enable due to circuit 2 alarm_SlotB

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8.14 Command / Logic

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8.14.1 Operation Principles

Following functions exist within the Command / Logic group:

Trip Seal-In.
Manual Open Seal.
Minimum Open Command Reset Time.
Minimum Close Command Reset Time.
Fail to Open / Close Time.
Manual Closing through Recloser.
Manual Close Synchrocheck Supervision 1.
Manual Close Synchrocheck Supervision 2.

8.14.1.a Trip Seal-In

To enable the Seal-In function the setting ***Trip Seal-In*** must be set to **YES**. Under these circumstances, the trip command over a pole of the breaker (**Pole A Trip**, **Pole B Trip**, **Pole C Trip**) will be kept activated as long as the opening of this is not detected (PA_OP, PB_OP and PC_OP open pole detector outputs). If setting ***Trip Seal-In*** is set to **NO**, the trip command resets when protection measuring elements or logic signals that generated trip activation reset.

This setting is of application when the breaker associated to the protection fails or is very slow (very slow auxiliary contacts 52/a for breaking the current of the trip circuit), and an upstream breaker clears the fault, the trip contact would be compelled to open the trip circuit causing its destruction.

The failed or slow breaker, once the function that caused the trip is reset, makes the relay contact to open before the breaker auxiliary contact 52/a, even after the overrun time of the first. An active trip command prevents the relay contact from breaking the current of the trip circuit (mainly inductive and high), and related damage to same circuit as normally these currents exceed circuit rated current breaking capability.

8.14.1.b Manual Open Sealing Command

To enable the Manual Opening Command Sealing function the setting ***Manual Open Seal*** must be set to **YES**. Under these circumstances, once an opening and the corresponding breaker operate command has been generated; the command is active until open breaker is detected through the auxiliary contact.

If setting ***Manual Open Seal*** is set to **NO**, the opening command resets when protection the logic signals that generated trip activation reset, always respecting the minimum activation time of the adjusted opening command.

The application of this setting is the same as that of the trip sealing described in the previous section.

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8.14.1.c Breaker Open and Close Failure Time

Both for manual and protection element generated operations, a minimum open command activation time can be set. For this purpose the setting ***Minimum Open Command Reset Time*** is used the range of which is from 100ms to 5s.

If open command is generated by the activation of any protection element, the open command is active during the setting value; in case elements are active during a longer period of time, the open command will be active until elements deactivate.

If open command is manual, duration is always the setting value.

The open command (by trip) will be active until an open breaker is confirmed if setting ***Trip Seal-In*** is set to **YES**.

The open command will be active until an open breaker is confirmed if setting ***Manual Open Seal*** is set to **YES**.

A setting ***Minimum Close Command Reset Time*** is provided that allows setting the minimum time that close commands are active. Range is from 0s to 5s. The 0 value indicates that close commands will be active until closed breaker is detected or a close command failure is given.

Both for manual and protection element-generated or reclose-generated operations, if a breaker state change signal is not received, after an operate command is sent, within the operate failure time (settable separately for open and close operations), **Open Command Failure** or **Close Command Failure** signals are activated. If the **Close Command Failure** signal is produced before the breaker closes during a shot sequence, recloser will be blocked.

Nevertheless, open and close commands are active during the activation time setting even if Open or Close Command Failure is produced.

8.14.1.d Manual Closing through Recloser

Breakers can be closed using Recloser logic in order for the logic to decide to close the breaker. For this to happen, ***Manual Close by Recloser*** setting (Within the Recloser ***Cycle Control*** settings) must be set to **YES**.

8.14.1.e Manual Close Synchrocheck Supervision

As already mentioned in the corresponding Recloser paragraph, there is no need to use Recloser logic to close the breaker; this is the **External Manual Close**.

For these close commands to be synchronism check supervised, the setting ***Manual Close Synchrocheck Supervision*** must be set to **YES**.

8.14.1.f Close Blocking

Each coil supervision has an associated setting, ***Close Blocking***, that allows enabling the automatic blocking of breaker close commands, such that, if the close blocking setting ***SLOT X Coil 1 and 2*** (where X can be A and/or B) is enabled, when an anomaly of this coil occurs, the recloser close commands and the manual close command will be blocked.

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8.14.2 Setting Ranges

Control					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Trip Seal-In	Trip Seal-in	SCBR1.TrSeal	NO / YES		NO
Manual Open Seal	Manual Open Seal	PTRC1.OpnCmdSeal (SPG ext.)	NO / YES		NO
Minimum Open Command Reset Time	Min Opening Res T	SCBR1.OpnPlsTmms	0.1-5 s	0.1 s	0.2
Fail to Open Time	Fail to Open Time	SCBR1.OpnFlTmms	0.02-2 s	0.005 s	0.02 s
Minimum Close Command Reset Time	Min Closing Res T	SCBR1.ClsPlsTmms	0-5 s	0.1 s	0.2
Fail to Close Time	Fail to Close Time	SCBR1.ClsFlTmms	0.02-5 s	0.01 s	0.02 s
Manual Close Synchrocheck Supervision 1	Syncr. Supervision	SCBR1.ManClsChk	YES / NO		NO
Manual Close Synchrocheck Supervision 2*	Syncr. Supervision	SCBR2.ManClsChk	YES / NO		NO
Load Restoration Enable	Load Restorat.Ena				
REP DLS1**	LOAD REST1	SCBR1.LodShedMsk	YES / NO		NO
Close Blocking**					
Slot A Coil 1	Slot A Coil 1	SCBC1.CBBlkEna1	YES / NO		NO
Slot A Coil 2	Slot A Coil 2	SCBC1.CBBlkEna2	YES / NO		NO
Slot B Coil 1	Slot B Coil 1	SCBC2.CBBlkEna1	YES / NO		NO
Slot B Coil 2	Slot B Coil 2	SCBC2.CBBlkEna2	YES / NO		NO

(*) Only for models with Double Breaker of Breaker-and-a-half bay configuration capability.
(**) Not available in models with Double Breaker of Breaker-and-a-half bay configuration capability.

8.14.3 Digital Inputs to the Command / Logic Module

Table 8.14-1: Digital Inputs to the Command / Logic Module

Name	Group	IEC 61850	Description	Vis.	Function
M_OPN1	Breaker Control	SCBR1.OpnCmdIn	Breaker 1 Manual Open Command		Their activation generates manual open and close commands respectively; they can be allocated to the HMI, communications, digital inputs or any programmable logic signal. Their application is oriented to being allocated to COMMANDS.
M_OPN2		SCBR2.OpnCmdIn	Breaker 2 Manual Open Command		
M_CLS1		SCBR1.ClsCmdIn	Breaker 1 Manual Close Command		
M_CLS2		SCBR2.ClsCmdIn	Breaker 2 Manual Close Command		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.14.4 Auxiliary Outputs and Events of the Command / Logic Module

Table 8.14-2: Auxiliary Outputs and Events of the Command Failure Module						
Name		Group	IEC 61850	Description	Vis.	Function
DLF-A	DLF-B					
E_BLQ_CIERRE	IN_79_x	Breaker Control	SCBRx.ClsBlkIn	X Close Blocking Input		Close Blocking Input.
CIERRE	CLOSE_CMDx		SCBRx.ColCls	X Close Command		Close Command.
ORD_CIERRE	IN_CLOSE_CMD1		SCBRx.ClsCmdIn	X Manual Close Command		Manual Close Command.
OCAx	OCAx		SCBRx.ClsOpIntr	X Close Command Canceled		Close Command Canceled.
FOC	FAIL_CLOSEx		SCBRx.ClsFail	X Close Command Failure		Close Command Failure.
IN_CLS_EXCMD	IN_CLSx_EXCMD		SCBRx.ExClsCmd	X External Close Command Activation		External Close Command Activation.
APERTURA	OPEN_CMDx		SCBRx.ColOpn	X Open Command		Open Command.
ORD_APERTUA	IN_OPEN_CMDx		SCBRx.OpnCmdIn	X Manual Open Command		Manual Open Command.
APER_TR	OPEN_3PHx			Three Pole Open Command		Three Pole Open Command.
FOA	FAIL_OPENx		SCBRx.OpnFail	X Open Command Failure		Open Command Failure.
IN_OPN_EXCMD	IN_OPNx_EXCMD		SCBRx.ExOpnCmd	X External Open Command Activation		External Open Command Activation.
APER_A	OPEN_Ax			X Pole A Open Command		Pole A Open Command.
FOA_A	FAIL_OPEN_Ax			X Pole A Open Command Failure		Pole A Open Command Failure.
APER_B	OPEN_Bx			X Pole B Open Command		Pole B Open Command.
FOA_B	FAIL_OPEN_Bx			X Pole B Open Command Failure		Pole B Open Command Failure.
APER_C	OPEN_Cx			X Pole C Open Command		Pole C Open Command.
FOA_C	FAIL_OPEN_Cx			X Pole C Open Command Failure		Pole C Open Command Failure.

In Column **Description**: X= Breaker 1 or Breaker 2 for models with double breaker capability. For models with single breaker capability no suffix is added.
In column **Name**: x= 1,2 for models with double breaker capability. For models with single breaker capability no suffix is added.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.14.5 IEC 61850 Logical Node

CLASS DLFSCBR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
SumSwARs1	BCR	Accumulative KA2 phase A
SumSwARs2	BCR	Accumulative KA2 phase B
SumSwARs3	BCR	Accumulative KA2 phase C
OpCntRs1	INC	Number of pole A closing operations
OpCntRs2	INC	Number of pole B closing operations
OpCntRs3	INC	Number of pole C closing operations
OpCntRs4	INC	Number of pole 3 phase closing operations
SwA1	MV	Current opened phase A
SwA2	MV	Current opened phase B
SwA3	MV	Current opened phase C
Status information		
ArcStrIn1	SPS	Pole A arc initiation input
ArcStrIn2	SPS	Pole B arc initiation input
ArcStrIn3	SPS	Pole C arc initiation input
NumTrAlm	SPS	Alarm excessive number of trips
SwAAlm1	SPS	Alarm KA2 phase A
SwAAlm2	SPS	Alarm KA2 phase B
SwAAlm3	SPS	Alarm KA2 phase C
SwARsCmd1	SPC	Reposition command KA2 phase A
SwARsCmd2	SPC	Reposition command KA2 phase B
SwARsCmd3	SPC	Reposition command KA2 phase C
SwABlkIn	SPS	Accumulative kA2 block input
OpCntRs1	INC	Reposition command open current phase A
OpCntRs2	INC	Reposition command open current phase B
OpCntRs3	INC	Reposition command open current phase C
CBInA	SPS	Breaker pole A open input
CBInB	SPS	Breaker pole B open input
CBInC	SPS	Breaker pole C open input
CBInOR	SPS	Breaker any pole open input
CBInAND	SPS	Breaker all pole open input
AnyPoleOpn	ACT	Breaker any pole open
OnePoleOpn	SPS	Breaker one pole open
AllPoleOpn	SPS	Breaker all pole open
OpnFail	SPS	Breaker open command failure
ClsFail	SPS	Breaker close command failure
ColOpn	SPS	Breaker open command executed
ColCls	SPS	Breaker close command executed
ClsOpIntr	SPS	Breaker close command canceled

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Status information (cont.)		
OpnCmdIn	SPC	Breaker open command
ClsCmdIn	SPC	Breaker close command
ClsBlkIn	SPS	Breaker close command block input
Settings		
MaxTrEna	SPG	Enable maximum number of trips
MaxNumTr	ING	Maximum number of trips value
MaxSwA	ASG	Value for KA2 alarm
SwARsVal1	ASG	Reposition value for KA2 phase A
SwARsVal2	ASG	Reposition value for KA2 phase B
SwARsVal3	ASG	Reposition value for KA2 phase C
SwAExp	ASG	KA2 index
ArcDlTmCyc	ASG	Arc initiation delay
ArcEvTmCyc	ING	Arc calculation window
NumIn	ENG	Open Pole number of breaker inputs
OpnCurA	ASG	Open Pole current pole A open
OpnCurB	ASG	Open Pole current pole B open
OpnCurC	ASG	Open Pole current pole C open
OpnPlsTmms	ING	Minimum open command time
ClsPlsTmms	ING	Open command failure
ClsFlTmms	ING	Minimum close command time
ClsPlsTmms	ING	Close command failure
StrInf	SPG	Fault report with pickups
MagVisMod	ENG	Primary/secondary values in fault report
ManClsChk	SPG	Synchrocheck for closing
LodShedMsk	SPG	Load shedding close command enable
CBBlkEna1	SPG	Close command block enable due to circuit 1 alarm_SlotA
CBBlkEna2	SPG	Close command block enable due to circuit 2 alarm_SlotA
CBBlkEna1	SPG	Close command block enable due to circuit 1 alarm_SlotB
CBBlkEna2	SPG	Close command block enable due to circuit 2 alarm_SlotB

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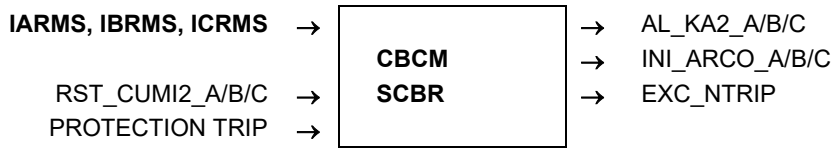
8.15 Breaker Monitoring

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8.15.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Breaker Monitoring Element	SCBR1	CBCM	CBCM

8.15.2 General Block



8.15.3 Operation Principles

In case of relays adapted for Breaker and a half with line CT configuration, Circuit Breaker Command Monitoring is done by external equipment and therefore internal monitoring is disable. Furthermore, under this configuration, no information of currents from each breaker is available and therefore this units is not applicable. In this case, if setting ***Number of Breakers*** is set to **I1**, which indicates single breaker configuration, Circuit Breaker Command Monitoring is enable. If it is set to **I1+I2**, it is disable.

8.15.3.a Cumulated Amps

Relays are provided with an improved Breaker Supervision function that carries out a more accurate calculation of the arc energy dissipated by the breaker contacts. On the other hand, this calculation is performed for each breaker pole.

The theoretical formula for the energy of the arc generated during the contact opening process will be: $E_{arc}=\int(I_{arc}*V_{arc})dt$, where I_{arc} and V_{arc} represent arc current and voltage. As $V_{arc}=I_{arc}*R_{arc}$, where R_{arc} is arc resistance, the above formula can be expressed as $E_{arc}=\int(I_{arc}^2*R_{arc})dt$. If a constant arc resistance is assumed, arc energy will be proportional to $I_{RMS}^2*T_{arc}$, where I_{RMS} is the calculated current RMS value during a time frame coinciding exactly with the arc duration and T_{arc} is the duration of the arc between the breaker contacts.

The IEDs calculate the above expression, with no need for using variable frames (T_{arc} varies from one opening to another), based on the following formula $I_{RMS}^2*T_{window}$, where T_{window}, representing the calculation time frame, is fixed and high enough to cover for arc duration.

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Based on typical arc durations included in Standard IEC T100a (from 4 to 25 ms), a calculation time frame of 2 cycles has been considered. Said time frame must start at the time when the arc is established between contacts, which can be determined in two ways:

- Taking into account the time when the corresponding breaker pole open signal (whether external or internal to the relay) activates, after adding said pole contact opening time (device operating time: breakers with 2, 3, 5 and 8 cycle operating time have typical contact opening times of 1.5, 2, 3 and 4 cycles).
- Taking into account breaker pole state contact (52b or 52a) operate time after subtracting said contact delay time with respect to the main contacts.

In order to select the most convenient way, based on breaker available information, the arc initiate signal (**Pole X** (X=A, B, C) **Arc Initiate** input) can be configured through the programmable logic (opening signal or breaker state contacts). At the time of activation of said signal, a settable time (***Arc Start Delay***: from -1 to 50 cycles in ¼ cycle steps) is added or subtracted.

If neither the contact opening time nor the secondary contact (52b/52a) delay time with respect to the main contacts is known, neither the arc initiate time nor its duration can be calculated. In that case, the best choice is to consider an arc duration of 1 cycle letting the relay store the current RMS value with calculation time frames of equal duration (just setting ***Calculation Window Length*** to 1 cycle), starting at the time of breaker pole open signal activation (set ***Arc Start Delay*** to 0 cycles).

The equipment will generate magnitudes called **IA_ABIERTA**, **IB_ABIERTA**, **IC_ABIERTA**. Said magnitude will be equals to the RMS value of the current circulating through breaker n X pole, calculated during the above defined frame. The value of this magnitude updates every time the **X Pole Arc Initiate Input** activates, the calculation frame being completed and the **X Pole Open Input** activated. The magnitude resets to 0 under various conditions:

- When, after completing the calculation frame, a **X Pole Open Command Failure** occurs (in this case the **X Pole Open Input** will not activate).
- When the ***Calculation Window Length*** setting sets to 0
- When the **kA Counter Blocking Input** is activated. Said input prevents current buffers from increasing (see below) when relays are being checked with secondary injection equipment (during which the breaker current is zero).

Arc energy has been previously considered proportional to $I_{RMS}^2 * T_{arc}$, assuming constant arc resistance. Actually, arc resistance depends on the arc current value, thus arc energy will be proportional to $I_{RMS}^N * T_{arc}$, where N has a value between 1 and 2. The breaker manufacturer as a rule gives two figures of the number of operations at a given current: n1 operations at I1 kA and n2 operations at I2 kA. In order for the energy calculated for both current levels to be the same, an exponent N other than 2 must be used for the current: $n1*I1^N=n2*I2^N$. IEDs have the possibility to select the exponent N through a setting.

The devices generate other magnitude, **ACUMI_X** (X=A, B, C Pole Opened Current), which stores the following value, every time the **X Pole Open Current** updates:

$$\left(I_{RMS_X} \times R_{TIABC}\right)^N \times T_{window}$$

where I_{RMS_X} represents the breaker X pole opened current, R_{TIABC} represents the phase current transformation ratio, N represents the exponent selected and T_{window} represents the selected calculation time frame.

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The total stored value is obtained as percentage of the ***I2 Sum Alarm*** setting (expressed in kAeN* cycle). When the **X Pole Stored Current** magnitude reaches 100%, the function activates the **Pole X Open kA Counter Alarm** signal that can be used to activate one output through the programmable output function; also a write is added to the event recorder.

The stored current magnitude is updated every time the arc initiate input is activated, nevertheless said magnitude can be modified manually, via **Pole X kA Counter Reset** input activation. In that case the latter magnitude will take the value of the ***I Pole X Dropout*** setting. Said setting represents the base stored value above which successive values corresponding to later openings will be added. Manual modification allows taking into account the breaker pole opening history when installing the relay and the updated value after a maintenance operation.

When the setting ***I^2 Sum alarm*** is set to 0, the cumulated amp counter does not cumulate and an alarm will never be generated. When this setting is changed, the cumulated magnitudes and current interrupt magnitudes are reset and go to their defined reset value.

8.15.3.b Excessive Number of Trips

The Excessive Number of Trips function is intended to interrupt an uncontrolled sequence of openings and closings that could damage the breaker. When a certain number of trips have occurred, adjustable between 1 and 40 in a definite time period (30 minutes), an output signal is generated and it can be connected to any of the IED's physical auxiliary contact outputs.

The activation of the **Excessive Number of Trips** output function disables any further reclose initiation by placing the recloser function in the state of **Recloser Lockout due to Open Breaker** status. This condition will reset only after a manual close command or a loss of auxiliary supply.

8.15.4 Setting Ranges

Breaker Supervision					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable Excessive Trips	Enable Excess Trip	SCBR1.MaxTrEna	YES / NO		NO
Excessive Trips	Excessive Trips	SCBR1.MaxNumTr	1-40	1	40
I^2 Sum Alarm	I² Sum Alarm	SCBR1.MaxSwA	0-99,999.99kA^2	0.01	99,999.99
I Pole A Dropout	I Pole A Dropout	SCBR1.SwARsVal1	0-99,999.99kA^2	0.01	0 kA^2
I Pole B Dropout	I Pole B Dropout	SCBR1.SwARsVal2	0-99,999.99kA^2	0.01	0 kA^2
I Pole C Dropout	I Pole C Dropout	SCBR1.SwARsVal3	0-99,999.99kA^2	0.01	0 kA^2
kA Index	kA Index	SCBR1.SwAExp	1-2	0.1	2
Arc Start Delay	Arc Start Delay	SCBR1.ArcDlTmCyc	(-1)-50 cycles	¼ cycle	0 cycles
Calculation Window Length	Window Length	SCBR1.ArcEvTmCyc	0 / 1 / 2 cycles	0.01	2 cycles

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8.15.5 Analog Inputs to the Unit

Table 8.15-1: Analog Inputs to the Breaker Monitoring Module		
Name	**Description**	**IEC 61850**
IARMS	Phase A RMS Current	MHAI1.HRmsA.phsA
IBRMS	Phase B RMS Current	MHAI1.HRmsB.phsA
ICRMS	Phase C RMS Current	MHAI1.HRmsC.phsA

8.15.6 Digital Inputs to the Breaker Monitoring Module

Table 8.15-2: Digital Inputs to the Breaker Monitoring Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_KA	Breaker Monitoring	SCBR1.SwABlkIn	kA Counter Blocking Input	I	Activating this input blocks current store.
IN_KA_STR_A		SCBR1.ArcStrIn1	Pole A Arc Start Input	I	The activation of this input starts the window calculating the RMS current value open by the X pole of the breaker.
IN_KA_STR_B		SCBR1.ArcStrIn2	Pole B Arc Start Input	I	
IN_KA_STR_C		SCBR1.ArcStrIn3	Pole C Arc Start Input	I	
RST_CUMIA	Reposition Commands	SCBR1.SwARsCmd1	Pole A kA Counter Reset	I	Activating this input resets breaker X Pole Stored Current magnitude to the “I Pole X Dropout” setting.
RST_CUMIB		SCBR1.SwARsCmd2	Pole B kA Counter Reset	I	
RST_CUMIC		SCBR1.SwARsCmd3	Pole C kA Counter Reset	I	

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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8.15.7 Auxiliary Outputs and Events of the Breaker Monitoring Module

Table 8.15-3: Auxiliary Outputs and Events of the Breaker Monitoring Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
AL_KA_A	Breaker Monitoring	SCBR1.SwAAlm1	Pole A Open kA Counter Alarm	I	Indication that the kA^{N*} cycles accumulated by pole (A/B/C) of the breaker have reached the alarm level.
AL_KA_B		SCBR1.SwAAlm2	Pole B Open kA Counter Alarm	I	
AL_KA_C		SCBR1.SwAAlm3	Pole C Open kA Counter Alarm	I	
EXC_NTRIP		SCBR1.NumTrAlm	Excessive Number of Trips	I	Indication that the maximum number of trips set has been reached.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.15.8 IEC 61850 Logical Node

CLASS IRLSCBR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
SumSwARs1	BCR	Accumulative KA2 phase A
SumSwARs2	BCR	Accumulative KA2 phase B
SumSwARs3	BCR	Accumulative KA2 phase C
OpCntRs1	INC	Number of pole A closing operations
OpCntRs2	INC	Number of pole B closing operations
OpCntRs3	INC	Number of pole C closing operations
OpCntRs4	INC	Number of pole 3 phase closing operations
SwA1	MV	Current opened phase A
SwA2	MV	Current opened phase B
SwA3	MV	Current opened phase C
Status information		
ArcStrIn1	SPS	Pole A arc initiation input
ArcStrIn2	SPS	Pole B arc initiation input
ArcStrIn3	SPS	Pole C arc initiation input
NumTrAlm	SPS	Alarm excessive number of trips
SwAAlm1	SPS	Alarm KA2 phase A
SwAAlm2	SPS	Alarm KA2 phase B
SwAAlm3	SPS	Alarm KA2 phase C

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Status information (cont.)		
SwARsCmd1	SPC	Reposition command KA2 phase A
SwARsCmd2	SPC	Reposition command KA2 phase B
SwARsCmd3	SPC	Reposition command KA2 phase C
SwABlkIn	SPS	Accumulative kA2 block input
OpCntRs1	INC	Reposition command open current phase A
OpCntRs2	INC	Reposition command open current phase B
OpCntRs3	INC	Reposition command open current phase C
CBInA	SPS	Breaker pole A open input
CBInB	SPS	Breaker pole B open input
CBInC	SPS	Breaker pole C open input
CBInOR	SPS	Breaker any pole open input
CBInAND	SPS	Breaker all pole open input
AnyPoleOpn	ACT	Breaker any pole open
OnePoleOpn	SPS	Breaker one pole open
AllPoleOpn	SPS	Breaker all pole open
OpnFail	SPS	Breaker open command failure
ClsFail	SPS	Breaker close command failure
ColOpn	SPS	Breaker open command executed
ColCls	SPS	Breaker close command executed
ClsOpIntr	SPS	Breaker close command canceled
OpnCmdIn	SPC	Breaker open command
ClsCmdIn	SPC	Breaker close command
ClsBlkIn	SPS	Breaker close command block input
Settings		
MaxTrEna	SPG	Enable maximum number of trips
MaxNumTr	ING	Maximum number of trips value
MaxSwA	ASG	Value for KA2 alarm
SwARsVal1	ASG	Reposition value for KA2 phase A
SwARsVal2	ASG	Reposition value for KA2 phase B
SwARsVal3	ASG	Reposition value for KA2 phase C
SwAExp	ASG	KA2 index
ArcDlTmCyc	ASG	Arc initiation delay
ArcEvTmCyc	ING	Arc calculation window
NumIn	ENG	Open Pole number of breaker inputs
OpnCurA	ASG	Open Pole current pole A open
OpnCurB	ASG	Open Pole current pole B open
OpnCurC	ASG	Open Pole current pole C open
TrSeal	SPG	Sealed enable
OpnPlsTmms	ING	Minimum open command time
ClsPlsTmms	ING	Open command failure
ClsFlTmms	ING	Minimum close command time
ClsPlsTmms	ING	Close command failure
StrInf	SPG	Fault report with pickups
MagVisMod	ENG	Primary/secondary values in fault report
ManClsChk	SPG	Synchrocheck for closing
LodShedMsk	SPG	Load shedding close command enable

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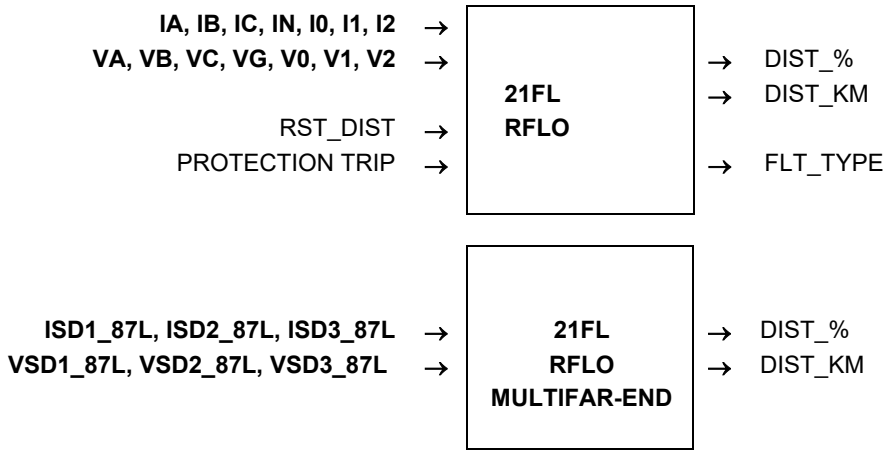
8.16 Fault Locators

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8.16.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Fault Locator	RFLO	FLOC	21FL

8.16.2 General Block



8.16.3 Introduction

The equipment has two fault locators working at the same time. The first one is based on local measurements while the second one, called multi-end fault locator, uses both local and remote magnitudes.

8.16.4 Fault Locator with Local Magnitudes

The operation of the Fault Locator with local magnitudes is based, first, on defining the type of fault through the Phase Selector (refer to Chapter 8.8). Then, the fault distance is found by applying the corresponding algorithm to each type of fault.

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8.16.4.a Fault Locator Settings

- **Line Impedance**

The settable electrical parameters of the line are: ***Pos. Seq. Magnitude***, ***Pos. Seq. Angle***, ***Zero Seq. Angle*** and ***Z1 k0 Factor***, where all values are secondary ohms.

The ***Z1 k0 Factor*** setting allows you to define the zero sequence compensation factor ($\mathbf{Z_0 = k_0 \times Z_1}$).

- **Local Source Impedance**

The impedance of zero sequence of source line (magnitude and angle) must also be set if only two phase-phase voltage transformers (VAB and VBC) are being used.

Note: setting ranges of Positive Sequence Magnitude and Zero Sequence Magnitude will depend on the Current Nominal value.

- **Length and Units**

Line Length

This setting corresponds to the length of the line that the locator is going to operate on. It is a dimensionless value.

Length Units

The line ***Length Units*** setting allows selecting the unit of length, Kilometers or miles, for the preceding setting.

Locator Units

The ***Locator Units*** setting can be a unit of length or a percentage of the line length. When there is a fault, the locator will express the measurements according to this setting.

- **Indication**

Permanent Indication and Indication Duration

Once the distance to the fault is calculated, the location measurement variable will maintain the value calculated for some time. This time depends on the ***Permanent indication*** and ***Time Indication*** settings.

If the ***Permanent Indication*** setting is **YES**, the value of the variable will not change until a new fault report is stored. Then it will change to the new value. In this operation mode, the location measurement will always be the value calculated for the last Fault Report stored.

If, on the contrary, the ***Permanent Indication*** setting is **NO**, the measurement variable will maintain the value for the time defined in the ***Time Indication*** setting. If another fault report is stored meanwhile, the corresponding distance to the fault is not stored in the location measurement variable, although it is stored in its corresponding fault report record.

This operating mode is the same for the fault distance indication in the display as well as for the distance value which can be configured to be sent by communications through any of the available protocols.

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Minimum Zero Sequence Current Value

You can set a zero sequence current (3 x I_0) threshold value for single-phase faults. This way, if two and a half cycles after the pickup of the first element the 3 x I_0 magnitudes is less than this setting, the fault will be classified as an **Unknown Fault**. The setting is ***Zero Seq. Min Value*** and it refers to primary values.

Indication Zone

The setting ***Indication Zone*** selects if the fault locator calculates distance to the fault for faults inside the protected line of for any fault detected by the relay. The availability of the information is limited to the display in the HMI, fault reports and communications.

With the option ***Internal Faults***, information is available for faults located inside the defined length for the protected line.

With the option ***Internal and External***, information is available for any fault independent of the location being inside or outside of the defined length.

It is important to consider the setting ***Pickup Report*** described in section 8.14 (Command / Logic).

With the option ***Internal Faults*** is possible to consider the pickup of the units. In any case all the faults are detected.

The option ***Internal and External*** requires setting the ***Pickup Report*** to **YES** to be able to detect faults outside the protected line and calculate the distance to the fault (in these cases under normal operation the relay will not generate trips). Unless the directional units are set to reverse, the relay cans only pickup for faults upstream but never trip. Therefore, the only way to detect such faults is via the pickup report. Same applies for faults located over 100% of the line length. If the relay is coordinated properly, and for normal operating conditions the relay will pickup but never trip. Again, the only way to detect such faults is via the pickup of the units.

8.16.4.b Configuration of the Fault Locator

As indicated, the Fault Locator has a setting for sending the distance through remote communications (in the control profile):

Time Indication: 1 - 120 min

If the ***Permanent Indication*** setting is **NO**, the locator takes the ***Time Indication*** setting into account for sending the distance through the communications profile. When a fault report occurs, the indication of the distance through the control profile lasts the time set. If a new fault occurs meanwhile, the distance sent by communications is still that of the first fault. When the set time transpires, an invalid value for the distance is sent. Now if a new fault occurs the distance to this last fault is sent. In contrast, the **Last Trip** indication in the display and the **Fault Report** always show the locator's distance for the last trip produced.

If the ***Permanent Indication*** setting is **YES**, communications always sends the distance of the last fault registered. If the relay has not registered a fault, it will be sending an invalid value.

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The Fault Locator has a setting to block distance-to-fault calculation for single-phase faults with 3 x I_0 values below the setting two and a half cycles after the pickup. The fault will be classified as an UNKNOWN FAULT:

Minimum value of zero sequence current:0 - 500A

This setting refers to primary values.

Those faults that last less than 2.5 cycles will also be classified as an UNKNOWN FAULT.

Any fault occurring during the 15 cycles after the breaker closes will also be classified as an UNKNOWN FAULT. This logic only considers the breaker status change. It makes the locator insensitive to the inrush currents of the transformers that are energized when the breaker closes.

8.16.4.c Location Information

- **From Display**

The indication of the distance to the fault can be set to be offered either in line length units (kilometers or miles) or in percentage of the line length. It is always accompanied by the type of fault (AN, BN, CN, AB, BC, CA, ABN, BCN, CAN and THREE-PHASE). The default screen will indicate this distance when there is a fault.

The messages that the fault locator can present in the display depend on the calculations that it performs. The possibilities are:

- Negative distances.
- Positive distances.
- When the locator lacks information for calculating the distance: the display shows UNKNOWN FAULT.
- While the distance is being calculated: the display shows the message, CALCULATING DISTANCE.

- **Fault Report**

The information about the distance to the fault that can appear in the report is the same as that shown in the display, that is, the elements are the same as those chosen to be presented in it.
It is only necessary to add that when the fault is unknown, the distance will be filled in with asterisks and the type of fault will indicate UNKNOWN FAULT.

- **Information via Remote Communications**

The distance to the fault value sent via communications by the protocol selected is fully configurable; that is, its **Full-Scale** value and the **Type of Elements** in which it is sent can be chosen.

The options for configuring it in the programmable logic so that it will be sent are: **Percentage Value**, the **Value in Kilometers** or the **Value in Miles**. The selection is totally independent of the magnitude used for presenting it on the display and in the fault reports.

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With the ***ZIV e-NET tool***® it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the maximum defined counts are sent for each protocol (4095 counts for PROCOME and MODBUS and 32767 counts for DNP 3.0).
- **Nominal Flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

The expression that allows defining this **Full-Scale** value is the following:

When the **Nominal Flag** is enabled:

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{4095}{Limit}$$ for PROCOME and MODBUS

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{32767}{Limit}$$ for DNP 3.0

When the **Nominal Flag** is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{4095}{Limit}$$ for PROCOME and MODBUS

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{32767}{Limit}$$ for DNP 3.0

Taking into account this system for sending values, if the distance is to be sent so that 0 counts are sent in 0% and the maximum number of counts allowed by the protocol are sent in 100%, the settings must be:

The **Percentage Value** of the distance is selected. The following settings are made:

Offset value = 0
Limit = 100
Nominal Flag = NO

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To create a profile like that of figure, the following configuration is required:

The **Percentage Value** of the distance is selected. The following settings are made:

Offset value = -20
Limit = 120
Nominal Flag = NO

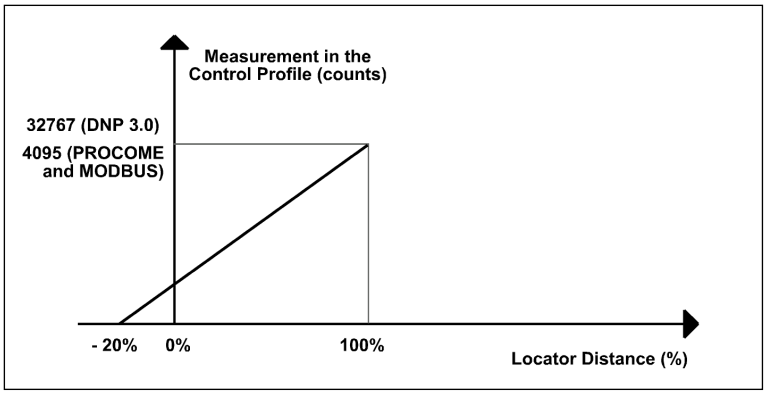


Figure 8.16.1 Scale of the Locator Measurements in the Control Profile.

Moreover, if between -20% and 0%, 0 counts should be sent, all that is needed is an algorithm in the programmable logic generating a user magnitude that is the **User Percentage Value**. This new magnitude is the one that will be sent via communications. It is generated as follows:

- An **Analog Selector** is configured. Its inputs are the **Percentage Value** and a **Zero**; its output is the **User Percentage Value**.
- A **Comparator** is configured to activate its output of **Greater than (>)** when the **Percentage Value** is greater than **0**, and subsequently *denies* this output.
- This *denied output* is used as a signal to control the Analog Selector.

Thus, the following is received via communications:

Distance: -20% → 0 counts
Distance: 100% → 32767 counts (DNP 3.0) or 4095 counts (PROCOME and MODBUS)

This way, if the distance that the locator calculates is greater than 100% or is less than or equal to 0%, the measurement sent in the control profile is **0** counts.

If the idea is to send the distance in kilometers or miles, sending the same number of counts as kilometers or miles shown on the display and the fault report will require the following configuration:

The value in **Kilometers** or **Miles** of the distance is selected. The following settings are made:

Offset value = 0
Limit = 4095 for PROCOME and MODBUS and 32767 for DNP 3.0
Nominal Flag = NO

As indicated previously, there are two locator settings in protection related to the transmission of the distance to control protocol: ***Permanent Indication*** and ***Time Indication***.

There is another input to the fault locator module, the **Distance Reset** input. Its function is to set the value of the distance to the fault and the type of fault that can be sent via communications to zero.

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8.16.5 Multi-End Fault Locator

This fault locator will work with the positive sequence voltages and currents of all line ends at the instant of fault (1.5 cycles after start). The distance to the fault is only calculated when one of the following units is triggered:

- Any differential unit.
- Any distance unit.
- Any overcurrent unit (includes trip by overcurrent protection scheme).
- Programmable trip.
- External trip (inputs APE, APE_TR, APE_A, APE_B, APE_C).

The multi-end fault locator determines which leg is in fault and indicates this in the fault report.

- **Enabling capacitive current compensation**

When capacitive current compensation is enabled, the capacitive current previously removed from the positive sequence currents is added. The following currents will be used for this purpose:

$$I_{1n}' = I_{1n} + V_{1n} \cdot \frac{Y1}{m},$$

Where n is the end of the line (n=E1, E2 and E3) and m is the number of ends performing capacitive current compensation; Y1 is the total positive sequence admittance of the line (sum of the positive sequence admittances of each line section).

- **Line with one or multiple sections**

In this locator, a series of line sections can be configured that allow the line to be divided into sections (ideal for mixed lines with overhead line and cable). The following section configurations are available:

- One section and two ends. It is the default setting and the positive sequence impedance values and the positive sequence or susceptance admittance of this section, called Section E1E2, are the set of the line impedances group. All other sections must be disabled.
- Two sections and two ends. Composed of sections E1M1 and M1E2. Composed of sections E1M1 and M1E2.
- Three sections and two ends. Composed of sections E1M1, M1M2 and M2E2. Composed of sections E1M1 and M1E2.
- Three sections and three ends. Composed of sections E1M1, M1E3 and M1E2. Composed of sections E1M1 and M1E2.

In this case the distance to the fault is calculated assuming that the fault is in each of the sections. This assumption will be made sequentially until the section in fault is found, which will be the one that provides a distance to the fault greater than zero, but less than the length of the section.

The distance to the fault is calculated considering positive sequence currents and voltages at all ends of the line, both of fault and pure fault (subtracted the pre-fault component and frozen two cycles before the start of the fault). The calculation will be done with both types of magnitude. The method with the least dispersion generated in the distance to the fault calculated with and without angular error is selected.

If the fault is located outside the line, the multi-end fault locator will not provide any fault measurement regardless of the ***Indication Zone*** setting value.

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8.16.6 Setting Ranges

Protection / Fault Locator					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Length and Units	Length and Units				
Line Length	Line Length	RFLO1.LinLen	0.1 - 1000	0.01	100
Length Units	Length Units	RFLO1.LenUnit	Kilometers Miles		Kilometers
Locator Units	Locator Units	RFLO1.FLoUnit	Length Units % of Length		% of Length
Parallel Line Coupling	Par.Line Coupling				
Mutual Coupling Compensation Enable	Mut Coupl. Comp. Ena	RFLO1.MutCompEna	YES / NO		NO
Non-Homogeneity Compensation	Non-Homog. Comp.	RFLO1.NHomComp	YES / NO		NO
Indicación	Indication				
Permanent Indication	Perman. Indication	RFLO1.PermInd	YES / NO		NO
Time indication	Time indication	RFLO1.IndTmm	1 - 120 min	1 min	5 min
Zero Seq. Min Value	Zero Seq Min Value	RFLO1.MinZerA	0 - 500 A	0.01 A	0 A
Indication Zone	Indication zone	RFLO1.IndZn	Internal Faults Internal and External		Internal Faults

Line Section					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Section E1E2	Section E1E2	RFLO1.E1E2Sect	YES / NO		SÍ
Section E1M1	Section E1M1	RFLO1.E1M1Sect	YES / NO		NO
Section M1E2	Section M1E2	RFLO1.M1E2Sect	YES / NO		NO
Section M1M2	Section M1M2	RFLO1.M1M2Sect	YES / NO		NO
Section M1E3	Section M1E3	RFLO1.M1E3Sect	YES / NO		NO
Section M2E2	Section M2E2	RFLO1.M2E2Sect	YES / NO		NO

Section n Impedances (E1M1, M1E2, M1M2, M1E3, M2E2)					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Positive Sequence Impedance Magnitude	Pos. Seq. Z Mod	RFLO1.ExMxZ1Mod	0.001-10 ohm/L	0.001 ohm/L	0.5 ohm/L
Positive Sequence Impedance Angle	Pos. Seq. Z Angle	RFLO1.ExMxZ1Ang	0-90º	0.1º	75º
Positive Sequence Susceptance	Pos. Seq. B Mod	RFLO1.ExMxB1Mod	0.1-1000 uS/L	0.001 ohm/L	0.5 ohm/L
Length	Section Long.	RFLO1.ExMxLen	0.01-1000 length units	0.01	50

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8.16.7 IEC 61850 Logical Node

CLASS IRLRFLO		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Measured values		
FltZ	CMV	Fault Impedance
FltDiskm	MV	Fault distance in Km
Settings		
Z1Mod	ASG	Positive sequence line impedance value
Z1Ang	ASG	Positive sequence line impedance angle
Z0Mod	ASG	Zero sequence line impedance value
Z0Ang	ASG	Zero sequence line impedance angle
Extended Data		
FltDisPct	EXT_MV	Fault distance in %
FltDisMile	EXT_MV	Fault distance in miles
FltLoop	EXT_ENS	Type of fault
LinLen	EXT_ASG	Line length
LenUnit	EXT_ENG	Units of line lenght
FLoUnit	EXT_ENG	Unit of fault locator
PermInd	EXT_SPG	Permanent indication
IndTmm	EXT_ING	Time of indication
MinZerA	EXT_ASG	Minimum zero sequence current
IndZn	EXT_ENG	Indication zone

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8.17 General Settings

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8.17.1 Description

The following settings are included within the General Settings group:

Description Settings.
Unit in service.
Operation Mode.
CT / VT Ratios.
Capacitive VT.
Phase Sequence.
IG Type
Angle Reference.
Invert Polarity.
PLL Enable.
Simultaneous Commands.
Overcurrent Pickup

8.17.1.a Description Settings

The equipment has 6 settings to be able to describe the equipment by means of a maximum of 64 characters per setting:

Name.
Breaker.
Division.
Zone.
Description1.
Description2.

8.17.1.b Unit In Service

Relay enabled (**YES**), means that all relay functions work normally (dependent on function settings).

If relay is disabled (**NO**), all functions are restricted to measurement operations only. Measurements are visualized on display and through local and remote communications.

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8.17.1.c Operation Mode

The operation of the relay can be configured in five different modes:

- **On**: equivalent to equipment in service. It implies the normal development of all the functions integrated in it (always depending on the settings configured for these functions).
- **Blocked**: the outputs of the equipment are disabled, they are all set to OFF. In this mode, the relay can operate its units normally; however, the outputs to the outside are blocked.
- **Test**: the equipment accepts data inputs with TEST quality (GOOSEs and commands). All IEC 61850 data issued by the equipment will be indicated as TEST in its quality. The external outputs will operate normally.
- **Test blocked**: the equipment accepts data inputs with TEST quality (GOOSEs and commands) and all IEC 61850 data emitted by the equipment will be indicated as TEST in its quality. Unlike the previous one, the outputs will be blocked.
- **Off**: equivalent to equipment out of service. It means that the units will not operate and the outputs will be OFF. Measurements and communications will be active, but all IEC 61850 data issued by the equipment will bear the INVALID indication in its quality.

In the following table you can see the characteristic overview of the operational functions of each mode:

Funtion	ON	Blocked	Test	Blocked Test	OFF
Operation	YES	YES	YES	YES	NO
Output to process	YES	NO	YES	NO	NO
Quality (q) issued data	q.test = false	q.test = false	q.test = true	q.test = true	q.validity = true
Quality (q) received data*	q.test = false	q.test = false	q.test = false q.test = true	q.test = false q.test = true	---
Normal commands	YES	YES	NO	NO	NO
Test Commands	NO	NO	YES	YES	NO
Communications	YES	YES	YES	YES	YES

*** Necessary quality of the data to be processed.**

8.17.1.d Transformer Ratios

Transformer ratio defines how analog values are displayed on the protection display. If transformer ratio is set to 1, secondary values are displayed. If, on the other hand, the transformer ratio corresponding to analog input adapter transformer is selected, primary values are displayed. Settable turn ratios are:

- Phase, ground and parallel line ground currents.
- Phase, synchronism and ground voltage.

In all cases, all overcurrent and overvoltage protection element settings are referred to secondary values. Programmable logic analog settings could refer both to secondary and primary values. In case of models with double breaker capability, and different CT ratio for each CT group, current secondary values used for protection are referred to CT Ratio 1 internally and shown as compensated currents.

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8.17.1.e Capacitive Transformer Transient Filtering

The devices incorporate for fault location a filter algorithm for voltage wave transients from capacitive voltage transformers. The objective is reducing locator overreach in electrical systems incorporating capacitive transformers. Filtering can be enabled or disabled through the general setting ***Capacitive VT*** (Capacitive Voltage Transformer).

8.17.1.f Phase Sequence

Power system phase sequence (ABC or ACB) can be selected in order to:

- Adequately calculate sequence components.
- Select correct directional element polarization magnitudes.
- Select the angle between side A and side B voltages of Synchronism Element.

The ***Phase Sequence*** setting tells the relay the actual system rotation and all functions operate correctly if analogue current and voltage connections are the same as indicated for A, B and C phases in the external connection scheme.

ATTENTION. If the phase sequence is reversed in a DLF, the same operation must be carried out for the rest of the DLFs connected to each other to maintain the homogeneity of measurement in the positive and negative sequence differential protection functions.

8.17.1.g IG Type

When the ***IG Type*** is set to **IG**, the protection relay can be set to use a CT to measure the grounding current and, thus, this measurement can be used to polarize the directional ground element (torque control **67N**) through the ***Ipol*** magnitude.

When the ***IG Type*** is set to **IN**, the directional character of the neutral elements (**67N**) will cease to be affected by the ***Ipol*** magnitude, since it will be meaningless as the protection relay knows that the wired current is the result of an external sum of the phase currents.

The directional character of the ground elements (**67G**), being meaningless, will not be affected by this setting, since in this type of connection, the current flowing through the ground CT is unidirectional, so it will not be involved in the polarization of the directional elements such as ***Ipol*** and has no effect on the operation of the same.

In any case, the neutral and ground overcurrent elements are always operative. This setting affects the operation of the Restricted Earth Fault element.

8.17.1.h Angle Reference

The angle reference is settable: it can be the measurement carried out by the VA phase voltage analog channel or the measurement carried out by the A phase current analog channel.

Likewise, the minimum values of current or voltage required to carry out the calculation of the angles can be adjusted.

When there is no angle reference magnitude, all angles will be displayed in the relay with an invalid value (***) and the oscillogram will display them at 0˚.

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8.17.1.i Invert Polarity

Inverts the polarity of any analog input set as YES.

8.17.1.j Digital PLL

The equipments include an algorithm that automatically adapts the sampling frequency to the network frequency, varying the time between samples, to ensure that the DFT calculation window comprises exactly one network cycle. If this adaptation should not take place, said window would not comprise one periodic wave, which will result in DFT measurement errors. These errors will be greater as the deviation between the window time and the period of the sampled wave is also greater.

The algorithm of sampling frequency adaptation is disabled by default. It can only be enabled through the HMI or Configuration Program, which is only recommended in those cases in which large variations in the frequency are likely to be produced.

8.17.1.k Simultaneous Commands

The setting ***Simultaneous Commands*** allows setting the behavior of command acceptance. When this setting is set to **NO**, the relay will allow running a single command at a time, namely, once a command is received, any other command will be rejected until completing the preceding command already in progress, whether satisfactorily or not. Namely, new commands are not admitted when there is one in progress.

With the setting set to **YES**, the relay allows concurrent commands except if they are on the same logic element, in which case they will be rejected. Commands will start running once the operation of preceding command has started, and a maximum of 32 concurrent commands may be queued or carried out.

At the time of running the commands, the concurrent conditions are checked 2 times to give more security over the change of conditions from the time it is received to the time it is finally going to be run. The command is deemed to be in progress only if there are no running problems and the blocking is only checked once since it depends on the status and this changes from instant to instant. In this way, a command running process will be:

1. Assessment of concurrent conditions. Progress continues anyway.
2. Blocking conditions are assessed, an error being returned if there is blocking.
3. If the above concurrent conditions are not complied with, a concurrent error is returned.
4. A non-interrupt zone is entered in real time.
5. The concurrent conditions are assessed again, an error being returned if they are not complied with.
6. Activation of the command being run (this prevents new commands from entering).
7. Return to interrupt zone.
8. Activation of the command pulse if the process above has been satisfactory.

8.17.1.l Number of Breakers

This setting indicates the bay configuration the IED is working on:

I1. Single breaker or double bus with double breaker.
I1+I2. Breaker-and-a-half or double busbar with single breaker.

8.17.1.m Overcurrent Pickup

Overcurrent units pickup can be set from 100% up to 110% of the specific pick up setting.

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8.17.2 Setting Ranges

General					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Name		LPHD1.Name	Max Charac=20		""
Breaker		LPHD1.Breaker	Max Charac=5		""
Division		LPHD1.Division	Max Charac=64		""
Zone		LPHD1.Zone	Max Charac=64		""
Description1		LPHD1.Desc1	Max Charac=64		""
Description2		LPHD1.Desc2	Max Charac=64		""
Unit In Service		LPHD1.UnitInSvc	NO / YES		YES
Operation Mode	Operation Mode	LPHD1.UnitInSvc	ON Blocked Test Test Blocked OFF		ON
Phase 1 CT Ratio	Phase 1 CT Ratio	PHSTCTR1.Rat	1 - 100000	0.01	1
Phase 2 CT Ratio	Phase 2 CT Ratio	PHSTCTR2.Rat	1 - 100000	0.01	1
Phase 3 CT Ratio	Phase 3 CT Ratio	PHSTCTR3.Rat	1 - 100000	0.01	1
Ground CT Ratio	Ground C.T. Ratio	GNDTCTR1.Rat	1 - 100000	0.01	1
Parallel CT Ratio	Gnd Paral CT Ratio	GNDSTCTR1.Rat	1 - 100000	0.01	1
Phase VT Ratio	Phase VT Ratio	PHSTVTR1.Rat	1 - 100000	0.01	1
VT1 Ratio	VT1 Ratio	V1TVTR1.Rat	1 - 100000	0.01	1
VT2 Ratio	VT2 Ratio	V2TVTR1.Rat	1 - 100000	0.01	1
VT3 Ratio	VT3 Ratio	V3TVTR1.Rat	1 - 100000	0.01	1
Ground VT Ratio	Ground VT Ratio	GNDTVTR1.Rat	1 - 100000	0.01	1
Capacitive VT	Capacitive VT	GENTVTR1.CapVT	YES / NO		NO
Phase Sequence	Phase Sequence	LPHD1.PhSeq	ABC / ACB		ABC
IG Type	IG type	LPHD1.IGTyp	IN / IG		IG
PLL Enable	PLL Enable	GENTVTR1.PLLEna	YES / NO		YES
Simultaneous Commands	Simultaneous Cmds	LPHD1.LmtCmdEna	YES / NO		YES
Overcurrent Pickup	Overcurrent Pickup	GENTVTR1.NumVT	100-110	1	105
Number of Breakers	No. of Breakers	LPHD1.CBNum (ENG)	1I /1I+I2		I1
Angle Reference					
Reference Angle	Reference angle	LPHD1.AngRef	VA / IA		VA
Minimum Voltage Value	Minimum voltage	LPHD1.AngRefMinV	0.5 - 110 V	0.001 V	0.5 V
Minimum Current Value	Minimum current	LPHD1.AngRefMinA	0.02 - 5 A	0.001 A	0.02 A

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General					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Invert Polarity					
Va	Va	PHSTVTR1.InvPolPhsA	YES / NO		NO
Vb	Vb	PHSTVTR1.InvPolPhsB	YES / NO		NO
Vc	Vc	PHSTVTR1.InvPolPhsC	YES / NO		NO
Vsync	Vsync	SYNCTVTR1.InvPol	YES / NO		NO
Vg	Vg	GNDTVTR1.InvPol	YES / NO		NO
Ia	Ia	PHSTCTR1.InvPolPhsA	YES / NO		NO
Ib	Ib	PHSTCTR1.InvPolPhsB	YES / NO		NO
Ic	Ic	PHSTCTR1.InvPolPhsC	YES / NO		NO
Ig par	Ig par	GNDTCTR2.InvPol	YES / NO		NO
Ig	Ig	GNDTCTR1.InvPol	YES / NO		NO

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8.18 Configuration Settings

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8.18.2 Setting Ranges 8.18-4

8.18.1 Description

The following setting groups are included into the Configuration group:

Nominal Values.
Passwords.
Communications.
Operation Enable (when there are commands in the control logic configured to be carried out from HMI).
Date and Time.
Image.
Autodimming.

8.18.1.a Nominal Values

Nominal operating values are selected through these settings, both for current and voltage. Following parameters can be selected:

- **Nominal IABC**: Nominal Phase Current.
- **Nominal IG**: Nominal Ground Current.
- **Nominal IGPAR**: Nominal Parallel Line Ground Current.
- **Nominal VABC**: nominal phase-to-phase voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied to phase voltage.
- **Nominal Frequency**: to select system nominal frequency, regardless whether the frequency adaptation system is later capable of adjusting to changes produced in this magnitude.
- **Nominal V1**: nominal voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied to synchronism voltage 1*.
- **Nominal V2**: nominal voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied to synchronism voltage 2*.
- **Nominal V3**: nominal voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied to synchronism voltage 3*.

(*) For models with Double Breaker of Breaker-and-a-Half bay configuration capability.

After modification of any of the settings above, only accessible from HMI display, relay resets the same as if it were switched off and then switched on; no setting or information is lost.

8.18.1.b Access Passwords

The Passwords option allows changing access passwords for options: Configuration, Operations and Settings.

Select the Configuration option to change access password for configuration group options. Also, different passwords can be configured for operations and settings modification options.

These settings are only available through HMI and the passwords are numerical consisting of four digits.

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8.18.1.c Communications

See paragraph 1.5.8 on Communications.

8.18.1.d Date and Time

Selecting date and time in the configuration menu displays this setting to configure relay date and time.

- **Local Time Zone Setting**

Setting ***Local Time Zone*** allows putting UTC time forward or back as required.

- **Summer Time / Winter Time Change**

Relay allows configuring the dates when summer time / winter time change takes place. In the first case the relay clock is put one hour forward (+1 Hour). In the second case the relay clock is put one hour back (-1 Hour) for the winter season.

To configure a change of season the following must be specified:

- **Begin Time**: time when change of season takes place. Range 0 to 23 h.
- **Begin Day Type**: type of day when change of season takes place. It can take the following values **First Sunday**, **Second Sunday**, **Third Sunday**, **Fourth Sunday**, **Last Sunday** of the month and **Specific Day**.
- **Begin Day**: in case **Specific Day** is selected, state in which specific day of the month the change of season takes place.
- **Begin Month**: state the month in which the change of season takes place.

These settings are independent for the summer and winter seasons.

Note: if the Begin Day setting value is higher than the number of days of a given month, the last valid day of said month is taken as the day for the change of season.

The change of season function can be activated or deactivated through ***Summer / Winter Change Enable*** setting.

8.18.1.e Contrast Adjustment

This setting modifies the display contrast value (high value = more contrast).

8.18.1.f Autodimming Function

Autodimming function keeps the display background light off when not in use during an adjustable time. The display lights on when:

- A key is pressed.
- The relay trips.
- Activation of an internal alarm.

Being the display off, any key pressed will activate the display showing the as-default information under normal conditions for a period of time previously configured as long as no more keys are pressed. On that sense, pressing any key will always initiate the timer for the auto-dimming of the display.

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If the relay is displaying a screen other than the default screen, the autodimming timer will not be initiated. Once the set ***Return Time*** times out, when the screen returns to the default screen, this autodimming function will begin.

Any protection trip or internal alarm within the relay will immediately switch-on the display to show the relevant information. The display will keep on until that trip or alarm is reset / acknowledged by the operator.

The screen will never be permanently switched off through setting.

8.18.1.g Return Time

If the relay displays a screen other than the default screen, it will not return to this state until the set ***Return Time*** times out.

If the ***Return Time*** is less than the ***Autodimming*** time, the latter is used as return time.

8.18.2 Setting Ranges

Communications Program	HMI	IEC 61850	Range	Step	Default
Nominal Values					
Nominal IABC1	Nominal IABC	PHSTCTR1.ARtg	1 A / 5 A		5 A
Nominal IG	Nominal IG	GNDTCTR1.ARtg	1 A / 5 A		5 A
Nominal IGPAR	Nominal IGPAR	GNDTCTR2.ARtg	1 A / 5 A		5 A
Nominal VABC	Nominal VABC	PHSTVTR1.VRtg	50-230 V	0.1	110 V
Nominal Freq.	Nominal Freq.	GENTVTR1.HzRtg	50Hz / 60Hz	10	50 Hz
Nominal V1*	Nominal V1	PV1TVTR1.VRtg	50-230 V	0.1	110 V
Nominal V2*	Nominal V2	PV2TVTR1.VRtg	50-230 V	0.1	110 V
Nominal V3*	Nominal V3	PV3TVTR1.VRtg	50-230 V	0.1	110 V
Autodimming					
Autodimming Enable		LPHD1.AutoDimEna	NO / YES		NO
Time Delay	Display Time	LPHD1.AutoDimTmm	1-100 min	1 min	2 min
Communications					
See 1.5.8, Communications.					
Passwords					
The factory-specified access password (full access) is 2140. Nevertheless, you can change the password to access the following options with the keypad: **Configuration**, **Operations** and **Settings**.					
Image					
Not available			-01 to +04		-01
T RETURN					
Not available	T RETURN		1-100 min	1	2 min

(*) For models with Double Breaker of Breaker-and-a-Half bay configuration capability.

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8.19 Change Settings Groups

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8.19.3 Auxiliary Outputs and Events to Change Settings Groups 8.19-4

8.19.1 Description

The Protection, Logic and Recloser settings include four alternative groups (GROUP 1, GROUP 2, GROUP 3, GROUP 4, GROUP 5, GROUP 6, GROUP 7 and GROUP 8), which can be activated or deactivated from the keypad, through the communication ports, by using digital inputs or with signals generated in the programmable logic.

This function permits modifying the active setting groups and, thereby, the response of the protection. This way, the behavior of the IED can adapt to changes in the external circumstances.

Two logic input signals can block changes in the active group from the HMI as well as via communications. When **Settings Group Change by Communications Disable (INH_CGRP_COM)** and **Settings Group Change by HMI Disable (INH_CGRP_MMI**) digital inputs are active, groups cannot be changed with commands via communications nor through the HMI.

If the digital inputs are used to change groups, up to four digital inputs may need to be configured through the programmable digital inputs:

- Command to activate Settings Group 1 by digital input (**Settings Group 1 Activation by Digital Input**, **CMD_GRP1_DI**).
- Command to activate Settings Group 2 by digital input (**Settings Group 2 Activation by Digital Input**, **CMD_GRP2_DI**).
- Command to activate Settings Group 3 by digital input (**Settings Group 3 Activation by Digital Input**, **CMD_GRP3_DI**).
- Command to activate Settings Group 4 by digital input (**Settings Group 4 Activation by Digital Input**, **CMD_GRP4_DI**).
- Command to activate Settings Group 1 by digital input (**Settings Group 5 Activation by Digital Input**, **CMD_GRP5_DI**).
- Command to activate Settings Group 2 by digital input (**Settings Group 6 Activation by Digital Input**, **CMD_GRP6_DI**).
- Command to activate Settings Group 3 by digital input (**Settings Group 7 Activation by Digital Input**, **CMD_GRP7_DI**).
- Command to activate Settings Group 4 by digital input (**Settings Group 8 Activation by Digital Input**, **CMD_GRP8_DI**).

Activation of said inputs will result in the activation of GROUP 1, GROUP 2, GROUP 3, GROUP 4, GROUP 5, GROUP 6, GROUP 7 and GROUP 8 respectively.

If, while one of the inputs is active, either of the other three or several of them are activated, no group change will take place. The status contact settings group control logic will recognize a single input only. If all four inputs are deactivated, however, the IED will remain in the last active settings group.

Note: Groups can be changed by activating T1, T2, T3, T4, T5, T6, T7 and T8 only if the display is in the default screen.

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8.19.2 Digital Inputs to Change Settings Groups

Table 8.19-1: Digital Inputs to Change Settings Groups					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
INH_CGRP_COM	Tables of Settings	-	Settings Group Change by Communications Disable		It blocks any change of the active group by the PROCOME procedure.
INH_CGRP_HMI		-	Settings Group Change by HMI Disable		It blocks any change of the active group through the HMI menu.
CMD_GRP1_COM	Commands	-	Settings Group 1 Activation by Communications		Commands to change the active group.
CMD_GRP1_DI		-	Settings Group 1 Activation by Digital Input		
CMD_GRP1_HMI		-	Settings Group 1 Activation by HMI		
CMD_GRP2_COM		-	Settings Group 2 Activation by Communications		
CMD_GRP2_DI		-	Settings Group 2 Activation by Digital Input		
CMD_GRP2_HMI		-	Settings Group 2 Activation by HMI		
CMD_GRP3_COM		-	Settings Group 3 Activation by Communications		
CMD_GRP3_DI		-	Settings Group 3 Activation by Digital Input		
CMD_GRP3_HMI		-	Settings Group 3 Activation by HMI		
CMD_GRP4_COM		-	Settings Group 4 Activation by Communications		
CMD_GRP4_DI		-	Settings Group 4 Activation by Digital Input		
CMD_GRP4_HMI		-	Settings Group 4 Activation by HMI		
CMD_GRP5_COM		-	Settings Group 5 Activation by Communications		
CMD_GRP5_DI		-	Settings Group 5 Activation by Digital Input		
CMD_GRP5_HMI		-	Settings Group 5 Activation by HMI		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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Table 8.19-1: Digital Inputs to Change Settings Groups					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
CMD_GRP6_COM	Commands	-	Settings Group 6 Activation by Communications		Commands to change the active group.
CMD_GRP6_DI		-	Settings Group 6 Activation by Digital Input		
CMD_GRP6_HMI		-	Settings Group 6 Activation by HMI		
CMD_GRP7_COM		-	Settings Group 7 Activation by Communications		
CMD_GRP7_DI		-	Settings Group 7 Activation by Digital Input		
CMD_GRP7_HMI		-	Settings Group 7 Activation by HMI		
CMD_GRP8_COM		-	Settings Group 8 Activation by Communications		
CMD_GRP8_DI		-	Settings Group 8 Activation by Digital Input		
CMD_GRP8_HMI		-	Settings Group 8 Activation by HMI		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.19.3 Auxiliary Outputs and Events to Change Settings Groups

Table 8.19-2: Auxiliary Outputs and Events to Change Settings Groups					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
T1_ACTIVATED	Tables of Settings	-	Settings Group 1 In Service		Indication of the active group.
T2_ACTIVATED		-	Settings Group 2 In Service		
T3_ACTIVATED		-	Settings Group 3 In Service		
T4_ACTIVATED		-	Settings Group 4 In Service		
T5_ACTIVATED		-	Settings Group 5 In Service		
T6_ACTIVATED		-	Settings Group 6 In Service		
T7_ACTIVATED		-	Settings Group 7 In Service		
T8_ACTIVATED		-	Settings Group 8 In Service		

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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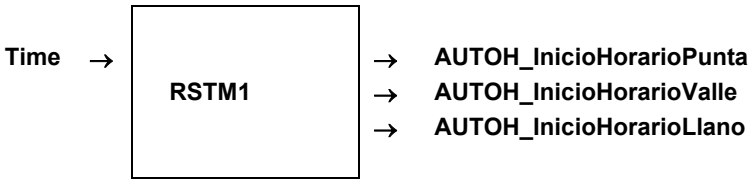
8.20 Time Zone Calendar

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8.20.1 Identification

Description of the Protection Element	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Time Zone Calendar	RSTM1		

8.20.2 General Block



8.20.3 Description

Time Zone Calendar function allows carrying out applications dependent on time zones defined by relay protection settings. Three time zones can be set, namely, peak time, valley time and flat time, with access to time zone indication signals in the control part, such that can be used, for instance, to change settings tables, blocking protection elements or starting automatic controls. The time zones defined will be common to the 7 days of the week, discerning between working days, Saturdays or holidays not being possible.

8.20.4 Setting Ranges

Schedule of Time					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Enable	Enable	RSTM1.LNInSvc	NO / YES		NO
Start Peak Schedule	Start Peak Sched	RSTM1.StrTmm1	00:00-24:00	00:01	00:00
Start Valley Schedule	Start Valley Sched	RSTM1.StrTmm2	00:00-24:00	00:01	00:00
Start Flat Schedule	Start Flat Sched	RSTM1.StrTmm3	00:00-24:00	00:01	00:00

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8.20.5 Auxiliary Outputs of the Time Zone Calendar

Table 8.20-1: Auxiliary Outputs of the Time Zone Calendar					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
AUTOH_InicioHorarioPunta	Automatons	RSTM1.StrInd1	Peak Schedule		Indicates that the current time is within the time zone defined as Peak
AUTOH_InicioHorarioValle		RSTM1.StrInd2	Valley Schedule		Indicates that the current time is within the time zone defined as Valley
AUTOH_InicioHorarioLlano		RSTM1.StrInd3	Flat Schedule		Indicates that the current time is within the time zone defined as Flat

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

8.20.6 IEC 61850 Logical Node

CLASS IRLRSTM		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
StrInd1	SPS	Peak Time zone
StrInd2	SPS	Off-peak time zone
StrInd1	SPS	Plain time zone
Settings		
LnInSvc	SPG	In Service
StrTmm1	ING	Time zone definition for peak time
StrTmm2	ING	Time zone definition for off-peak time
StrTmm3	ING	Time zone definition for plain time

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8.21 Programmable Logic

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8.21.1 Description

One of the functions of the devices is a fully configurable one called Programmable Logic. The user can freely interconnect this logic digitally and analogically by using the ***ZIV e-NET tool***® program.

All the signals generated by the equipment will be available to the events, oscillograph records, digital inputs and outputs, HMI and communications according to how their programmable logic has been configured.

From the signals or readings generated by any of the functions of the relay (Protection units, Digital inputs, Communications, Command functions and Analog inputs), the user can define a logical operation using primitive logic functions (AND, OR, XOR, NOT, etc.), bistable circuits (latched or not), timers, comparators, constants, values, etc.

The programming function allows definition of the trip logic, control logic, interlocks, functional modules, local and remote states and control hierarchy required for complete protection and operation of a bay.

Priorities may also be selected in the programmable logic. There are three run cycles, of 2, 10 and 20 milliseconds, and priorities may be allocated placing the logics in either cycle. In this way, control logic can be carried out and use them as protection functions as they can be run with a priority similar to the functions implemented into the equipment firmware itself. For more information, please refer to the ***ZIV e-NET tool***® manual.

The processing of the input signals produces logical outputs that can be assigned to existing connections between the IED and the exterior: auxiliary output contacts, display, LEDs, communications, HMI, etc.

Maximum size for the programmable logic will be 64kb; i.e. around 1000 primitive logic gates.

8.21.2 Functional Characteristics

The IEDs can execute local programmable control functions associated with the bay as well as the logic associated with internal and external interlockings, treatment and generation of alarms and processing of signals. They are all programmable.

The execution of interlockings towards the external circuits implies being able to execute continuously active outputs depending on the combination of the state of various input signals through logic gates. These interlocking outputs are used for interrupting / continuing an exterior command circuit. These interlockings are the consequence of the logic capacity pointed out in the following sections.

The execution of internal interlockings implies being able to obtain logic outputs of permission / blocking of commands towards the external circuits according to the combination of the state of various input signals through logic gates. These processed logic signals affect the permissions / lockouts of commands generated both from the unit's local control module and from the Central Unit originating in the control display, central programmable control functions and/or remote.

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Logical alarms can be generated with data from the combination of the state of various input signals through logic gates as well as from "timers" of presence / absence of a given signal, either physical or logic.

The processing of analog signals offers the possibility of comparing analog inputs with set points and of generating digital ON/OFF signals as a result of this comparison as well as the possibility of adding and multiplying analog signals. Analog values can be used in primary or secondary values.

Logic configurations can also generate user defined values such as counters. These values are the result of the user defined logic algorithms. User defined values can be displayed on the HMI, sent via communications and retrieved using ***ZIV e-NET tool***®.

Likewise, it is also possible to define new user settings in the IED associated with the logic. These settings can be consulted afterwards from the HMI or communications.

In addition, the logic configurations can disable protection elements of the IED. The disabling of an element allows it to be replaced by another that operates under user-defined algorithms.

Basically, the system takes input signals from various sources, both external to the IED (communications or HMI) and internal; processes these signals according to the configuration that has been loaded and the pre-established settings and activates certain output signals that will be used for sending information messages or measurements to the central unit as well as commands to relays, LEDs and protection or logic units.

The **Programmable Logic** and its **Configuration** comprise the engine of this whole system. The logic has a set of *blocks* that encompass a series of logic operations. Each of these blocks determines an *outcome* (state of one or more signals) depending on the state of the inputs of that *block*. The **Configuration** determines the use of one or another *block*.

If the required input signals are signals that arrive through communications, they arrive encoded according to the PROCOME, MODBUS or DNP 3.0 communications protocol, which forces associating each necessary signal with its corresponding protocol. This process is performed in **Input Tagging** and the associations are made in one form or another according to the configuration. The same happens with the signals sent through communications; the software process is carried out in **Output Tagging** and is also determined by the Configuration.

New logic-generated values can be redirected to the IED's different communication protocols as well as to the HMI.

The **Programmable Logic** can be used to generate events with any available digital signal that the IED can capture with the PROCOME communications protocol and the program. It doesn't matter if this signal is a digital input or a signal received via communications from the central unit or, on the contrary, is the outcome of internal operations included in the programmed algorithm itself. Moreover, there is the option of recording the event by the rising edge of the chosen signal, by the falling edge or by both.

Once the event is generated, it can be captured the same as the rest of the events generated by the IED (as, for example, trip events) with the ***ZIV e-NET tool***® communications program.

There is an exclusive option to simplify the task of configuring the Digital Inputs, Digital Outputs and LEDs. This voids the need to work with complex algorithms that would make the task unnecessarily difficult.

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8.21.3 Control Commands

The system uses **ON** / **OFF** action groups. In this way, when a command is configured through the configuration program, action groups are defined, also called logic actions (ON, OFF…) and then, for each action group, as many physical actions as the user requires, up to a maximum of 256. For the rest of the configuration, when an actual action is to be run, the action group is selected (not the action linked to the pulse signal, but the logic action).

Every command element has an operating time setting (*opertimeout*). One setting may not be allocated to several different commands.

8.21.3.a Command or Source Hierarchy

For protocol configuration, the user must select the source from which the group action is run. By default, this value is Station-Control (2) or HMI.

In this way, the relay will be able to manage the source knowing the source of each command with no need to configure it in the logic.

This new configuration mechanism is intended to use only one ON action (and other OFF action) with all possible sources. However, for non-IEC61850 protocols, command sources cannot be discerned, since only one signal is activated when the single ON (and OFF) action to be configured is run. Therefore, as many ON (and OFF) actions must be configured as sources to be discerned, if required, assigning different signals to activate. Specific cases are analyzed:

- Sources 1 and 4 made from the logic through the COMMAND opcode can be controlled through logic.
- Source 1 from HMI can be controlled by logic looking at the simultaneity of signals ControlLocal = 1 and the Signal to be Activated.
- Source 7 can be controlled by logic looking at the simultaneity of signals ControlMaintenance = 1 and the Signal to be Activated.
- Source 2 can be controlled by logic looking at the simultaneity of signals ControlPanel = 1 and the Signal to be Activated.
- Source 3 can be controlled by logic looking at the simultaneity of signals Remote Control = 1 and the Signal to be Activated.
- Sources 5 and 6 can be framed the same as sources 2 and 3, respectively, otherwise they must be discerned (the first will be HMI and the second, remote control). If it must be discerned whether it is a control function or not, specific actions must be defined for sources 5 and 6 (it seems the latter has not been used until now).

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8.21.3.b Successful and Failed Command Signals

For single and dual commands, the relay will automatically allocate a value to the success and failure signals configured through the ***ZIV e-NET tool***®. This will be arranged by the relay as a function of the command and action group (**ON / OFF**) status signal. Once the command has been run, whether successfully or not, a pulse will be generated in the corresponding **Success signal** / **Failure signal** allocated through the configuration program of long enough duration to be detected by all the possible clients (logic, LEDs, protocols…). The duration will be 22ms.

These signals, designated **Successful signal** / **Failure signal**, will be marked as used and may only be designated as **Successful signal** / **Failure signal** in the same command group (**ON / OFF**), for the same or different actions. The same signal can be used for success and failure.

8.21.3.c Running simultaneous Commands

The relay has a setting, ***Simultaneous commands*** (General Settings), to allow or not to allow running simultaneous commands. The relay operation as a function of the new setting is as follows:

- **NO**: the relay will allow running a single command at a time. Once the command is received, any other command received will be rejected until the command in progress is completed, whether satisfactorily or not. Namely, when there is a command in progress, new commands are not allowed.
- **YES**: the relay allows concurrent commands, except if they are over the same logic element, in which case they will be rejected. The command will start running once the action of the previous command has been initiated and may be queued or run up to a maximum of 32 concurrent commands.

8.21.3.d Command Treatment

When commands are run, concurrent conditions are checked 2 times. This is intended to provide greater reliability upon changing conditions since the command is received until the moment when it is finally to be run. The command is deemed to have progressed only if no running problems occur. Blocking is only checked once, since it is a function of the status and this changes all the time. In this way, the command running process is as follows:

1. Assessment of concurrent conditions. Progress goes on in any case.
2. Blocking conditions are examined. If blocking occurs, an error is issued.
3. If the above concurrent conditions are not met, a concurrent error is issued.
4. A non-interruptible area is entered in real time.
5. Concurrent conditions are reassessed. If they are not met, an error is issued.
6. Activation of the command being run (which will prevent new commands from entering).
7. An interruptible area is entered again.
8. Command pulse activation (if the complete process above has been satisfactory).

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In this way, always:

- Concurrent conditions are checked 2 times. First, before the command. Then, in a no longer interruptible area, to verify that it has not changed and that the command can still execute.
- The command is deemed to have progressed only if no running problems occur.
- Blocking is only checked once, in concurrent conditions. The reason is that the block depends on the status and this changes all the time. If evaluated at the beginning, when executing the command later there could already be a blocking.

In either case, a new signal indicating, at all times, that a Command is running is available (either an analog or digital Command). With the ***Simultaneous Commands*** to YES, this signal could be added by setting to blocking all the commands.

8.21.3.e Command Blocking as a Function of the Hierarchy

Local-Control	Maintenance-Control	Panel-Control	Remote-Control	Bay-control (1)	Station-control (2)	Remote-control (3)	Automatic-bay (4)	Automatic-station (5)	Automatic-remote(6)	Maintenance (7)	Process (8)
0	0	0	0	BLOCKED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
0	0	0	1	BLOCKED	BLOCKED	ALLOWED	ALLOWED	BLOCKED	ALLOWED	BLOCKED	ALLOWED
0	0	1	0	BLOCKED	ALLOWED	BLOCKED	ALLOWED	ALLOWED	BLOCKED	BLOCKED	ALLOWED
0	0	1	1	BLOCKED	ALLOWED	ALLOWED	ALLOWED	ALLOWED	ALLOWED	BLOCKED	ALLOWED
0	1	0	0	BLOCKED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	ALLOWED	ALLOWED
0	1	0	1	BLOCKED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	ALLOWED	ALLOWED
0	1	1	0	BLOCKED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	ALLOWED	ALLOWED
0	1	1	1	BLOCKED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	ALLOWED	ALLOWED
1	0	0	0	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	0	0	1	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	0	1	0	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	0	1	1	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	1	0	0	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	1	0	1	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	1	1	0	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED
1	1	1	1	ALLOWED	BLOCKED	BLOCKED	ALLOWED	BLOCKED	BLOCKED	BLOCKED	ALLOWED

PanelControl signals (these will be mapped through configuration to the command that LLN0.LocSta in IEC 61850 is finally linked to) and **Remote Control** can be both 0 or both 1.

LocalControl has full priority, then **MaintenanceControl** and, finally, the other two with the same priority (**LocalControl** and **Remote Control**).

The table has two exceptions to be dealt with when the commands are sent through communications:

1) When **LocalControl** ("LLN0.Loc" in IEC 61850) is set to **TRUE**, all commands sent through communications will be rejected, indicating in *IEC 61850 AddCause=Blocked-by-switching-hierarchy*, regardless the source (including source 1).
2) Source 4 (Automatic-Bay) will never be allowed from communications. It will always be rejected. These are always commands made in the relay logic, namely, always with source in the relay. Therefore, they are not allowed through communications.

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8.21.4 Description of Logic Operations

For each configuration, only the logic functions indicated in the profile of the model being configured will be available. This section describes the logic functions defined for the different **ZIV** models.

The value of a signal or variable can be allocated directly to another variable of the same type by connecting the two variables with no need for using intermediate logic operators. The value of a variable can be allocated to several variables.

8.21.4.a Boolean Operations (Booleans)

AND: AND operation between digital inputs.

Operands	From 2 up to a maximum of 16 digital inputs.			
Results	1 digital output.			
Truth table for two inputs	In0	In1	Q	
	0	0	0	
	0	1	0	
	1	0	0	
	1	1	1	

OR: OR operation between digital inputs.

Operands	From 2 up to a maximum of 16 digital inputs.			
Results	1 digital output.			
Truth table for two inputs	In0	In1	Q	
	0	0	0	
	0	1	1	
	1	0	1	
	1	1	1	

XOR: OR operation-exclusive between two digital inputs.

Operands	2 digital inputs.			
Results	1 digital output.			
Truth table for two inputs	In0	In1	Q	
	0	0	0	
	0	1	1	
	1	0	1	
	1	1	0	

NOT: moves the digital input negation result to the digital output.

Operands	1 digital input.		
Results	1 digital output.		
Truth table for two inputs	In	Q	
	0	1	
	1	0	

M0DLFA1907I
DLF: Line Differential Protection
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8.21.4.b Move Instructions

BCD_TO_DINT: BCD to integer.

This opcode sets up the value of an integer analog output from a number of digital inputs.

Operands	Up to 16 digital inputs (I0..I15).
Results	1 Integer type Analog Output resulting from the operation: Q=(I0+(I1<<1)+(I2<<2)+(I2<<3))+ (I3+(I4<<1)+(I5<<2)+(I6<<3))*10+...

BCD_TO_REAL: BCD to real.

This opcode sets up the value of a floating type analog output from a number of digital inputs.

Operands	Up to 16 digital inputs (I0..I15).
Results	1 Floating type Analog Output resulting from the operation: Q=(I0+(I1<<1)+(I2<<2)+(I2<<3))+ (I3+(I4<<1)+(I5<<2)+(I6<<3))*10+...

BIN_TO_DINT: Binary to integer.

This opcode sets up the value of an integer analog output from a number of digital inputs.

Operands	Up to 16 digital inputs (I0..I15).
Results	1 Integer type Analog Output resulting from the operation: Q=I0+(I1<<1)+(I2<<2)+...(IN<<N+1)

BIN_TO_REAL: Binary to real.

This opcode sets up the value of a floating type analog output from a number of digital inputs.

Operands	Up to 16 digital inputs (I0..I15).
Results	1 Floating type Analog Output resulting from the operation: Q=I0+(I1<<1)+(I2<<2)+...(IN<<N+1)

BOOL_TO_DINT: Boolean to integer.

This opcode converts a boolean value into an integer (0 or 1).

Operands	1 boolean input.
Results	1 Integer type Analog Output.

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BOOL_TO_REAL: Boolean to real.

This opcode converts a boolean value into a real number (0 or 1).

Operands	1 boolean input.
Results	1 Real type Analog Output.

DINT_TO_BCD: Integer to BCD.

This opcode, from an integer type analog input, sets up the value of a number of digital outputs representing the integer value of the magnitude in BCD format.

Operands	An integer type analog input.
Results	From 1 up to 16 digital outputs (Q0, Q1,...,Q15).

DINT_TO_Bin: Integer to binary.

This opcode, from an integer type analog input, sets up the value of a number of digital outputs representing the integer value of the magnitude in Binary format.

Operands	An integer type analog input.
Results	From 1 up to 16 digital outputs (Q0, Q1,...,Q15).

MUX: multiplexor.

Based on a selector, sets up the output value with the value of one of both inputs. Input type (no selector) must match the output type.

Operands	1 digital input acting as selector (SEL). 2 inputs (I0, I1).		
Results	Q = 1 Output.		
Truth table for two inputs	***Sel***	Q	
	0	***E0***	
	1	***E1***	

REAL_TO_BCD: Real to BCD

This opcode, sets up, from a real type analog input, the value of a number of digital outputs representing the integer value of the magnitude in BCD format.

Operands	Integer type analog input
Results	From 1 up to 16 digital outputs (Q0, Q1,...,Q15).

REAL_TO_Bin: Binary to real.

This opcode, sets up, from a real type analog input, the value of a number of digital outputs representing the integer value of the input.

Operands	A real type analog input.
Results	From 1 up to 16 digital outputs (Q0, Q1,...,Q15).

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VALID:

The digital output is set to 1 whenever the input has a valid value. Otherwise, the output is set to 0.

Operands	IN = analog input (measure, setting or analog constant).
Results	Q = Digital output (1, if valid input; 0, otherwise).

8.21.4.c Pulse Activation Operations (Triggers)

FFD: D type latch.

Every time a rising edge is produced in the digital input displayed as a clock, the latch takes the input value.

Operands	1 clock digital input. Digital input.				
Results	1 digital output.				
Truth table		**E**	**CLK**	Q	
		0	↑	0	
		1	↑	1	

FFDmem:

Same parameters and operation as for the FFD logic operation. The only difference resides in that, in this case, the value is memorized.

FFRS: RS type latch.

While the S digital input is activated, the latch takes the input value. When the R input is activated, the latch takes the value 0.

Operands	1 digital input R. 1 digital input S..				
Results	1 digital output				
Truth table		**R**	**S**	Qt+ Δt	
		0	0	Qt	
		0	1	1	
		1	0	0	
		1	1	1	

FFRSmem:

Same parameters and operation as for the FFRS logic operation. The only difference resides in that, in this case, the value is memorized.

PLSTRAIN : Pulse train.

This opcode is a logic block that produces a pulse train while the digital input is active.

Operands	1 digital input for pulse train activation. 1 analog input indicating the time of the active pulse in seconds (TM1). 1 analog input indicating the time of inactive pulse in seconds (TM0).
Results	1 digital output.

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PLSTRAINmem: pulse train memorized.

Same parameters and operation as for PLSTRAIN logic operation. The only difference resides in that, in this case, the value is memorized.

PULSE:

When the digital input switches from 0 to 1, the output activates during the time specified as parameter.

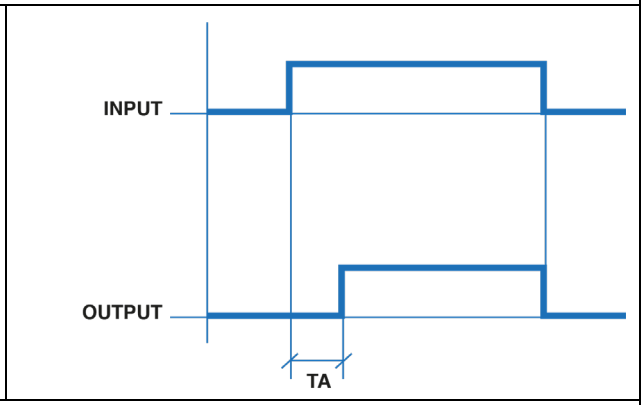
Operands	1 digital input. 1 analog setting or pulse time constant in seconds (TM).
Results	1 digital output.
Limits	The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

PULSEmem:

Same parameters and operation as for PULSE logic operation. The only difference resides in that, in this case, the value is memorized.

TMA: A- Timer.

When the setting value of the time elapsed since the digital input switches from 0 to 1 times out, the output sets to 1 provided the input is not reset.

Operands	1 digital input 1 setting or delay time constant in seconds
Results	1 digital output
Operating diagram	
Limits	The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

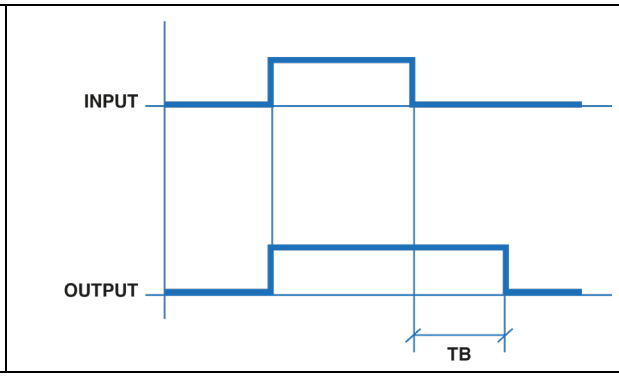
TMAmem:

Same parameters and operation as for TMA logic operation. The only difference resides in that, in this case, the value is memorized.

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TMB: B- Timer.

When the setting value of the time elapsed since the digital input switches from 1 to 0 times out, the output sets to 0 provided the input is not reset.

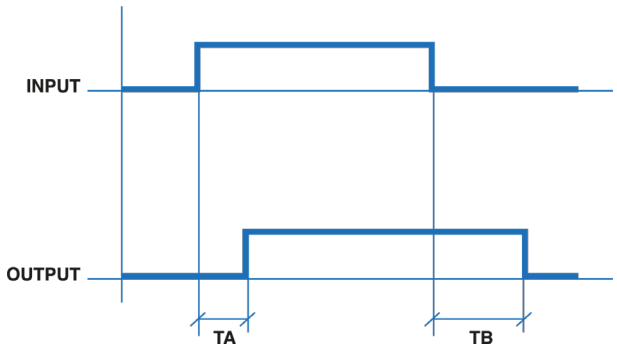
Operands	1 digital input. 1 setting or delay time constant in seconds.
Results	1 digital output.
Operating diagram	
Limits	The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

TMBmem:

Same parameters and operation as for TMB logic operation. The only difference resides in that, in this case, the value is memorized.

TEMPOR:

Timer to configure both the start of output activation and deactivation time.

Operands	IN: 1 digital input. TA: 1 setting or delay time constant in seconds. TB: 1 setting or reset time constant in seconds.
Results	Q: 1 digital output
Operating diagram	

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R_TRIG: Rising edge:

This opcode activates the digital output when detecting the switching of the digital input from 0 to 1.

Operands	1 digital input.
Results	1 digital output.

8.21.4.d Counters

COUNT_I: Counter (integer).

This opcode handles a counter that increments with each rising edge of the digital input displayed as a clock. When the reset input activates, the counter resets to 0. The output is an integer type analog signal.

Operands	1 reset digital input (RST). 1 clock digital input (CLK).
Results	1 Integer type Analog Output.
Limits	The counter saturates at 65535. Later increments do not change the counter output value.

COUNTmem_I: Counter (integer - memorized).

This opcode handles a counter that increments with each rising edge of the digital input displayed as a clock. When the reset input activates, the counter resets to 0. The difference with the COUNT_I opcode resides in that, in this case, the output is memorized.

COUNT_R: Counter (real).

This opcode handles a counter that increments with each rising edge of the digital input displayed as a clock. When the reset input activates, the counter resets to 0. The output is a floating (= real) type analog signal.

Operands	1 reset digital input (RST). 1 clock digital input (CLK).
Results	1 Float Analog Output.
Limits	The counter saturates at 65535. Later increments do not change the counter output value.

COUNTmem_R: Counter (real - memorized).

This opcode handles a counter that increments with each rising edge of the digital input displayed as a clock. When the reset input activates, the counter resets to 0. The difference with the COUNT_R opcode resides in that, in this case, the output is memorized. The same as for the case above, the analog output is floating (= real) type.

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8.21.4.e Arithmetic Operations

+ : Addition.

This opcode sets up the value of the analog output with the result of the sum of analog inputs.

Operands	2 Analog inputs.
Results	1 Analog output.

- : Subtraction.

This opcode sets up the value of the analog output with the result of the subtraction of analog inputs.

Operands	2 Analog inputs (minuend IN1 and subtrahend IN2).
Results	1 Analog output.

* : Multiply.

This opcode sets up the value of the analog output with the result of the product of analog inputs.

Operands	2 Analog inputs.
Results	1 Analog output.

/ : Divide.

This opcode sets up the value of the analog output with the result of the division between analog inputs.

Operands	2 Analog inputs.
Results	1 Analog output.

- **Comparison Operations**

< : Less Than.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is less than IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

<= : Less or Equal.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is less than IN2, or IN1 is equal to IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

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<> : Is not equal.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is not equal to IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

= : Is Equal.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is equal to IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

> : Greater than.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is greater than IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

>= : Greater or equal.

This opcode compares two analog inputs IN1 and IN2, and sets up the value of the digital output based on the result of the comparison. If IN1 is equal to or greater than IN2, the digital output activates. Otherwise, the output sets to 0.

Operands	2 Analog inputs.
Results	1 digital output.

CMPCONT: Counter Comparator.

Compares the value of the counter CON input with the value defined in the Vc input. If the comparison is greater or equal, the output activates. Otherwise, the output deactivates.

Operands	1 DINT (CON) type counter input. 1 input Vc.
Results	1 digital output Q.
Operating logic	If CON >= Vc Q activates. If CON<Vc Q deactivates.

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DNIVEL: Range evaluator.

It works as follows: takes the value of the field measurement (represented in MEA input), and compares it with the inputs Vc (equal), Vmin (less than) and Vmax (greater than), such that:

If [MEA] >= Vmax => the GT output signal activates.
If [MEA] = Vc => the EQ output signal activates.
If [MEA] <= Vmin => the LT output signal activates.

Operands	1 measurement type input (REAL) (MEA). 1 REAL input Vmax. 1 REAL input Vc. 1 REAL input Vmin.
Results	1 digital output GT. 1 digital output EQ. 1 digital output LT.
Operating logic	If [MEA] >= Vmax => output signal activates GT. If [MEA] = Vc => the EQ output signal activates. If [MEA] <= Vmin => the LT output signal activates.

LVCOMP: Level comparator.

This opcode compares the analog input with respect to a minimum and maximum reference value with respect to a minimum and maximum reference value, and sets up the digital output based on the same. Thus:

The output sets to 1 if the input is greater than the maximum reference value.
The output sets to 0 if the input is less than the minimum reference value.
Otherwise, the output remains with the same value.

Operands	1 Analog input IN. One analog input as minimum reference value (Min). One analog input as maximum reference value (Max).
Results	1 digital output1 digital output LT.

LVCOMPmem: Level comparator (memorized).

Same as for LVCOMP with the only difference that, in this case, the output is memorized.

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8.21.4.f Special Operations

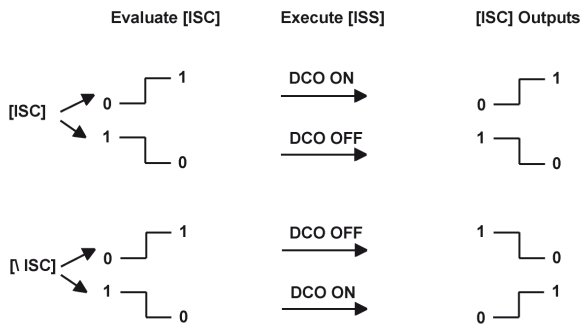
DEACT:

This function activates the digital output if and only if there is only a single active input. Otherwise, the output deactivates.

Operands	Up to 16 possible digital inputs (IN0..IN15).				
Results	1 digital output.				
Truth table (specific case with 3 inputs)	**IN0**	**IN1**	**IN2**	Q	
	0	0	0	0	
	0	0	1	1	
	0	1	0	1	
	0	1	1	0	
	1	0	0	1	
	1	0	1	0	
	1	1	0	0	
	1	1	1	0	

ESC:

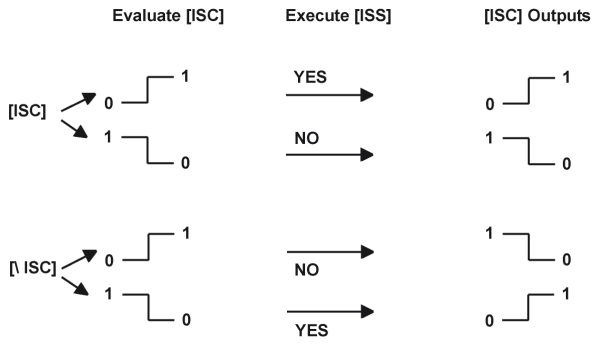
This logic function writes ISS outputs with the DCO_ON if the ISC signal is active and writes ISS outputs with the DCO_OFF if the ISC input signal is inactive. Also, the value of the ISC input is allocated to the outputs.

Operands	1 ISC digital input to activate / deactivate the ISS output writing. 1 digital input that represents the ISS or output writing over which the command is run. 1 setting or integer constant that sets the value of the DCO_ON with which the command is run, if the input ISC is active. 1 setting or integer constant that sets the value of the DCO_OFF with which the command is run, if the input ISC is inactive.
Results	Up to 32 possible digital outputs. When the command is run, these outputs take the value of the input ISC.
Operating diagram	

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COMMAND:

This logic function (FB)runs the ISE input command with the DCO specified, and the value of the input ISC is allocated to the outputs, every time the ISC input is activated (namely, switches from 0 to 1) or deactivated in case the input is negated. For the ISE input, only commands (or ISEs signals) of the central unit database not belonging to the “LOGICA” logic equipment are allowed, since it makes no sense that an equipment issues a command on itself.

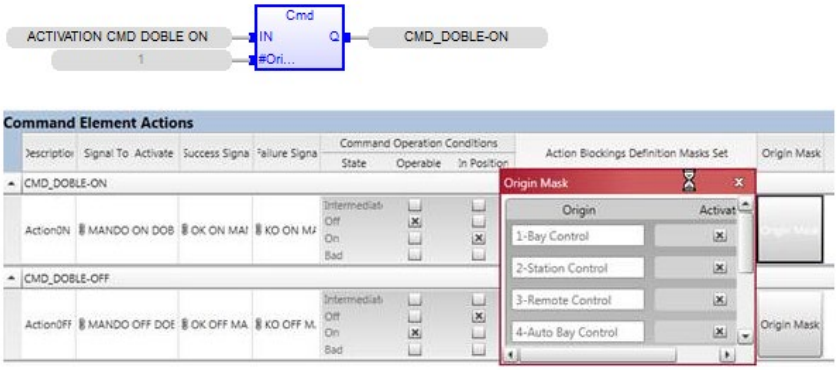
Operands	1 ISC digital input to activate the command. 1 digital input representing the ISE or signal on which the command is issued. 1 setting or integer constant that defines the DCO with which the command is run.
Results	Up to 32 possible digital outputs. When the command is run, these outputs take the value of the input ISC.
Operating diagram	

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- **Command Operations**

Cmd:

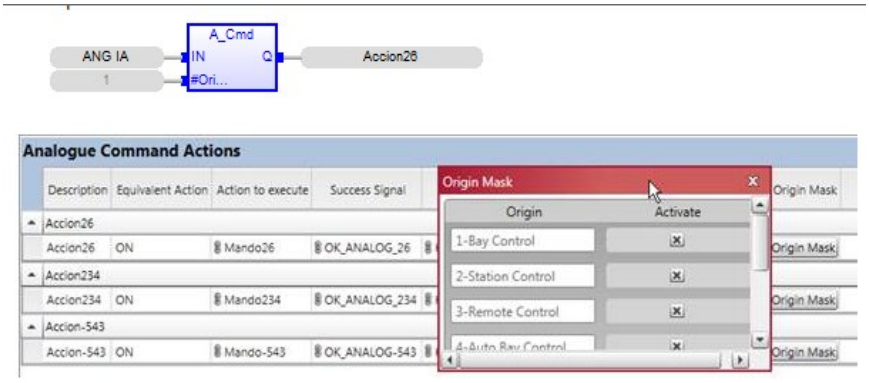
This function block tries to execute a command action whenever the input is activated.

Operands	Two Inputs: Digital input used to trigger the command. Integer input which represents the origin for the execution of the command. It is a numeric identifier which corresponds to the identifier used in IEC-61850. When returning from the Logic Editor, the application will reject any value which is not considered as a valid origin within the equipment.
Results	A single output which corresponds to the "Action Group" of the digital command which wants to be executed.
Operation logic	When there is activation of the input signal IN (by rising edge) the function block triggers the "digital command action group" indicated in output Q. This results in the generation of a pulse in the signal configured as "Signal to activate" which corresponds to the first action with the origin indicated in input '#Origin' set from all of the actions in the group action indicated in the output Q. (Note: The pulse will be generated, provided the action is not blocked and the state of the command allows the action to take place). Example:  When signal "Activation CMD Doble ON" is activated, group action "CMD_DOBLE-ON" with origin = 1 is triggered. That means that the equipment will look for the action, in group action "CMD_DOBLE-ON", which has the origin "1 (Bay control)" set in the origin mask. Once the action is located, the equipment will try to generate a pulse in the signal configured in "Signal to activate". In the example, the equipment will try to generate a pulse over signal "Mando ON Doble". Should there be more than one action with #Origin set in the origin mask, only the first action found with that origin will be executed. Should there be no action with #Origin set in the origin mask, no action will be executed.

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A-Cmd:

This function attempts to execute an analog command action when the analog input value changes.

Operands	Two Inputs: Analogue input which triggers the command. Integer input which represents the origin for the execution of the command. It is a numeric identifier which corresponds to the identifier used in IEC-61850. When returning from the Logic Editor, the application will reject any value which is not considered as a valid origin within the equipment.
Results	A single output which corresponds to the "Action Group" of the analogue command which wants to be executed.
Operation logic	When the value of the analogue input signal IN (by rising edge) changes, the function block triggers the "analogue command action group" indicated in output Q. This results in the signal configured as "Signal to activate", which corresponds to the first action with the origin indicated in input '#Origin' set from all of the actions in the group action indicated in the output Q, to take the same value as the one in input IN. (Note: The value will be assigned to the analogue signal provided the action is not blocked and the state of the command allows the action to take place). Example:  When the value of "Ang IA" is modiifed, group action "Accion26" is triggered with origin 1 (Bay Control). The equipment will look for the first action with the origin 1 set in its origin mask. If found, the value of the input IN, in this case the value of "Ang IA" will be copied into "Mando26" which is the "Action to execute" configured for action "Accion26". Should there be more than one action with #Origin set in the origin mask, only the first action found with that origin will be executed. Should there be no action with #Origin set in the origin mask, no action will be executed.

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Chapter 9.

Records

9.1 Oscillographic Recording

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9.1.1 Operation Principles

The Oscillography function is composed of two different sub functions: **Capture** and **Display**. The first captures and stores protection data inside the IED and is part of the relay's software; the second retrieves and presents the stored data graphically with one or more programs running on a PC connected to the protection.

For 50Kz, sampling and storage frequency is 4800Hz (96 samples per cycle) with 15 seconds of maximum storage per oscillography recording (14 seconds of fault and 1 second of pre-fault, both adjustable times) and 100 seconds of total memory storage and 64 files. Permanence of the information, with the IED disconnected from the power supply, is guaranteed since the IED stores the information in non-volatile Flash memory with cache in RAM.

The IEDs come with a display and analysis program, because the waveform records are in binary COMTRADE format according to IEEE standard C37.111-1999. The COMTRADE file generated considers the changes in frequency that can occur in the system, so that the analog magnitudes are stored with complete fidelity to how they have evolved on the system.

9.1.2 Capture Function

It is possible to record measured analog values, *User Defined Magnitudes*, digital inputs to the IED, internal logic signals generated by the protection and the programmable logic up to a total of 64 oscillographs in cyclical memory.

9.1.3 Stored Data

The following data are stored with a resolution time equal to the sampling rate:

- Value of the samples of the selected parameters (measured and *User Defined*) and of the digital and analogical signals programmed for this purpose.
- Time stamp of the Oscillography startup.

When there is no angle reference magnitude, all angles will be displayed in the relay with an invalid value (***) and the oscillogram will display them at 0˚.

9.1.4 Number of Channels and Digital Signals

It is possible to record all the analog inputs, eight (8). In addition, up to a maximum of 16 additional *User Defined Magnitudes* can be added.

User magnitudes are those selected from the magnitudes calculated by the relay, including the ones calculated under the programmable logic through ***ZIV e-NET tool***®.

Models with Power Supply Voltage Monitoring measure the voltage via a transducer input. This value is considered an *User Defined* value.

User Defined values include any type of parameters. If sine waves are recorded the Oscillography records the changes of the RMS value.

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Values are stored in the COMTRADE oscillography format with the label assigned in the programmable logic. The power supply voltage is stored with the label VDC.

It is also possible to assign direct metering from the analog channels as a *User Defined* value. Being waveforms the RMS value is stored. COMTRADE label is VALUE_u (ie. VA_u).

The maximum number of digital signals that can be registered is 160.

9.1.5 Start Function

The Start Function is determined by a programmable mask applied to certain internal signals (element pickups, open command, etc.) and to an External Pickup signal (which, if it is to be used, must be connected to any of the physical status contact inputs, to a programmable button of the HMI, to a command via communications or to a signal configured for this purpose in the programmable logic).

If the start function mask setting is **YES**, this signal activates the Oscillography startup. This signal will not start the Oscillography function if its mask setting is **NO**.

9.1.6 Oscillograph Deletion Function

Since the Oscillograph records are stored in non-volatile memory, there is a mechanism that allows deleting all the content of this memory externally.

The Oscillograph Deletion Function can operate by activating the **Deletion of Oscillographs** signal, which can be assigned by the programmable logic to any of the physical inputs, to a programmable button of the HMI, to a command via communications, etc.).

9.1.7 Trip Required

Data are stored only if a trip occurs within the time configured as Oscillography Record ***Length***.

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9.1.8 Concatenation Stream Mode

The **YES** / **NO** setting allows extending the oscillography record length if new pickups of elements occur while one is being recorded. The recording system restarts the count of sequences to store if any other element picks up before the element generating the oscillography pickup resets.

It is possible for multiple pickups to occur during a fault. Sometimes these pickups are not simultaneous, but they are staged in the early moments of a fault. The available memory to store oscillography is divided in zones, depending on the oscillography ***Length*** setting. To optimize the memory management, pickups occurring during the interval of pickups set of a fault do not extend the length of the oscillography.

9.1.9 Pre-Fault Time

This is the length of pre-fault data that must be stored before the start function initiates a record. The setting range is from 0 to 1 second of pre-fault.

9.1.10 Length of the Oscillograph

It is the duration time of the storage window. The number of records stored in memory varies and depends on the number of channels recorded and the length of the fault records. Once the recording memory is full, the next event will overwrite the oldest one stored.

The maximum number of oscillography recordings is 64, the maximum length per oscillography recording is 15 seconds and the maximum memory 100 seconds. Depending on the length selected, the maximum number varies.

Set number of seconds	Max. number of oscillographs
15	6
10	10
7	14
...	...
3	33
1.56	64

9.1.11 Interval between Triggers

Startup Interval Seconds setting is used to discriminate whether consecutive elements pick-ups correspond to the same fault or not. This way, all activations during that interval would be considered as belonging to the same fault and, therefore, the record is not enlarged

However, for activations after that time, and as long as the ***Continuous Mode*** setting is enabled, the record will be enlarged as per the ***Length*** of the Oscillograph setting.

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9.1.12 Setting Ranges

Oscillography					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Trip Required	Trip Required	RDRE1.TrReq	YES / NO		YES
Continuous Mode	Continuous Mode	RDRE1.ReTrgMod	YES / NO		NO
PreStartup Length Seconds	Pretrig. Length Seconds	RDRE1.PreTmms	0-1 s	0.01 s	0.1 s
Length	Postfault Length Seconds	RDRE1.PstTmms	0.1-14 s	0.01 s	0.1 s
Startup Interval Seconds	Trigger interval	RDRE1.ExclTmms	0.01-10 s	0.01 s	0.08 s

Trigger Mask			
Setting	**Step**	**Default**	**IEC 61850**
DTT	YES / NO	NO	RDRE1.DTTPDIFTrg
Phase Differential with Restraint	YES / NO	NO	RDRE1.PDIFTrg
Phase Differential without Restraint	YES / NO	NO	RDRE1.NRPDIFTrg
Neutral Differential	YES / NO	NO	RDRE1.GNDPDIFTrg
Positive Sequence Differential	YES / NO	NO	RDRE1.NSPDIFTrg
Negative Sequence Differential	YES / NO	NO	RDRE1.PSPDIFTrg
Instantaneous Phase Overcurrent (50F1, 50F2 and 50F3)	YES / NO	NO	RDRE1.PHIOCTrgX
Instantaneous Neutral Overcurrent (50N1, 50N2 and 50N)	YES / NO	NO	RDRE1.NIOCTrgX
Instantaneous Ground Overcurrent (50G1, 50G2 and 50G3)	YES / NO	NO	RDRE1.GNDIOCTrgX
Instantaneous Negative Sequence Overcurrent (50Q1, 50Q2 and 50Q3)	YES / NO	NO	RDRE1.NSIOCTrgX
Time-delayed Phase Overcurrent (51F1, 51F2 and 50F3)	YES / NO	NO	RDRE1.PHTOCTrgX
Time-delayed Neutral Overcurrent (51N1, 51N2 and 50N3)	YES / NO	NO	RDRE1.NTOCTrgX
Time-delayed Ground Overcurrent (51G1, 51G2 and 50G3)	YES / NO	NO	RDRE1.GNDTOCTrgX
Time-delayed Negative Sequence Overcurrent (51Q1, 51Q2 and 50Q3)	YES / NO	NO	RDRE1.NSTOCTrfX
Phase Undervoltage (27F1, 27F2 and 27F3)	YES / NO	NO	RDRE1.PHTUVTrgX
Phase Overvoltage (59F1, 59F2 and 59F3)	YES / NO	NO	RDRE1.PHTOVTrgX
Neutral Overvoltage (59N1, 59N2 and 59Ns)	YES / NO	NO	RDRE1.NTOVTrgX
Neutral Overvoltage (64-1, 64-2 and 64-3N3)	YES / NO	NO	RDRE1.GNDTOVTrgX
Negative Sequence Overvoltage (47)	YES / NO	NO	RDRE1.NSTOVTrg
Underfrequency (81m1, 81m2, 81m3 and 81m4)	YES / NO	NO	RDRE1.PTUFTrgX
Overfrequency (81M1, 81M2, 81M3 and 81M4)	YES / NO	NO	RDRE1.PTOFTrgX
Rate of Change of the Frequency (81D1, 81D2, 81D3 and 81D4)	YES / NO	NO	RDRE1.PFRCTrgX
Load Shedding	YES / NO	NO	RDRE1.LodShedTrg
Open Phase	YES / NO	NO	RDRE1.OPHTOCTrg
Thermal Image (49)	YES / NO	NO	RDRE1.PTTRTrg
External	YES / NO	NO	RDRE1.ExtTrg
Zones (1 / 2 / 3 / 4 / 5 / 6) Phase	YES / NO	NO	RDRE1.PHDISTrgx
Zones (1 / 2 / 3 / 4 / 5 / 6) Ground	YES / NO	NO	RDRE1.GDISTrgx
Programmable Trip	YES / NO	NO	RDRE1.ProgTrg
FDS Programmable Trip	YES / NO	NO	RDRE1.FDSProgTrg
1PHASE / 3PHASE Programmable Trip	YES / NO	NO	RDRE1.Prog13Trg
FDS 1PHASE / 3PHASE Programmable Trip	YES / NO	NO	RDRE1.FDSPr13Trg

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Trigger Mask			
Setting	**Step**	**Default**	**IEC 61850**
Power Swing Trip	YES / NO	NO	
Remote Open Breaker	YES / NO	NO	
CO Fault	YES / NO	NO	
Pole Discrepancy	YES / NO	NO	RDRE1.PPDSTrg
Pole Discrepancy 2*	YES / NO	NO	RDRE2.PPDSTrg

(*) For models with Double Breaker of Breaker-and-a-Half Bay configuration capability.

Analog Channel Mask			
Setting	**IEC61850**	**Step**	**Default**
VA	RDRE1.AnChgMsk1	YES / NO	YES
VB	RDRE1.AnChgMsk2	YES / NO	YES
VC	RDRE1.AnChgMsk3	YES / NO	YES
VSYN	RDRE1.AnChgMsk4	YES / NO	YES
VG	RDRE1.AnChgMsk5	YES / NO	YES
IA	RDRE1.AnChgMsk6	YES / NO	YES
IB	RDRE1.AnChgMsk7	YES / NO	YES
IC	RDRE1.AnChgMsk8	YES / NO	YES
IGPAR	RDRE1.AnChgMsk9	YES / NO	YES
IG	RDRE1.AnChgMsk10	YES / NO	YES
IN	RDRE1.AnChgMsk11	YES / NO	YES
IA1	RDRE1.AnChgMsk12	YES / NO	YES
IB1	RDRE1.AnChgMsk13	YES / NO	YES
IC1	RDRE1.AnChgMsk14	YES / NO	YES
IA2	RDRE1.AnChgMsk15	YES / NO	YES
IB2	RDRE1.AnChgMsk16	YES / NO	YES
IC2	RDRE1.AnChgMsk17	YES / NO	YES
IA3	RDRE1.AnChgMsk18	YES / NO	YES
IB3	RDRE1.AnChgMsk19	YES / NO	YES
IC3	RDRE1.AnChgMsk20	YES / NO	YES
IDIFA	RDRE1.AnChgMsk21	YES / NO	YES
IDIFB	RDRE1.AnChgMsk22	YES / NO	YES
IDIFC	RDRE1.AnChgMsk23	YES / NO	YES
IRSTA	RDRE1.AnChgMsk24	YES / NO	YES
IRSTB	RDRE1.AnChgMsk25	YES / NO	YES
IRSTC	RDRE1.AnChgMsk26	YES / NO	YES
V2*	RDRE1.AnChgMsk11	YES / NO	YES
V3*	RDRE1.AnChgMsk12	YES / NO	YES

(*) For models with Double Breaker of Breaker-and-a-Half Bay configuration capability.

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User Defined Values (Up to 16 values)				
ACTGRP	HARM2 IA	HARM7 VG	MREF A	VAB
ALARMS	HARM2 IB	HARM8 IA	N.A.ENGY	VAB_ANG
ANG IA	HARM2 IC	HARM8 IB	N.R.ENGY	VB
ANG IB	HARM2 IG	HARM8 IC	N_CLOSING	VBC
ANG IC	HARM2 IN	HARM8 IG	N_OPENING_A	VBC_ANG
ANG IG	HARM2 VA	HARM8 IGS	N_OPENING_B	VC
ANG IN	HARM2 VB	HARM8 IN	N_OPENING_C	VCA
ANG IGPAR	HARM2 VC	HARM8 VA	NSC	VCA
ANG IPOL	HARM2 VG	HARM8 VB	NSV	VCA_ANG
ANG NSC	HARM3 IA	HARM8 VC	NTRAPS	VG
ANG PSC	HARM3 IB	HARM8 VG	Null	VMAX
ANG PSV	HARM3 IC	HARM9 IA	OPENI_A	VMIN
ANG VA	HARM3 IG	HARM9 IB	OPENI_B	VN
ANG VB	HARM3 IN	HARM9 IC	OPENI_C	VSYNC
ANG VC	HARM3 VA	HARM9 IG	P	WARMSTARTS
ANG VG	HARM3 VB	HARM9 IN	P.Active Energy	ZSC
ANG VN	HARM3 VC	HARM9 VA	P.React. Energy	ZSV
ANG VSYNC	HARM3 VG	HARM9 VB	P_A	VAB C2
ANG ZSC	HARM4 IA	HARM9 VC	P_B	VAB PR C2
ANG ZSV	HARM4 IB	HARM9 VG	P_C	VAB PI C2
C REENG	HARM4 IC	IA	PF	VBC C2
COLDSTARTS	HARM4 IG	IB	PF_A	VBC PR C2
CUMIOPEN_A	HARM4 IN	IC	PF_B	VBC PI C2
CUMIOPEN_B	HARM4 VA	IG	PF_C	VCA C2
CUMIOPEN_C	HARM4 VB	IMCNPAR_A	PMAX	VCA PR C2
DIST	HARM4 VC	IMCA	PMIN	VCA PI C2
DISTk	HARM4 VG	IMCA_A	PSC	U.TFALTA
DISTm	HARM5 IA	IMCB	PSV	VMCA
FAULTT	HARM5 IB	IMCB_A	Q	VMCB
FREQ	HARM5 IC	IMCC	Q_A	VMCC
FREQ PLL	HARM5 IG	IMCC_A	Q_B	VMCSD
FREQ SYNC	HARM5 IN	IMCNPAR	Q_C	IMCSD
HARM10 IA	HARM5 VA	IMCSI	QMAX	IMCSD_A
HARM10 IB	HARM5 VB	IMCSI_A	QMIN	IMCSH_A
HARM10 IC	HARM5 VC	IMCAB	RMSIA	VMCA_A
HARM10 IG	HARM5 VG	IMCAB_A	RMSIB	VMCB_A
HARM10 IN	HARM6 IA	IMCBC	RMSIC	VMCC_A
HARM10 VA	HARM6 IB	IMCBC_A	ROC FREQ	VMCSI
HARM10 VB	HARM6 VG	IMCCA	S	VMCSI_A
HARM10 VC	HARM7 IA	IMCCA_A	S_A	VMCSH
HARM10 VG	HARM7 IB	IGN	S_B	VMCSH_A
HARM6 IC	HARM7 IC	IGPAR	S_C	VMCAB
HARM6 IG	HARM7 IG	IMAX	SMAX	VMCAB_A
HARM6 IN	HARM7 IGN	IMIN	SMIN	VMCBC
HARM6 VA	HARM7 VA	IN	THERMAL IMG	VMCBC_A
HARM6 VB	HARM7 VB	IPOL	THREE PH RECL	VMCCA
HARM6 VC	HARM7 VC	L.FAULTT	VA	VMCCA_A
				V2*
				V3*

(*) For models with Double Breaker of Breaker-and-a-Half Bay configuration capability.

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Digital Channel Selection (maximum 160)
Selectable from all configurable Digital Inputs and Digital Signals

9.1.13 Digital Inputs of the Oscillographic Recording

Table 9.1-1: Digital Inputs of the Oscillographic Recording

Name	Group	IEC 61850	Description	Vis.	Function
TRIG_EXT_OSC	Logic Inputs to Protection	RDRE1.RcdTrg	Oscillography External Trigger	I	Input intended for external triggering.
DEL_OSC	Reposition Commands	RDRE1.MemClr	Delete Oscillography Command	I	The activation of this input deletes all the oscillographs stored.
ENBL_OSC	Enabling Commands	RDRE1.Mod	Oscillography Enable Input		Activation of this input puts the element into service. The default value of this logic input signal is a "1."

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

9.1.14 Auxiliary Outputs and Events of the Oscillographic Recording

Table 9.1-2: Auxiliary Outputs and Events of the Oscillographic Recording

Name	Group	IEC 61850	Description	Vis.	Function
PU_OSC	Others	RDRE1.RcdStr	Oscillography Triggered	I	Indicates that a oscillographic recording is on process.
OSC_ENBLD	Enabled Units Protection Outputs	RDRE1.Mod	Oscillography Enable	I	Indication of enabled or disabled status of the element.

Note: The Visualization column (Vis.) indicates whether the signal is shown as indication in the relay status (I) through the communications program and in the Fault Report (F).

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9.1.15 IEC 61850 Logical Node

CLASS IRLRDRE		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Controls		
MemClr	SPC	Clear memory
Status Information		
RcdMade	SPS	Recording made
FltNum	INS	Fault Number
RcdStr	SPS	Recording started
Settings		
PreTmms	ING	Pre-trigger time
PstTmms	ING	Post-trigger time
ReTrgMod	ING	Retrigger mode
ExclTmms	ING	Exclusion time
Extended Data		
RcdTrg	EXT_SPC	External trigger
TrReq	EXT_SPG	Trip required
PHIOCTrgX	EXT_SPG	Trigger mask
NIOCTrgX	EXT_SPG	Trigger mask
SGIOCTrg	EXT_SPG	Trigger mask
NSIOCTrgX	EXT_SPG	Trigger mask
PHTOCTrgX	EXT_SPG	Trigger mask
NTOCTrgX	EXT_SPG	Trigger mask
SGTOCTrg	EXT_SPG	Trigger mask
ESGTOCTrg	EXT_SPG	Trigger mask
NSTOCTrgX	EXT_SPG	Trigger mask
PSDETrg	EXT_SPG	Trigger mask
PHTUVTrgX	EXT_SPG	Trigger mask
PHTOVTrgX	EXT_SPG	Trigger mask
GNDTOVTrgX	EXT_SPG	Trigger mask
NSTOVTrg	EXT_SPG	Trigger mask
PTUFTrgX	EXT_SPG	Trigger mask
PTOFTrgX	EXT_SPG	Trigger mask
PFRCTrgX	EXT_SPG	Trigger mask
LodShedTrg	EXT_SPG	Trigger mask
RDRE1.OPHTOCTrg (SPG)	EXT_SPG	Trigger mask
PTTRTrg	EXT_SPG	Trigger mask
PDOPTrgX	EXT_SPG	Trigger mask
PTUCTrg	EXT_SPG	Trigger mask
PPAMTrg	EXT_SPC	Trigger mask
PVPHTrg	EXT_SPG	Trigger mask
PVOCTrg	EXT_SPG	Trigger mask
CRVVOCTrg	EXT_SPG	Trigger mask

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Extended Data (Cont.)		
ExTrg	EXT_SPG	Trigger mask
ZBATLTrg	EXT_SPG	Trigger mask
ZBATHTrg	EXT_SPG	Trigger mask
ProgTrg	EXT_SPG	Trigger mask
PPDSTrg	EXT_SPG	Trigger mask
GNDIOCTrgX	EXT_SPG	Trigger mask
GNDTOCTrgX	EXT_SPG	Trigger mask
GNDDIFTrg (	EXT_SPG	Trigger mask

Note: X is the index of the corresponding unit.

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9.2 Event Record

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9.2.1 Introduction

Depending on the model there are up to two different event record systems in the equipment, one based on internal resources and one based on resources from IEC 61850 data model (SYSLOGSOE event recorder). The first one is described as follows while the second one is described in Section 9.2.3.

9.2.2 Protection Event Record

9.2.2.a Operation Principles

The capacity of the IED is 2000 records in non-volatile memory where each record stores all events that have been generated at the same time up to a maximum of 16 activation or deactivation events per record. The signals that generate the events are user-selectable and are recorded with a resolution of 1 ms together with a maximum of 12 values also selectable from all the available metering values measured or calculated by the IED (*User Defined Values*, including VDC in models with Power Supply Voltage Monitoring).

Each of the functions that the system uses records an event in the Event Record when any of the situations listed in the tables nested in the description of each function occur. Moreover, the events listed in Table 9.2-1 -the IED's general services- are also recorded. The tables mentioned above only list the events available with the default configuration. The list of signals can be expanded with those that the user configures in the programmable logic (any signal existing in the programmable logic can be configured to generate an event with the description that the user defines).

Table 9.2-1: Event Record

Name	Description
Equipment Cold Start Up	It activates each time the relay is power-supplied.
Equipment Warm Start Up	It activates after a relay reset (configuration loading, manual reset…) but with the relay power supply on.
Digital Inputs Power Failure	It activates when no voltage is present at the digital input selected for the ED supervision.
Summer Time	It activates when the relay is in summer time mode.
Local Control	Digital signal indicating relay local control enable. See paragraph 8.19.3, relative to the commands.
Panel-controlled	Digital signal indicating relay control from control panel or HMI enable. See paragraph 8.19.3, relative to the commands.
Remote	Digital signal indicating operations enabled on the equipment from remote control. See paragraph 8.19.3, relative to the commands.
Maintenance Control	Digital signal indicating operations enabled on the equipment from maintenance. See paragraph 8.19.3, relative to the commands.
System Non Critical Error	They write down that a technical issue in the relay has occurred.
System Critical Error	
System Event	It indicates that a relay SW reset has taken place.
Change of Settings Initialization	It is shown when a setting is changed.

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Table 9.2-1: Event Record	
Name	**Description**
HMI Access	It activates every time the HMI is accessed from the relay home screen and deactivates when returning to the home screen.
SNTP Sync	The relay is receiving SNTP synchronization.
Clock Synchronization	The relay is synchronized.
Communication Failure Local Port	They activate when no communications activity through the ports is present for a time set for each of them.
Communication Failure Remote Port 1	
LAN1 / Communication Failure PROCOME Protocol	
LAN1 / Communication Failure Protocol 1	
LAN1 / Communication Failure Protocol 2	
LAN1 / Communication Failure Protocol 3	
LAN1 / Communication Failure Protocol 4	

All the configured events as well as the pre-existing ones in the default configuration can be masked.

The text indicated in the events tables is expanded with the message **Activation of...** when the event is generated by activation of any of the signals or **Deactivation of...** when the event is generated by deactivation of the signal.

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9.2.2.b Organization of the Event Record

The Event Record reaches the last 2000 events generated, in a circular pile form, so that event writing above this capacity will result in erasing the events written at the beginning of the pile. The following information is stored in each event register:

- Values of the 12 magnitudes selected at the time the event is generated.
- Event date and time.

Event recorder management is optimized so that simultaneous operations generated by the same event occupy a single position in the event memory. For example, the simultaneous occurrence of the phase A and neutral time overcurrent pickups are recorded in the same memory position. However, if the occurrences are not simultaneous, two separate events are generated. Simultaneous events are those operations occurring within a 1 ms interval, the resolution time of the recorder. Each pile register can store a maximum of 16 activation or deactivation events per register so that the actual maximum capacity will be 32000 events when 16 different events are generated in every millisecond.

9.2.2.c Event Mask

There is the possibility of masking events that are not necessary, or are not useful, when studying the behavior of the equipment. This possibility can only be made via communications.

Important: Events that can be generated in excess should be masked since they could fill the memory and erase more important previous events.

9.2.2.d Consulting the Record

The communications and remote management program, ***ZIV e-NET tool***®, has a completely decoded system for consulting the Event Record.

9.2.2.e Event Record Settings (Only via Communications)

Events Mask
IED events may be masked separately

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User Defined Values (Up to 16 values)				
ACTGRP	HARM2 IA	HARM8 IA	N.A.ENGY	VAB_ANG
ALARMS	HARM2 IB	HARM8 IB	N.R.ENGY	VB
ANG IA	HARM2 IC	HARM8 IC	N_CLOSING	VBC
ANG IB	HARM2 IG	HARM8 IG	N_OPENING_A	VBC_ANG
ANG IC	HARM2 IN	HARM8 IGS	N_OPENING_B	VC
ANG IG	HARM2 VA	HARM8 IN	N_OPENING_C	VCA
ANG IN	HARM2 VB	HARM8 VA	NSC	VCA
ANG IGPAR	HARM2 VC	HARM8 VB	NSV	VCA_ANG
ANG IPOL	HARM2 VG	HARM8 VC	NTRAPS	VG
ANG NSC	HARM3 IA	HARM8 VG	Null	VMAX
ANG PSC	HARM3 IB	HARM9 IA	OPENI_A	VMIN
ANG PSV	HARM3 IC	HARM9 IB	OPENI_B	VN
ANG VA	HARM3 IG	HARM9 IC	OPENI_C	VSYNC
ANG VB	HARM3 IN	HARM9 IG	P	WARMSTARTS
ANG VC	HARM3 VA	HARM9 IN	P.Active Energy	ZSC
ANG VG	HARM3 VB	HARM9 VA	P.React. Energy	ZSV
ANG VN	HARM3 VC	HARM9 VB	P_A	VAB C2
ANG VSYNC	HARM3 VG	HARM9 VC	P_B	VAB PR C2
ANG ZSC	HARM4 IA	HARM9 VG	P_C	VAB PI C2
ANG ZSV	HARM4 IB	IA	PF	VBC C2
C REENG	HARM4 IC	IB	PF_A	VBC PR C2
COLDSTARTS	HARM4 IG	IC	PF_B	VBC PI C2
CUMIOPEN_A	HARM4 IN	IG	PF_C	VCA C2
CUMIOPEN_B	HARM4 VA	IMCNPAR_A	PMAX	VCA PR C2
CUMIOPEN_C	HARM4 VB	IMCA	PMIN	VCA PI C2
DIST	HARM4 VC	IMCA_A	PSC	U.TFALTA
DISTk	HARM4 VG	IMCB	PSV	VMCA
DISTm	HARM5 IA	IMCB_A	Q	VMCB
FAULTT	HARM5 IB	IMCC	Q_A	VMCC
FREQ	HARM5 IC	IMCC_A	Q_B	VMCSD
FREQ PLL	HARM5 IG	IMCNPAR	Q_C	IMCSD
FREQ SYNC	HARM5 IN	IMCSI	QMAX	IMCSD_A
HARM10 IA	HARM5 VA	IMCSI_A	QMIN	IMCSH_A
HARM10 IB	HARM5 VB	IMCAB	RMSIA	VMCA_A
HARM10 IC	HARM5 VC	IMCAB_A	RMSIB	VMCB_A
HARM10 IG	HARM5 VG	IMCBC	RMSIC	VMCC_A
HARM10 IN	HARM6 IA	IMCBC_A	ROC FREQ	VMCSI
HARM10 VA	HARM6 IB	IMCCA	S	VMCSI_A
HARM10 VB	HARM6 VG	IMCCA_A	S_A	VMCSH
HARM10 VC	HARM7 IA	IGN	S_B	VMCSH_A
HARM10 VG	HARM7 IB	IGPAR	S_C	VMCAB
HARM6 IC	HARM7 IC	IMAX	SMAX	VMCAB_A
HARM6 IG	HARM7 IG	IMIN	SMIN	VMCBC
HARM6 IN	HARM7 IGN	IN	THERMAL IMG	VMCBC_A
HARM6 VA	HARM7 VA	IPOL	THREE PH RECL	VMCCA
HARM6 VB	HARM7 VB	L.FAULTT	VA	VMCCA_A
HARM6 VC	HARM7 VC	MREF A	VAB	
	HARM7 VG			

Note: all magnitudes for each event are stored in secondary values; therefore not affected by any primary-to-secondary ratio except for energy magnitudes that are always recorded in primary values.

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9.2.2.f SYSLOGSOE Event Record

In addition to the protection Event Log, the user can configure the protection events to be stored in a second log called SYSLOGSOE in Flash memory (non-volatile). All events stored in this log are automatically sent through the equipment's **Syslog** protocol (see Syslog Protocol Annex).

The SYSLOGSOE event file (.*soe* extension) will be available in the /SYSLOGSOE directory (at the same level as the COMTRADE, COMFEDE, and SCL directories, and with the same access security level as these, i.e. with the same permissions) so that the user can download it through the FTP or SFTP client-server service.

The configuration of the events to be sent via the Syslog protocol is done by activation of the corresponding settings (event masks) located in **Settings\Communications\Protocols\Syslog\Soe Events\Events Mask** (see ***ZIV e-NET tool***® / ***ZIVercomPlus***®).

It is important to note that for an event to be assigned to the SYSLOGSOE log, it must also be assigned to the Event Log, i.e. the user must enable both the Syslog event mask (**Settings\Communications\Protocols\Syslog\Soe Events\Events Mask**) and the main Event Log mask (***Settings\Records\Events\Events Mask***).

User events generated in the logic through the ***ZIV e-NET tool***® (defined as Procome events) will be automatically available to be configured within both the Event Log (***Settings\Records\Events\Events Mask***) and the SYSLOGSOE log (**Settings\Communications\Protocols\Syslog\Soe Events\Events Mask**).

Once the event masks have been enabled, each event can be configured (with the corresponding setting) with a "***Facility***" and "**Severity**" as defined by the protocol.

The ***Facility*** setting options available are as follows:

- 13 log audit.
- 16 local use 0 (local0).
- 17 local use 1 (local1).
- 18 local use 2 (local2).

Regarding the ***Severity*** setting options, the equipment supports the following:

- 2 Critical: critical conditions.
- 4 Warning: warning conditions.
- 6 Informational: informational messages.
- 7 Debug: debug-level messages.

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The default settings for the different groups of settings are described in the following table:

Events / Events Group	***Facility***	***Severity***
Digital Inputs/Output/LEDs/Buttons	18	6
Protection	18	6
Recloser	18	6
Control	18	6
User Events (Programmable Logic)	17	6
Oscillography	18	6
Breaker Supervision	18	6
Coil Circuit Supervision	18	6
Energy Counters Reset & Pick value Reset	18	6
Schedule	18	6
System		
System\Equipment Cold Start Up	16	4
System\Equipment Warm Start Up	16	4
System\Alarms\System Critical Error	16	2
System\Alarms\System Non Critical Error	16	4
System\Alarms\System Event	16	4
System\Date and Time	16	6
System\Control State	18	6
System\Settings	18	6
System\HMI	18	6
System\Synchronization	16	6
Communications	18	6

- **SYSLOG Event Format**

The format (see below) is described in detail in the Syslog Protocol Annex.

```
HEADER SP STRUCTURED-DATA [SP MSG]
```

Example of SYSLOG events:

```
<110>1 2020-04-29T12:25:35.231Z 192.168.1.81 IRF1Q11F01 – IEC62351-14:1-nocyb
[62351-14@41912 ID=”7446544” Text=”On Phase A Instantaneous unit 1
Trip|On|Good” SOE=”1234567890”]
[VA63.1VVB34VVC63.41VVG26.87VIA13.81AIB24AIC13.41AIG23.87AIGS4.75ª]
```


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- **SYSLOGSOE File Format**

The SYSLOGSOE file format is as follows:

TIMESTAMP – EventId – PRI (only Severity description) - MSG

Example:

```
2000:01:01_00:03:19.716 - 3705006 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Digital Inputs
Enabled|Off|Good
2000:01:01_00:03:19.716 - 3702630 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Frequency Disabled by
Lack of Voltage|On|Good
2000:01:01_00:03:19.716 - 3702211 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Protection in
Service|On|Good
2000:01:01_00:03:19.716 - 3702207 - warning - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Equipment Warm Start
Up|On|Good
2000:01:01_00:03:19.716 - 3702821 - warning - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - System Event|On|Good
2000:01:01_00:03:19.716 - 3716911 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Communication Failure
PROCOME Protocol|On|Good
2000:01:01_00:03:19.716 - 3716912 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Communication Failure
Protocol 1|On|Good
2000:01:01_00:03:19.716 - 3716913 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Communication Failure
Protocol 2|On|Good
2000:01:01_00:03:19.716 - 3716914 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Communication Failure
Protocol 3|On|Good
2000:01:01_00:03:19.716 - 3716915 - debug - VA0.000V VB0.000V VC0.000V
VG0.000V IA0.000A IB0.000A IC0.000A IG0.000A IGS0.000A - Communication Failure
Protocol 4|On|Good
```


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9.2.3 IEC 61850 Based SYSLOGSOE Event Record

In addition to the protection Event Log, the user can configure events to be stored and/or sent in a second log called SYSLOGSOE in Flash memory (non-volatile). In this event recorder, only data from IEC 61850 data model is considered. Specifically, only changes on states and measurements, and their associated qualities, can produce events. These events can be sent through the Syslog protocol (see Syslog Protocol Annex), stored in a file or both. Two different types of files can be used to store events: Txt and XML.

The SYSLOGSOE event file will be available in the /SoE directory (at the same level as the COMTRADE, COMFEDE, and SCL directories, and with the same access security level as these, i.e. with the same permissions) so that the user can download it using an FTP/SFTP client. It is possible to download this event record file through the ***ZIV e-NET tool***® clicking on Tools/Device Access/Retrieval of Files.

The *Facility* and *Severity* of each event can be configured individually. All *Facility* and *Severity* options defined in the RFC 5424 are available.

Each event can be associated with a group of predefined magnitudes or measurements. These measurements must also be data from IEC 61850 data model. There is a limit of 20 measurement groups and each event can be associated to up to 32 measurements.

It is possible to configure if the quality changes of signals or measurements trigger events or not.

The events must be configured using the software ***ZIV e-NET tool***® though several configuration sheets: General, Syslog, Measure groups and Signals. Because signal sheet could have hundreds of signals, it is possible to copy and paste data to/from an excel spreadsheet considering the structure indicated in the Signals sheet.

It is possible to use predefined wildcards for some of the configurable fields. Wildcards are identified because they are between curly brackets, for example, {IEDName}. Additionally, it is possible to combine wildcards and free text. The following wildcards are possible:

- **{clientCode}**: It is the configuration parameter *clientCode* defined for each signal (e.g., INT502).
- **{phyLabel}**: It is the configuration parameter *phyLabel* defined for each signal (e.g., DI-2).
- **{desc}**: It is the configuration parameter *desc* defined in each signal (e.g., BREAKER 52 CLOSED).
- **{61850Desc}**: It is the description of the signal from the field d of the IEC 61850 data.
- **{acronym}**: It corresponds with the acronym of the value of the signal set in the Acronyms section, for example ON, when the event is triggered. If there is no acronym set, then the value will be empty.
- **{quality}**: It corresponds with the quality (validity of the q attribute) IEC 61850 when the event is triggered, for example GOOD. The admitted values are the one described in the IEC 61850 standard (good, invalid, reserved, questionable).
- **{goCBRef}**: It indicates the Goose Control Block path (complete GOOSE Control Block reference including the IEDName).
- **{FirstLAN}**: It is the IP address of the first enabled LAN port.

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- **{LAN1}**: It is the IP address of the first LAN port.
- **{LAN2}**: It is the IP address of the second LAN port.
- **{LAN3}**: It is the IP address of the third LAN port.
- **{LAN4}**: It is the IP address of the fourth LAN port.
- **{IEDName}**: It is the IEC 61850 IEDName of the equipment.
- **{intId}**: It is the internal identifier of the IEC 61850 signal.
- **{facility}**: It is the configuration parameter *facility* defined for each event.
- **{severity}**: It is the configuration parameter *severity* defined for each event.
- **{internalDesc}**: It is the internal description of the measure.

The following parameters related with SYSLOGSOE event recorder can be configured through the ***ZIV e-NET tool***®.

Events (SoE) and Fault reports - General				
Parameter	**Type**	**Range**	**Default**	**Description**
Event (SoE) file format	Selectable	Txt XML	Txt	Select the output file format of events recorder.
Quality changes generate events	Selectable	No Yes	Yes	Select whether a quality change generates events.

Events (SoE) and Fault reports - Syslog				
Parameter	**Type**	**Range**	**Default**	**Description**
VERSION (HEADER)	Integer	1-255	1	Value of the VERSION field of the HEADER of Syslog.
HOSTNAME (HEADER)	Text (up to 255 char.)	{FirstLAN} {LAN1} {LAN2} {LAN3} {LAN4} {IEDName} Free text	{FirstLAN}	Value of the HOSTNAME field of the HEADER of Syslog. It can be an IP of the equipment IEDName or a free text.
APP-NAME (HEADER)	Text (up to 48 char.)	{IEDName} Free text	{IEDName}	Value of the APP-NAME field of the HEADER of Syslog. It can be the IEDName of the equipment or a free text.
MSGID (HEADER)	Text (up to 32 char.)	Free text	IEC62351 - 14:1-nocyb	Value of the MSGID field of the HEADER of Syslog.
SD-ID (STRUCTURED-DATA)	Text (up to 32 char.)	Free text	62351 - 14@41912	Value of the SD-ID field of the STRUCTURED-DATA of Syslog.
Send additional information (measures)	Selectable	No Yes	Yes	It indicates if measurement information is included in the Syslog event or not.

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Events (SoE) and Fault reports - Measure groups				
Parameter	**Type**	**Range**	**Default**	**Description**
Description (*)	Text			Description text of the measurement group.
IEC 61850 reference (**)	Non editable text			Select the IEC 61850 reference for the required measurement.
Description for Syslog (**)	Text	{61850Desc} Free text	{61850Desc}	Description of the measurement.

(*) For each measurement group.
(**) For each measurement.

Events (SoE) and Fault reports - Signals				
Parameter	**Type**	**Range**	**Default**	**Description**
IEC 61850 reference (*)	Non editable text			Select the IEC 61850 reference for the required data object.
Client code (*)	Text (up to 32 char.)			Customer defined code for the event.
Physical label (*)	Text (up to 32 char.)			Normally used for indicating if the signal is a digital input, digital output or LED.
Description (*)	Text (up to 128 char.)	{61850Desc} Free text	{61850Desc}	Text description of the event.
Facility (*)	Selectable	List according to RFC 5424		Category of the event according to RFC 5424.
Severity (*)	Selectable	List according to RFC 5424		Severity of the event according to RFC 5424.
Send by Syslog (*)	Checkbox	No Yes	Yes	It defines if the event should be sent by the Syslog protocol.
Save to file (*)	Checkbox	No Yes	Yes	It defines if the event should be stored in file.
ID (STRUCTURED-DATA Syslog) (*)	Text (up to 32 char.)	{intId} {clientCode} Free text	{IntId}	Value of the ID field of the STRUCTURED-DATA of Syslog. It can take the internal ID of the signal, the client code or another text.
A**X** (**)	Text (up to 48 char.)	Free text	Boolean: (0 - OFF; 1 - ON) Dbpos: (0 - INTERMEDIATE-STATE; 1 - OFF; 2 - ON; 3 - BAD-STATE) Enum: Value of (“ord” EnumVal IEC 61850) - Text of (“desc” EnumVal IEC 61850)	The description of the event state. For example: ON, OFF, OPEN, CLOSE, etc.

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Events (SoE) and Fault reports - Signals				
Parameter	**Type**	**Range**	**Default**	**Description**
E**X** (**)	Checkbox	No Yes	Yes	It defines if the event state generates events or not.
Text for Syslog (*)	Text (up to 128 char.)	{clientCode} {phyLabel} {desc} {acronym} {quality} {goCBRef} {IEDName} {facility} {severity} Free text	{desc}|{acronym}|{quality}	The text field for the event on Syslog protocol. It can be free text, wildcard or wildcards or a combination of wildcards and free text.
Text for file (*)	Text (up to 128 char.)	{clientCode} {phyLabel} {desc} {acronym} {quality} {goCBRef} {IEDName} {facility} {severity} Free text	{desc}|{acronym}|{quality}	The text field for the event on file. It can be free text, wildcard or wildcards or a combination of wildcards and free text.
Associated measures (*)	Selectable	(***)		It is used to indicate which measure groups come along with the event.

(*) For each event.
(**) There can exist several pairs of acronym and event for each event: for example, A0E0, A1E1 for an ON / OFF event.
(***) It depends on the already generated measure groups.

9.2.3.a SYSLOG Event Format

The format (see below) is described in detail in the Syslog Protocol Annex (Syslog format for protection events).

```
HEADER SP STRUCTURED-DATA [SP MSG]
```

Example of SYSLOG events:

```
<110>1 2020-04-29T12:25:35.231Z 192.168.1.81 IRF1Q11F01 - IEC62351-14:1-nocyb
[62351-14@41912 SOE="1234567890" ID="e8ca5212bec076cc" Text="INT502|ED-
2|BREAKER 52 CLOSED|ON|good"] VA=0.000V,0.000° VB=0.000V,0.000°
VC=0.000V,0.000° VG=0.000V,0.000° IA=0.000A,0.000° IB=0.000A,0.000°
IC=0.000A,0.000° IG=0.000A,0.000° IGS=0.000A,0.000°
```


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9.2.3.b SYSLOGSOE File Format

There are two available file formats: Txt and XML. Only one type of file is generated depending on the selected value for the parameter **Event (SoE) File Format** in the ***ZIV e-NET tool***®. This parameter can be found in **Protocols/IEC 61850/Events (SoE) and Fault reports/General**.

Note that the change of the file format from Txt to XML and vice versa will delete the previous event file.

- **Text File Format**

This file will be generated when the parameter **Event (SoE) File Format** takes the Txt value.

The Txt file has a size limit of 2Mbytes. After reaching this file size limit, old event data will be discarded to allow the recording of new events. The SYSLOGSOE Txt file format is as follows:

TIMESTAMP – **EventId** – **PRI** (only **Severity** description) – **MSG**

Example:

```
2022:04:25 14:05:04.268 - e8ca5212bec076cc - informational - INT502|ED-
2|BREAKER 52 CLOSED|ON|good - VA=0.000V,0.000° VB=0.000V,0.000°
VC=0.000V,0.000° VG=0.000V,0.000° IA=0.000A,0.000° IB=0.000A,0.000°
IC=0.000A,0.000° IG=0.000A,0.000° IGS=0.000A,0.000°
```

- **XML File Format**

This file will be generated when the parameter **Event (SoE) File Format** takes the XML value. The SYSLOGSOE XML file format is as follows:

The XML file has a size limit of 2Mbytes. After reaching this file size limit, old event data will be discarded to allow the recording of new events. The structure of the XML events file is the following one:

Node	Description	Children	Attributes
resource	Root node	source	**idRes**: It indicates that it is a fault report. It always takes the value **events**.
source	Unique section which indicates the events producer IED	event	**ip**: IP of the events producer IED. It equals to the field HOSTNAME of the HEADER of Syslog. E.g.: 192.168.1.1 **iedName**: Name of the events producer IED (IEC 61850). E.g.: L45GISDB. **man**: Name of the manufacturer. It takes the fixed value **ZIV**. **sn**: Serial number of the IED which generates the event. E.g.: 154988. **mod**: IED full model name which generates the event. E.g.: IRFA-1A24322A000000XXXX-3332873.

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Node	Description	Children	Attributes
event	Section which indicates the data of a single event	evtDatST, evtMeas	**sqNum**: Sequence number of the event. It equals to the field SOE of the STRUCTURED-DATA of Syslog. **date**: Timestamp of the event. It equals to the field TIMESTAMP of the HEADER of Syslog. **q**: Quality of the timestamp. It is an OR of the *ClockFailure* and *ClockNotSynchronized* bits of IEC 61850, this is, a 1 indicates synchronization failure. E.g.: *0*.
evtDatST	Section for the event itself	-	**propId**: Customer identifier. It equals to the configuration parameter *clientCode*. **stdrId**: Internal manufacturer identifier. **val**: Acronym corresponding to the value of the signal when the event is produced. If the acronym does not exist, then the value of the signal is used. **desc**: Description of the signal. It equals to the configuration parameter *Description*. **q**: Quality of the signal (considering only the two most significant bits of IEC 61850 quality) when the event has been triggered. The possible values are **good** (00), **invalid** (01), **reserved** (10) or **questionable** (11).
evtMeas	Section of measurements associated to the event	m	**origin**: It indicates if the measurement values are taken in **primary** or **secondary** winding of the CT. It only can take the fixed value of **primary**. E.g.: *primary*.
m	Measurement associated to the event (1)	-	**propId**: It can take the following values: **voltage**, **voltArg**, **current**, **curArg**, **difCurrent**, **biasCurrent**, **brkCurrent**, **frequency**, **difCheckZoneCurrent** and **biasCheckZoneCurrent**. **stdrId**: Same value as **propId**. **unit**: Unit of the measurement. It can take the values: **A**, **V**, **kV**, **s**, **deg** and **Hz**. **I1**: Phase A current measurement (mag. and angle). **I2**: Phase B current measurement (mag. and angle). **I3**: Phase C current measurement (mag. and angle). **I4**: It is the 4th current channel which could be the sensitive neutral current measurement (mag. and angle). **IN**: Neutral current measurement (mag. and angle). **V1**: Phase A voltage measurement (mag. and angle). **V2**: Phase B voltage measurement (mag. and angle). **V3**: Phase C voltage measurement (mag. and angle). **V4**: VSYN voltage measurement (mag. and angle). **VN**: Neutral voltage measurement (mag. and angle). **F**: Frequency measurement (mag. and angle).

(1) Available measurements within the event depends on the IED type. For IEDs with several windings, I1, I2, I3 and IN will correspond to the ones designed as reference winding. For busbar differential IEDs, I1, I2 and I3 will correspond to the ones designed as angle reference and the difCurrent and the biasCurrent will correspond to the busbar which has tripped. If several busbars have tripped, then they will correspond to the busbar with lowest index of them.

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Example:

```
<resource idRes="events">
 <source ip="192.168.1.81" iedName="BUS03" man="ZIV" sn="154988" mod="IRFA-
1A24322A000000XXXX-3332873">
  <event sqNum="1" date="2023-09-06T09:47:24.600Z" q="0">
   <evtDatST propId="FPR200" stdrId="cdf6ef6169a58d3d" val="ON" desc="DISTURBANCE
RECORD START" q="good"/>
   <evtMeas origin="primary">
    <m propId="current" stdrId="current" unit="A" I1="12.25" I2="0.16" I3="0.18" I4="0.00"
IN="12.40"/>
    <m propId="curArg" stdrId="curArg" unit="deg" I1="0.0" I2="0.0" I3="0.0" I4="0.0" IN="0.0"/>
    <m propId="voltage" stdrId="voltage" unit="kV" V1="0.00" V2="0.00" V3="0.00" V4="0.61"
VN="0.00"/>
    <m propId="voltArg" stdrId="voltArg" unit="deg" V1="0.0" V2="0.0" V3="0.0" V4="0.0"
VN="0.0"/>
    <m propId="frequency" stdrId="frequency" unit="Hz" F="0.00"/>
    <m propId="brkCurrent" stdrId="brkCurrent" unit="A" I1="0.00" I2="0.00" I3="0.00"/>
   </evtMeas>
  </event>
 </source>
</resource>
```


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9.3 Fault Reports

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9.3.1 Operation Principles

The terminal incorporates Fault Reports register, which stores the most relevant information about last 25 faults cleared by the IED. Access to this information is available through the communication ports or through HMI. The information stored in each of the annotations made on this record is distributed in three tags: **Fault Start Time Tag**, **Trip Command Time Tag** and **End of Fault Time Tag**.

The fault report magnitudes can be selected between primary and secondary by modifying the ***Fault Report Primary / Secondary Values*** setting. Finally, it is possible to modify the recording instant of the fault quantities by means of the ***Fault Register Time*** setting. This setting is useful for adjusting the recording of fault quantities before the opening time of the protection breakers.

9.3.2 Fault Start Time Tag

It presents the date and time of the pickup of the first element involved in the fault. It also includes:

- **Pre-fault currents and voltages**. They are the values of the phase, neutral, ground, parallel ground and of the measured voltages (phase and line) two cycles before the onset of the fault; that is, before the pickup of the element generating this fault report.

  The values of the negative and zero sequence currents and negative sequence voltage are also registered. The currents as well as the phase voltages are recorded with their angles.

- **Elements picked up** (depending on the model) for full fault duration.

9.3.3 Trip Command Time Tag

It presents the date and time of the trip command. It also presents:

- **Fault currents and voltages**. They are the values of the phase, neutral, ground, parallel ground and of the measured voltages (phase and line) two and a half cycles after the onset of the fault; that is, after the pickup of the element generating this fault report.

  The values of the negative and zero sequence currents and negative sequence voltage are also registered. The currents as well as the phase voltages are recorded with their angles.

- **Elements tripped** (depending on the model).
- **Distance to the fault and type of fault** (single-phase, two-phase, etc.).

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9.3.4 End of Fault Time Tag

It is the date and time of the reset of the last element involved in the fault. Angle values included in the report use as reference the pre-fault phase A voltage. Each annotation of the fault report shows the following information at the time of the trip.

- Fault currents and voltages.
- Frequency.
- Current Interrupted by Breaker.
- Thermal State.
- Setting Group activated at time of trip.
- Reclose Sequence in which the equipment is found before the trip is produced.
- Frequency.
- Distance to the fault in percentage of the entire line length (%).
- Thermal State.
- Breaker opening current per phase.
- Accumulated of KA^2sg per phase.

9.3.5 Pickup Reports

Fault reports are set up following the scheme below: they initiate upon a pickup and terminate when elements are reset. Fault report files are written only if a trip occurs during a fault condition.

Setting ***Pickup Reports*** allows selecting the option to write the report file when no trip has occurred. When setting is set to **YES**, the corresponding report is written to the Fault Report file with no need for the trip to occur.

At the same time, this setting affects the **Fault Locator** as, if set to **NO**, the distance to the fault is calculated only when a trip is produced after the pickup. If set to **YES**, the distance to the fault is calculated when pickup resets no matter whether a trip is produced or not.

9.3.6 Fault Report with Primary Values

The ***Fault Report Primary / Secondary Values*** setting allows to display the Fault Report in secondary or primary values (affected by the transformation ratios).

9.3.7 Fault Reports on HMI

The IEDs include the possibility to display fault reports on the HMI. To gain access to these records, enter the field **3- Information → 5 - Events → 1- Fault Reports**. Once the above field has been accessed, a list with the date and time of the last fault records will be displayed that will include the following information:

- Pick up and trip signals activated during the duration time of the fault: the short name of the signal will be used (refer to tables of digital outputs corresponding to each protection element). E.g. trip and pick up of the ground instantaneous overcurrent element 1 will be displayed as: **PU_IOC_N1** and **TRIP_IOC_N1**.
- Type of fault, type of trip, zone tripped, distance to fault, duration time of fault, active group, frequency, thermal state and reclose counter.
- Fault voltages and currents.

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9.3.8 Setting Ranges

Records / Fault Report					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Pickup Reports	Pick Up Report	SCBR1.StrInf	NO / YES		NO
Fault Report Primary / Secondary Values	Fault Report Units	SCBR1.MagVisMod	Primary Secondary		Second.
Fault Register Time		PTRC1.CycFltInf	1 - 4 cycles	0.01 s	1.5

9.3.9 COMFEDE Fault Report

This COMFEDE fault report is generated when the based IEC 61850 fault report is not available or when the parameter **Fault reports file format** takes the COMFEDE value in the ***ZIV e-NET tool***®. This parameter can be found in **Protocols/IEC 61850/Events (SoE) and Fault reports/General**.

Events (SoE) and Fault reports - General				
Parameter	**Type**	**Range**	**Default**	**Description**
Fault Report file format	Selectable	XML COMFEDE	XML	Select the output file format of fault report.

The fault report is stored in non-volatile memory (Flash) following the COMFEDE format according to IEEE C37.239 standard. The last 25 fault records will be stored in 25 files that will be managed in circular memory, so that, once completed, the last record generated will be stored, with the oldest record disappearing from memory. The files remain in memory after a configuration change in the equipment (Logic, Settings or CID).

Each COMFEDE fault report is displayed to the user according to the following nomenclature:

fr_newEntrTm_newEntr.CED

Where **fr** is fault report, **newEntrTm** is the date on which the file is generated (equipment trip), **newEntr** is the numerical identifier (sequential counter) of the file and **CED** is the extension of the COMFEDE file.

COMFEDE fault reports are available in the /COMFEDE folder (at the same level as the COMTRADE files and the SCL folder containing the equipment's CID). Access to the COMFEDE fault reports requires the same permissions as access to the COMTRADE folder. The files are downloaded using an FTP/SFTP client.

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In general, the structure of a COMFEDE fault report is as follows:

LOG (header):

- Entry (Event) => FAULT REPORT ACTIVATION
  - Entry\EntryData\agTimeStamp (fault start time tag).
  - Entry\TimeEntry (trip command time tag).
  - FltRpt\FaultClearingTime (end of fault time tag)
  - BreakerRpt, RecloserRpt, FaultType,… (information about the breaker, reclosures, type of fault,...).
  - agTgtData (indication of picked up units).
  - agTgtData (indication of tripped units).
  - ElectMeas (pre-fault magnitudes).
  - ElectMeas (fault magnitudes).

All elements of the COMFEDE file are displayed in English.

The common information of the COMFEDE fault report is shown below and then, in separate sections, the detailed structure of the COMFEDE fault report for each of the models (IRF, IDF, DLF and ZLF) is shown in detail.

COMFEDE Reference	Description	Type
logName	Log Name.	xs:normalizedString
oldEntrTm (*)	Indicates the timeOfEntry of the time at which the oldest log is stored. It is displayed in UTC format in ns.	xs:dateTime
newEntrTm (*)	Indicates the timeOfEntry of the time at which the last log is stored. It is displayed in UTC format in ns.	xs:dateTime
oldEntr (*)	Indicates the entryID of the oldest entry available in the log.	xs:unsignedLong
newEntr (*)	Indicates the entryID of the last entry available in the log.	xs:unsignedLong
companyName	Displays the setting value: Settings\General\Description 1 Default value=”Description 1”	xs:normalizedString minLength value="1”
stationName	Displays the setting value: Settings\General\Description 2 Default value=”Description 2”	xs:normalizedString minLength value="1”
bayName	Displays the setting value: Settings\General\Name Default value =”Name”	xs:normalizedString minLength value="1”
tmOfsTmm	Offset of local time from UTC in minutes.	xs:integer
sch:IEDNameplate\name	Feeder Protection Transformer Differential Protection Distance Protection Line Differential Protection Bus Bar Differential Protection ….	
sch:IEDNameplate \model	Complete software model.	xs:normalizedString minLength value="1”

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COMFEDE Reference	Description	Type
entryId	Unique reference to all entries that have the same TimeOfEntry value. Circular counter from 1 to 4294967295	xs:unsignedLong
timeOfEntry	Date of the moment when the report is stored in the LOG (date of the trip command). If no trip: timeOfEntry= EntryData\t	xs:dateTime
EntryData\t	Date of the moment when the fault report is generated (fault start due to unit pick-up).	xs:dateTime
faultTrigger	true if Settings\Records\Fault Report\Pickup Report = 0. false if Settings\Records\Fault Report\Pickup Report = 1	xs:boolean
sGroup	Active Settings Group	xs:unsignedInt
faultType	= Type of fault AG, BG, CG, AB, BC, CA, ABG, BCG, CAG, ABC, unknow	Enum
trip	true if Settings\Records\Fault Report\Pickup Report = 0. false if Settings\Records\Fault Report\Pickup Report = 1	xs:boolean
sch:ThreePhsCurr\desc	Name of the current transformer group (CT, CT1, CT2, CT3, CT4,…., CT60)	xs:normalizedString
fltCorrel	= Prefault for prefault magnitudes. = Fault for fault magnitudes Default value=none Postfault is not used in ZIV equipments.	Enum: Prefault, Fault, postfault, none.
preTmms	40 ms if Nominal Frequency = 50 Hz 33 ms if Nominal Frequency = 60 Hz	xs:integer
pstTmms	Settings\Records\Fault Report\Fault Report Time setting value (in ms).	xs:integer
xfmrRatPrimFact	Settings\General\Phase CTx Ratio setting value. X:1,…60 Settings\General\Phase VT Ratio setting value.	xs:float
xfmrRatSecFact	1	xs:float
ActTgtData	List of all units that have picked up.	
name	Name.	xs:normalizedString
desc	Description.	xs:normalizedString
FltClrTm	Duration of fault (end date of fault - start date of fault)	ms

(*) As there is only one (1) Entry in each file => newEntr = oldEntr and newEntrTm = oldEntrTm.

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9.3.9.a COMFEDE Fault Report for DLF

- **File nomenclature information**

COMFEDE Reference	Description	Type
sch:ThreePhsCurr differentialInputId="Differential"\PhsA	IDIFA Phase A Differential Current)	
sch:ThreePhsCurr differentialInputId="Differential"\PhsB	IDIFB (Phase B Differential Current)	
sch:ThreePhsCurr differentialInputId="Differential"\PhsC	IDIFC (Phase A Differential Current)	
sch:ThreePhsCurr differentialInputId="Differential"\Res	IDIFN (Neutral Differential Current)	
sch:ThreePhsCurr differentialInputId="Differential"\Sec\I1	IDIFP (Positive Sequence Differential Current)	
sch:ThreePhsCurr differentialInputId="Differential"\Sec\I2	IDIFQ (Negative Sequence Differential Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\PhsA	IRESTA (Phase A Restraint Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\PhsB	IRESTB (Phase B Restraint Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\PhsC	IRESTC (Phase C Restraint Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\Res	IRESTN (Neutral Restraint Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\Sec\I1	IRESTP (Positive Sequence Restraint Current)	
sch:ThreePhsCurr differentialInputId="Restraint"\Sec\I2	IRESTQ (Negative Sequence Restraint Current)	
sch:ThreePhsVolt desc="87L1"\PhsA	VA1_87L (End 1 Phase A Voltage)	
sch:ThreePhsVolt desc="87L1"\PhsB	VB1_87L (End 1 Phase B Voltage)	
sch:ThreePhsVolt desc="87L1"\PhsC	VC1_87L (End 1 Phase C Voltage)	
sch:ThreePhsVolt desc="87L1"\Sec\I1	PSV1_87L (End 1 Positive Sequence Voltage)	
sch:ThreePhsVolt desc="87L2"\PhsA	VA2_87L (End 2 Phase A Voltage)	
sch:ThreePhsVolt desc="87L2"\PhsB	VB2_87L (End 2 Phase B Voltage)	
sch:ThreePhsVolt desc="87L2"\PhsC	VC2_87L (End 2 Phase C Voltage)	
sch:ThreePhsVolt desc="87L2"\Sec\I1	PSV2_87L (End 2 Positive Sequence Voltage)	
sch:ThreePhsCurr desc="87L1"\PhsA	IA1_87L (End 1 Phase A Current)	
sch:ThreePhsCurr desc="87L1"\PhsB	IB1_87L (End 1 Phase B Current)	
sch:ThreePhsCurr desc="87L1"\PhsC	IC1_87L (End 1 Phase C Current)	
sch:ThreePhsCurr desc="87L1"\Sec\I1	PSC1_87L (End 1 Positive Sequence Current)	
sch:ThreePhsCurr desc="87L1"\Sec\I2	NSC1_87L (End 1 Negative Sequence Current)	
sch:ThreePhsCurr\PhsA\Mag	IA (magnitude in primary value of the phase A current). Setting "Settings\Records\Fault Report\Fault Report Primary/Secondary Values" is not taken int account	A xs:decimal
sch:ThreePhsCurr\PhsA\Ang	ANG IA (IA angle)	deg
sch:ThreePhsVolt\PhsA\Mag	VA (magnitude in primary value of the phase A voltage).	V xs:decimal

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COMFEDE Reference	Description	Type
Mult	Multiplier (optional).	Enum: m (0.001), h (100), k (1000), M (1000000)
eziv:Curr	IG (Ground Current)	A xs:decimal
eziv:CurrP	IPAR (Parallel Line Ground Current)	A xs:decimal
sch:ThreePhsCurr\Res	IN (Neutral Current)	A xs:decimal
I1, I2, I0	PSC, NSC, ZSC (Positive Sequence, Nehative Sequence and Zero Sequence currents)	A xs:decimal
eziv:CurrGN	IGN (Neutral Differential Current for Restricted Earth Faults Unit)	A xs:decimal
eziv:VoltS	VSYNC (Synchronism Voltage)	V xs:decimal
eziv:VoltG	VG (Ground Voltage)	V xs:decimal
sch:ThreePhsVolt\Res	VN (Neutral Voltage)	V xs:decimal
V1, V2, V0	PSV, NSV, ZSV (Positive Sequence, Nehative Sequence and Zero Sequence voltages)	V xs:decimal
PhsAB, PhsBC, PhsCA	VAB, VBC, VCA (Phase to Phase voltages)	V xs:decimal
Fq	FREQ (Frequency)	Hz xs:decimal
dFq	ROC FREQ (Frequency Rate of Change)	Hz/s xs:decimal
Thm	THERMALI (Thermal Image Magnitude)	% xs:decimal
Hspt	T HOT SPOT (winding hot spot temperature)	ºC xs:decimal
DistToFlt	DIST (Distance to the fault)	km
eziv:DistToFltM	DIST MEXT (Distance to the Fault Multi-End Locator)	
sch:FltCirc	FAULT SECC (Section on Fault)	xs:normalizedString
eziv:TrpZn	TRIP ZON (Trip Zone)	xs:normalizedString
shotCnt	C REENG (Reclosure Counter)	xs:nonNegativeInteger
OpTmmsOpnM	Mechanical opening time of the breaker contacts in ms.	xs:integer
OpTmmsOpnMP1	Mechanical opening time of the breaker pole A contacts in ms.	xs:integer
eziv:OpTmmsOpnE	Electrical opening time of the breaker contacts in ms.	xs:integer
eziv:OpTmmsClsM	Mechanical closing time of breaker contacts in ms	xs:integer
AOpenIA	OPENI_A in Amps (A). Open current by pole A.	xs:decimal
CumpuOpenIA	CUMIOPEN_A. KA accumulated pole A in "per unit" value, not in %.	xs:decimal

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- **File Structure**

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xmlns:eziv="http://www.ziv.es/COMFEDEExtension">
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<sch:Tgt name="PCOF1.Op" desc="Close onto Fault Trip"/>
<sch:Tgt name="PPDS1.Op" desc="Pole Discrepancy Trip"/>
<sch:Tgt name="LREFPDIF1.Str" desc="Restricted Ground Fault Unit Pickup"/>
<sch:Tgt name="LREFPDIF1.Op" desc="Restricted Ground Fault Unit Trip"/>
<sch:Tgt name="PTRC1.TrProg1" desc="Three Phase Programable Trip"/>
<sch:Tgt name="PTRC1.TrProg2" desc="Three Phase Programable Trip with fault detector supervision"/>
<sch:Tgt name="PTRC1.Tr13Prog1" desc="Mono/Three Phase Programable Trip"/>
<sch:Tgt name=" PTRC1.Tr13Prog2" desc="Mono/Three Phase Programable Trip with fault detector supervision"/>
<sch:Tgt name="DISPSCH1.WeiOp.General" desc="Distance scheme weak infeed Trip"/>
<sch:Tgt name="DISPSCH1.WeiOp.PhsA" desc="Distance scheme Phase A weak infeed Trip"/>
<sch:Tgt name="DISPSCH1.WeiOp.PhsB" desc="Distance scheme Phase B weak infeed Trip"/>
<sch:Tgt name="DISPSCH1.WeiOp.PhsC" desc="Distance scheme Phase C weak infeed Trip"/>
<sch:Tgt name="OCPSCH1.WeiOp.General" desc="Over current scheme weak infeed Trip"/>
<sch:Tgt name="OCPSCH1.WeiOp.PhsA" desc="Over current scheme Phase A weak infeed Trip"/>
<sch:Tgt name="OCPSCH1.WeiOp.PhsB" desc="Over current scheme Phase B weak infeed Trip"/>
<sch:Tgt name="OCPSCH1.WeiOp.PhsC" desc="Over current scheme Phase C weak infeed Trip"/>

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```
        <sch:Tgt name="Capacitive current compensation of Differential channel I1" desc="Capacitive current compensation of Differential channel I1"/>
        <sch:Tgt name="Capacitive current compensation of Differential channel I2" desc="Capacitive current compensation of Differential channel I2"/>
        <sch:Tgt name="Capacitive current compensation of Differential channel I3" desc="Capacitive current compensation of Differential channel I3"/>
      </ActTgtData>
      <eziv:BrkrRpt eziv:OpTmmsOpnM="40" eziv:OpTmmsOpnE="40" eziv:OpTmmsClsM="40" eziv:OpTmmsClsE="40" eziv:AOpenIA="950" eziv:AOpenIB="1100" eziv:AOpenIC="250" eziv:CumpuOpenIA="10" eziv:CumpuOpenIB="10" eziv:CumpuOpenIC="10"/>
    </PayloadData>
   </EntryData>
  </Entry>
 </Log>
</COMFEDE>
```

9.3.10 Based IEC 61850 Fault Report

This file will be generated when the parameter **Fault reports file format** takes the **XML** value in the ***ZIV e-NET tool***®. This parameter can be found in **Protocols/IEC 61850/Events (SoE) and Fault reports/General**.

Events (SoE) and Fault reports - General				
Parameter	**Type**	**Range**	**Default**	**Description**
Fault Report file format	Selectable	XML COMFEDE	XML	Select the output file format of fault report.

Each fault report is displayed to the user according to the following nomenclature:

fr_newEntrTm_newEntr.xml

Where **fr** is fault report, **newEntrTm** is the date on which the file is generated (equipment trip), **newEntr** is the numerical identifier (sequential counter) of the file and **XML** is the extension of the fault report file.

The fault reports are available in the /faults folder (at the same level as the COMTRADE files and the SCL folder containing the equipment's CID). Access to the fault reports requires the same permissions as access to the COMTRADE folder. The files are downloaded using an FTP/SFTP client.

The fault report is stored in non-volatile memory (Flash) following a proprietary format. Every fault will create a fault report file. The last 25 fault records will be stored in 25 files that will be managed in circular memory, so that, once completed, the last record generated will be stored, with the oldest record disappearing from memory. The files remain in memory after a configuration change in the equipment (Logic, Settings or CID).

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Each XML fault report is displayed to the user according to the following structure:

Node	Description	Children	Attributes
resource	Root node	source	**idRes**: It indicates that it is a fault report. It always takes the value **faults**.
source	Unique section which indicates the IED which generates the fault report.	fault	**ip**: IP of the IED fault report producer. **iedName**: Name of the IED (IEC 61850) which generates the fault report. E.g.: L45GISDB. **man**: Name of the manufacturer. It takes the fixed value **ZIV**. **sn**: Serial number of the IED which generates the fault report. E.g.: 154988. **mod**: IED full model name which generates the fault report. E.g.: IRFA-1A24322A000000XXXX-3332873.
fault	Section to indicate the data of the fault report.	starttime, endtime, type, units, fltMeas	**sqNum**: Sequence number of the fault report. E.g.: *123*. **date**: Timestamp of the fault trip. E.g.: *2022-05-04T12:24:15.480Z*. **q**: Quality of the timestamp. It is an OR of the *ClockFailure* and *ClockNotSynchronized* bits of IEC 61850, this is, a 1 indicates synchronization failure. E.g.: *0*.
starttime	Start time of the fault report.	-	**date**: Timestamp of the start time of the fault. E.g.: *2022-05-04T12:24:15.478Z*. **q**: Quality of the timestamp. It is an OR of the *ClockFailure* and *ClockNotSynchronized* bits of IEC 61850, this is, a 1 indicates synchronization failure. E.g.: *0*.
endtime	Final time of fault report.	-	**date**: Timestamp of the end time of the fault. E.g.: *2022-05-04T12:24:18.520Z*. **q**: Quality of the timestamp. It is an OR of the *ClockFailure* and *ClockNotSynchronized* bits of IEC 61850, this is, a 1 indicates synchronization failure. E.g.: *0*.
type	Fault data.	-	**fault**: Fault type. It can take the following values: **AG**, **BG**, **CG**, **AB**, **BC**, **CA**, **ABG**, **BCG**, **CAG**, **ABC**, **unknown**. E.g.: *CG*. **distance**: Fault distance in kilometres. **duration**: Time to clear the fault in ms. E.g.: *3042*.

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Node	Description	Children	Attributes
units	Protection units started or activated.	-	**fstdrId**: See (1) under this table. E.g.: *FPR349*. **desc**: See (1) under this table. E.g.: *Instantaneous overcurrent unit 1 Phase A*.
fltMeas	Section of measurements in two separated subsections: one for prefault measurements and the other one for fault measurements.	m	**origin**: It indicates if the measurement values are taken in **primary** or **secondary** winding of the CT. It only can take the fixed value of **primary**. E.g.: *primary*. **type**: It indicates if the measurements values are the **prefault**, **fault** or **other** ones. E.g.: *prefault*.
m	Measurements within the fault report (2).	-	**propId**: It can take the following values: **voltage**, **voltArg**, **current**, **curArg**, **timex**, **difCurrent**, **biasCurrent**, **brkCurrent**, **frequency**, **difCheckCurrent** and **biasCheckZoneCurrent**. **stdrId**: Same value as **propId**. **unit**: Unit of the measurement. It can take the values: **A**, **V**, **kV**, **s**, **deg** and **Hz**. **I1**: Phase A current measurement (mag. and angle). **I2**: Phase B current measurement (mag. and angle). **I3**: Phase C current measurement (mag. and angle). **I4**: It is the 4th current channel which could be the sensitive neutral current measurement (mag. and angle). **IN**: Neutral current measurement (mag. and angle). **V1**: Phase A voltage measurement (mag. and angle). **V2**: Phase B voltage measurement (mag. and angle). **V3**: Phase C voltage measurement (mag. and angle). **V4**: VSYN voltage measurement (mag. and angle). **VN**: Neutral voltage measurement (mag. and angle). **F**: Frequency measurement (mag. and angle).

(1) If the signal does appear in the Events (SoE) and Fault reports – Signals section of *ZIV e-NET tool*® – then the field stdrId will show the clientCode field and the field desc will show the desc field itself. Otherwise, the field stdrId will be empty and the field desc will show the internal description of the signal in the IED.
(2) Available measurements within the fault report depends on the relay type. For relays with several windings, I1, I2, I3 and IN will correspond to the ones designed as reference winding. For busbar differential relays, I1, I2 and I3 will correspond to the ones designed as angle reference and the difCurrent and the biasCurrent will correspond to the busbar which has tripped. If several busbars have tripped, then they will correspond to the busbar with lowest index of them.

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An example of an XML fault report is given below:


```
<?xml version="1.0" encoding="UTF-8"?>
 <resource idRes="faults">
   <source ip="192.168.1.1" iedName="L45GISDB" man="ZIV" sn="154988" mod="IRFA-
1A24322A000000XXXX-3332873">
    <fault sqNum="7" date="2022-05-04T12:24:15.480Z " q="0">
     <starttime date="2022-05-04T12:24:15.478Z " q="0"/>
     <endtime date="2022-05-04T12:24:18.520Z " q="0"/>
     <type fault="ABC" distance="7.39" duration="49926"/>
     <units>
      <u propId="FPR352" desc="PICKUP UNIT 1 51 TEMP. PHASE A"/>
      <u propId="FPR320" desc="PROT TRIP UNIT 1 51 TEMP. PHASE A"/>
      <u propId="FPR353" desc="PICKUP UNIT 1 51 TEMP. PHASE B"/>
      <u propId="FPR321" desc="PROT TRIP UNIT 1 51 TEMP. PHASE B"/>
      <u propId="FPR354" desc="PICKUP UNIT 1 51 TEMP. PHASE C"/>
      <u propId="FPR322" desc="PROT TRIP UNIT 1 51 TEMP. PHASE C"/>
      <u propId="FPR360" desc="PICKUP UNIT 2 51 TEMP. PHASE A"/>
      <u propId="FPR328" desc="PROT TRIP UNIT 2 51 TEMP. PHASE A"/>
      <u propId="FPR361" desc="PICKUP UNIT 2 51 TEMP. PHASE B"/>
      <u propId="FPR329" desc="PROT TRIP UNIT 2 51 TEMP. PHASE B"/>
      <u propId="FPR362" desc="PICKUP UNIT 2 51 TEMP. PHASE C"/>
      <u propId="FPR330" desc="PROT TRIP UNIT 2 51 TEMP. PHASE C"/>
     </units>
     <fltMeas origin="primary" type="prefault">
      <m propId="current" stdrId="current" unit="A" I1="120.38" I2="120.49" I3="120.48" I4="0.00" IN="0.24"/>
      <m propId="curArg" stdrId="curArg" unit="deg" I1="0.0" I2="240.2" I3="120.0" I4="163.8" IN="321.1"/>
      <m propId="voltage" stdrId="voltage" unit="kV" V1="25.41" V2="25.42" V3="25.41" V4="1.28"
VN="0.13"/>
      <m propId="voltArg" stdrId="voltArg" unit="deg" V1="0.0" V2="239.7" V3="119.7" V4="58.3"
VN="95.7"/>
      <m propId="frequency" stdrId="frequency" unit="Hz" F="50.00"/>
     </fltMeas>
     <fltMeas origin="primary" type="fault">
      <m propId="current" stdrId="current" unit="A" I1="1200.73" I2="1200.16" I3="1200.49" I4="0.00"
IN="2.38"/>
      <m propId="curArg" stdrId="curArg" unit="deg" I1="334.4" I2="214.4" I3="94.3" I4="99.1" IN="331.1"/>
      <m propId="voltage" stdrId="voltage" unit="kV" V1="25.41" V2="25.42" V3="25.41" V4="1.04"
VN="0.12"/>
      <m propId="voltArg" stdrId="voltArg" unit="deg" V1="334.5" V2="214.2" V3="94.2" V4="93.1"
VN="70.4"/>
      <m propId="frequency" stdrId="frequency" unit="Hz" F="50.00"/>
     </fltMeas>
     <fltMeas origin="primary" type="other">
      <m propId="brkCurrent" stdrId="brkCurrent" unit="A" I1="0.00" I2="0.00" I3="0.00"/>
     </fltMeas>
    </fault>
  </source>
```


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9.4 Metering History Log

9.4.1 Operation Principles 9.4-2
9.4.2 Setting Ranges 9.4-3
9.4.3 IEC61850 Logical Node 9.4-5

9.4.1 Operation Principles

This function records the evolution of the values monitored at the point where the IED is installed. Each second, it samples each of the values programmed for this purpose and calculates their average over the interval defined as ***Sampling Interval***. This time interval is adjustable between 1 and 15 minutes.

The ***Recording Interval*** is an adjustable period of time between 1 minute and 24 hours. The maximum and minimum averages recorded in the whole interval are recorded with their final time stamp. Figure 9.4.1 shows how the Metering History Log works.

-**SI**: Sampling Interval; the figure shows an SI value of one minute.

-**RI**: Recording Interval; the figure shows a RI of 15 minutes.

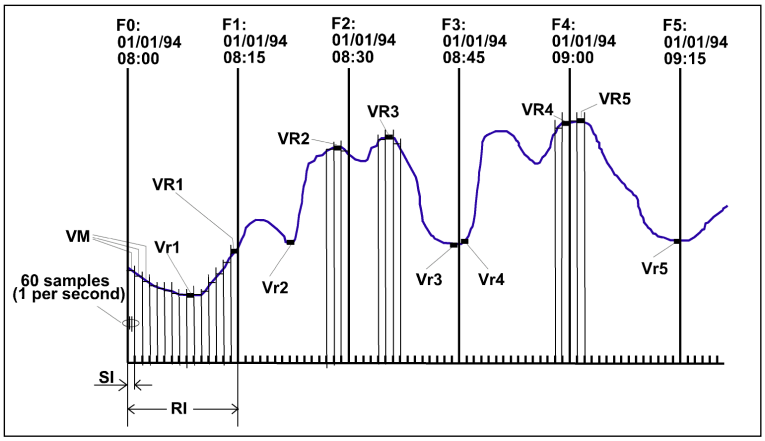


Figure 9.4.1 Explanatory Diagram of the Metering Log.

There are 12 History Log Groups. For each of those 12 values, up to **4 different metering** values can be selected.

Each **SI** window yields two **VM** values that correspond to the maximum and minimum averages of configured group magnitudes. If only one group magnitude is configured, the average value coincides with the maximum and minimum values (see Figure 9.4.1). Maximum and minimum value of all maximum and minimum group **VMs** computed are stored and shown in each **RI** interval. The profile of figure 9.4.1 yields the following values: VR1 - Vr1; VR2 - Vr2; VR3 - Vr3; VR4 - Vr4 and VR5 - Vr5.

Note: if any of the overcurrent elements pick up during the Sampling Interval, the average of the measurements made while the elements were not picked up is recorded. Otherwise, if the elements remain picked up throughout the SI, the value recorded is: 0A / 0V.

As already indicated, twelve (12) values can be configured among all the direct or calculated metering values (*User Defined* values, including VDC in models with Power Supply Voltage Monitoring) available in the IED (M_i). For each group, up to four different magnitudes can be selected, an average value being obtained for each magnitude along the **Window for Average Calculation**. See figure 9.4.2.

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Thus, for every group (up to 12 groups), maximum and minimum measurements of the different magnitudes (up to 4 magnitudes) in each average interval are calculated. Maximum and minimum values of all maximum and minimum measurements obtained along said interval for each group are recorded in each recording interval.

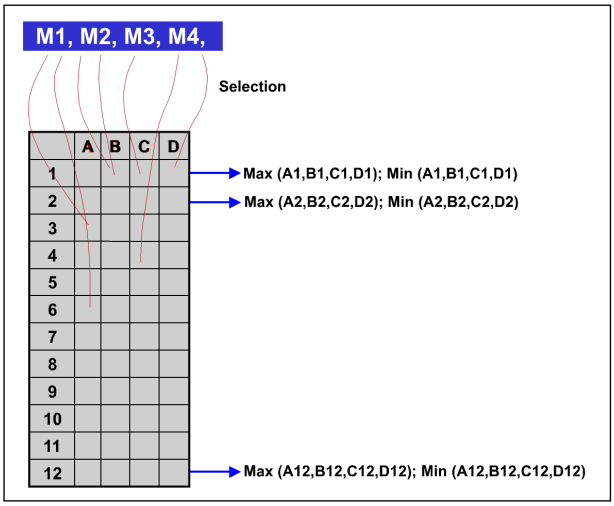


Figure 9.4.2 Metering History Log Logic.

The memory available for the Metering Log is RAM, large enough for 168. The memory can be customized by defining an hour range and ***Week Mask*** (the same hour range for all the days). No values outside the mask will be recorded.

Likewise, the phase currents and voltages as well as the powers are constantly sampled. The sampled values are compared with those already stored. This keeps a maximum/minimum demand metering of the phase currents and voltages and of the active, reactive and apparent powers up to date.

These maximum and minimum values are stored in non-volatile memory, so they are reset by the logic input signal, **Maximum Demand Element Reset**.

All this information is only available via communications through the communications and remote management program ***ZIV e-NET tool***®.

9.4.2 Setting Ranges

Records / Metering History Log					
Communications Program	**HMI**	**IEC 61850**	**Range**	**Step**	**Default**
Sampling Interval	Sample Interval	HISMSTA1.EvTmms	1 - 15 min		1 min
Recording Interval	Log Rec. Interval	HISMSTA1.RcdLenTmm	from 00:01 to 24:00 (hh:mm)		1 min
Week Mask		HISMSTA1.WeekMaskX X: 1 to 7	MONDAY to SUNDAY	YES/NO	YES
Recording Start Time	Hist. Start Time	HISMSTA1.RcdStrTmm	00:01 to 24:00 (hh:mm)		0 min
Recording End Time	Hist. End Time	HISMSTA1.RcdStopTmm	00:01 to 24:00 (hh:mm)		24 min

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Log Groups (Magnitudes)				
There are 12 Log Groups. Up to 4 different magnitudes may be defined within each group for historical record calculations. Said magnitudes are:				
ACTGRP	HARM2 IA	HARM8 IA	N.A.ENGY	VAB_ANG
ALARMS	HARM2 IB	HARM8 IB	N.R.ENGY	VB
ANG IA	HARM2 IC	HARM8 IC	N_CLOSING	VBC
ANG IB	HARM2 IG	HARM8 IG	N_OPENING_A	VBC_ANG
ANG IC	HARM2 IN	HARM8 IGS	N_OPENING_B	VC
ANG IG	HARM2 VA	HARM8 IN	N_OPENING_C	VCA
ANG IN	HARM2 VB	HARM8 VA	NSC	VCA
ANG IGPAR	HARM2 VC	HARM8 VB	NSV	VCA_ANG
ANG IPOL	HARM2 VG	HARM8 VC	NTRAPS	VG
ANG NSC	HARM3 IA	HARM8 VG	Null	VMAX
ANG PSC	HARM3 IB	HARM9 IA	OPENI_A	VMIN
ANG PSV	HARM3 IC	HARM9 IB	OPENI_B	VN
ANG VA	HARM3 IG	HARM9 IC	OPENI_C	VSYNC
ANG VB	HARM3 IN	HARM9 IG	P	WARMSTARTS
ANG VC	HARM3 VA	HARM9 IN	P.Active Energy	ZSC
ANG VG	HARM3 VB	HARM9 VA	P.React. Energy	ZSV
ANG VN	HARM3 VC	HARM9 VB	P_A	VAB C2
ANG VSYNC	HARM3 VG	HARM9 VC	P_B	VAB PR C2
ANG ZSC	HARM4 IA	HARM9 VG	P_C	VAB PI C2
ANG ZSV	HARM4 IB	IA	PF	VBC C2
C REENG	HARM4 IC	IB	PF_A	VBC PR C2
COLDSTARTS	HARM4 IG	IC	PF_B	VBC PI C2
CUMIOPEN_A	HARM4 IN	IG	PF_C	VCA C2
CUMIOPEN_B	HARM4 VA	IMCNPAR_A	PMAX	VCA PR C2
CUMIOPEN_C	HARM4 VB	IMCA	PMIN	VCA PI C2
DIST	HARM4 VC	IMCA_A	PSC	U.TFALTA
DISTk	HARM4 VG	IMCB	PSV	VMCA
DISTm	HARM5 IA	IMCB_A	Q	VMCB
FAULTT	HARM5 IB	IMCC	Q_A	VMCC
FREQ	HARM5 IC	IMCC_A	Q_B	VMCSD
FREQ PLL	HARM5 IG	IMCNPAR	Q_C	IMCSD
FREQ SYNC	HARM5 IN	IMCSI	QMAX	IMCSD_A
HARM10 IA	HARM5 VA	IMCSI_A	QMIN	IMCSH_A
HARM10 IB	HARM5 VB	IMCAB	RMSIA	VMCA_A
HARM10 IC	HARM5 VC	IMCAB_A	RMSIB	VMCB_A
HARM10 IG	HARM5 VG	IMCBC	RMSIC	VMCC_A
HARM10 IN	HARM6 IA	IMCBC_A	ROC FREQ	VMCSI
HARM10 VA	HARM6 IB	IMCCA	S	VMCSI_A
HARM10 VB	HARM6 VG	IMCCA_A	S_A	VMCSH
HARM10 VC	HARM7 IA	IGN	S_B	VMCSH_A
HARM10 VG	HARM7 IB	IGPAR	S_C	VMCAB
HARM6 IC	HARM7 IC	IMAX	SMAX	VMCAB_A
HARM6 IG	HARM7 IG	IMIN	SMIN	VMCBC
HARM6 IN	HARM7 IGN	IN	THERMAL IMG	VMCBC_A
HARM6 VA	HARM7 VA	IPOL	THREE PH RECL	VMCCA
HARM6 VB	HARM7 VB	L.FAULTT	VA	VMCCA_A
HARM6 VC	HARM7 VC	MREF A	VAB	
	HARM7 VG			

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Note: all the magnitudes shown in historical records are referred to the secondary and are not affected by Transformation Ratios. However, Energy is a special case and is always referred to the primary.

9.4.3 IEC61850 Logical Node

CLASS IRLHISMSTA		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Settings		
EvTmms	ASG	Window time to calculate samples
RcdLenTmm	ING	Time interval
WeekMask1	SPG	Weekly mask
WeekMask2	SPG	Weekly mask
WeekMask3	SPG	Weekly mask
WeekMask4	SPG	Weekly mask
WeekMask5	SPG	Weekly mask
WeekMask6	SPG	Weekly mask
WeekMask7	SPG	Weekly mask
RcdStrTmm	ING	Start time
RcdStopTmm	ING	Stop time
Gr01Mag1	ING	Magnitude 1 of group 1
Gr01Mag2	ING	Magnitude 2 of group 1
Gr01Mag3	ING	Magnitude 3 of group 1
Gr01Mag4	ING	Magnitude 4 of group 1
Gr02Mag1	ING	Magnitude 1 of group 2
Gr02Mag2	ING	Magnitude 2 of group 2
Gr02Mag3	ING	Magnitude 3 of group 2
Gr02Mag4	ING	Magnitude 4 of group 2
Gr03Mag1	ING	Magnitude 1 of group 3
Gr03Mag2	ING	Magnitude 2 of group 3
Gr03Mag3	ING	Magnitude 3 of group 3
Gr03Mag4	ING	Magnitude 4 of group 3
Gr04Mag1	ING	Magnitude 1 of group 4
Gr04Mag2	ING	Magnitude 2 of group 4
Gr04Mag3	ING	Magnitude 3 of group 4
Gr04Mag4	ING	Magnitude 4 of group 4
Gr05Mag1	ING	Magnitude 1 of group 5
Gr05Mag2	ING	Magnitude 2 of group 5
Gr05Mag3	ING	Magnitude 3 of group 5
Gr05Mag4	ING	Magnitude 4 of group 5
Gr06Mag1	ING	Magnitude 1 of group 6
Gr06Mag2	ING	Magnitude 2 of group 6
Gr06Mag3	ING	Magnitude 3 of group 6
Gr06Mag4	ING	Magnitude 4 of group 6

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Settings (Cont.)		
Gr07Mag1	ING	Magnitude 1 of group 7
Gr07Mag2	ING	Magnitude 2 of group 7
Gr07Mag3	ING	Magnitude 3 of group 7
Gr07Mag4	ING	Magnitude 4 of group 7
Gr08Mag1	ING	Magnitude 1 of group 8
Gr08Mag2	ING	Magnitude 2 of group 8
Gr08Mag3	ING	Magnitude 3 of group 8
Gr08Mag4	ING	Magnitude 4 of group 8
Gr09Mag1	ING	Magnitude 1 of group 9
Gr09Mag2	ING	Magnitude 2 of group 9
Gr09Mag3	ING	Magnitude 3 of group 9
Gr09Mag4	ING	Magnitude 4 of group 9
Gr10Mag1	ING	Magnitude 1 of group 10
Gr10Mag2	ING	Magnitude 2 of group 10
Gr10Mag3	ING	Magnitude 3 of group 10
Gr10Mag4	ING	Magnitude 4 of group 10
Gr11Mag1	ING	Magnitude 1 of group 11
Gr11Mag2	ING	Magnitude 2 of group 11
Gr11Mag3	ING	Magnitude 3 of group 11
Gr11Mag4	ING	Magnitude 4 of group 11
Gr12Mag1	ING	Magnitude 1 of group 12
Gr12Mag2	ING	Magnitude 2 of group 12
Gr12Mag3	ING	Magnitude 3 of group 12
Gr12Mag4	ING	Magnitude 4 of group 12

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A. PROCOME 3.0 Communications Protocol

A.1 Control Application Layer A-2
A.2 Control Data A-3

A.1 Control Application Layer

- **Application Functions**

☑ **Initialization of the secondary station**
☑ **Clock synchronization**
☑ **Control functions**
  ☑ Control interrogation
  ☑ Refreshing of digital control signals
  ☑ Write outputs
  ☑ Enabling and disabling of inputs
  ☑ *Overflow*
  ☑ Force Single Coil

- **Compatible ASDUs in Secondary-to-Primary Direction**

☑ **<5> Identification**
☑ **<6> Clock synchronization**
☑ **<100> Transmission of metering values and digital control signal changes**
☑ **<101> Transmission of counters**
☑ **<103> Transmission of digital control states**
☑ **<110> Write binary outputs**
☑ **<121> Force Single Coil**

- **Compatible ASDUs in Primary to Secondary Direction**

☑ **<6> Clock synchronization**
☑ **<100> Control data request (Metering values and control changes INF=200)**
☑ **<100> Control data request (Capture of counters INF=202)**
☑ **<100> Control data request (Request for counters INF=201)**
☑ **<103> Request for digital control states**
☑ **<110> Write binary outputs**
☑ **<112> Enable/disable binary inputs**
☑ **<121> Force single coil**

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A.2 Control Data

- **Control Metering (MEA-s)**

Configurable through the ***ZIV e-NET tool***®: any value measured or calculated by the protection or generated by the programmable logic. It is possible to select between primary and secondary values, taking into account the corresponding transformation ratios.

All the full scale values of the magnitudes are definable, and these magnitudes can be used to create *User Defined Values*. Some typical values are:

- Phase and sequence currents and harmonics: **Rated value I_{PHASE} + 20**% sends 4095 counts.
- Ground and synchronization currents: **Rated value I_{GROUND} + 20%** sends 4095 counts.
- Sensitive ground and directional ungrounded currents: **1.2 A** sends 4095 counts.
- Phase voltages, sequence and harmonics voltages: **(Rated value V / √3) + 20%** sends 4095 counts.
- Line and polarization voltages: **Rated value V + 20%** sends 4095 counts.
- Powers: 3 x 1.4 x Rated value I_{PHASE} x Rated value / √3 sends 4095 counts.
- Power factor: from **–1** to **1** sends from –4095 to 4095 counts.
- Frequency: from **0 Hz** to **1.2 x Frequency$_{RATED}$** (50Hz / 60Hz) sends 4095 counts.
- Thermal value: **240%** sends 4095 counts
- Distance to the fault:
  - Percentage value: **±100%** sends ±4095 counts (range from -100% to 100%).
  - Value in kilometers: with the ***Length*** of the line, it sends ±4095 counts (range from 0 km to the length of the line set in km. It can also send negative values).
  - Value in miles: with the ***Length*** of the line, it sends ±4095 counts (range from 0 km to the length of the line set in miles. It can also send negative values).

With the ***ZIV e-NET tool***® program, it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the defined maximum of counts (4095) is sent.
- **Nominal flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

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The expression that allows defining this full-scale value is the following:

- When the Nominal flag is enabled,

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{4095}{Limit}$$

- When the Nominal flag is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{4095}{Limit}$$

- **Counters**

Configurable through the ***ZIV e-NET tool***®: Counters can be created with any signal configured in the programmable logic or from the protection modules. The default counters are those of the real energies (positive and negative) and the reactive energies (capacitive and inductive).

The metering range of energies in primary values is from 100wh/varh to 99999 MWh/Mvarh. The magnitude transmitted via communications is this same primary value; that is, one (1) count represents 100 wh/varh.

- **Force Single Coil (ISE-s)**

Configurable through the ***ZIV e-NET tool***®: A command can be made on any input from the protection modules and on any signal configured in the programmable logic.

- **Write Control Outputs (ISS-s)**

Configurable through the ***ZIV e-NET tool***®: A writing can be made on any input from the protection modules and on any signal configured in the programmable logic.

- **Digital Control Signals (ISC-s)**

Configurable through the ***ZIV e-NET tool***®: Any input or output logic signal from the protection modules or generated by the programmable logic.

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B. DNP V3.00 Device Profiles Document

Dnp3 Basic Profile

(Version 02.44.00 is the last Software Version that supports this Profile)

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DNP V3.00 Basic Profile

DEVICE PROFILE DOCUMENT

This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**

Device Name: **IRF**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292 Received 292	Transmitted 2048 (if >2048, must be configurable) Received 249 (must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at _____ ☐ Configurable, range ___ to ___	☐ None ☒ Configurable, range 0 to 3 (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
_____
☐ Configurable. If 'Configurable', how?
_____

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Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always (not recommended)
- ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 and Class 2 responses that contain Event Data. (If there is no Event Data reported into a Class 1 or 2 response, Application Layer Confirmation is not requested)
- ☐ When sending multi-fragment responses (Slave devices only)
- ☐ Sometimes. If 'Sometimes', when?
- ☐ Configurable. If 'Configurable', how?

Timeouts while waiting for:

Data Link Confirm	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Complete Appl. Fragment	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm	☐ None	☐ Fixed at ____	☐ Variable	☒ Configurable
Complete Appl. Response	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable

Others

_____

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

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Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message 1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message 0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

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<table>
<tr><td colspan="2">FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:</td></tr>
<tr><td>Reports Binary Input Change Events when no specific variation requested:

☐ Never
☒ Only time-tagged
☐ Only non-time-tagged
☐ Configurable to send both, one or the other (attach explanation)</td><td>Reports time-tagged Binary Input Change Events when no specific variation requested:

☐ Never
☒ Binary Input Change With Time
☐ Binary Input Change With Relative Time
☐ Configurable (attach explanation)</td></tr>
<tr><td>Sends Unsolicited Responses:

☐ Never
☒ Configurable (See Note D)
☒ Only certain objects (Class 1 and 2)
☐ Sometimes (attach explanation)

☒ ENABLE/DISABLE UNSOLICITED Function codes supported</td><td>Sends Static Data in Unsolicited Responses:

☒ Never
☐ When Device Restarts
☐ When Status Flags Change

No other options are permitted.</td></tr>
<tr><td>Default Counter Object/Variation:

☐ No Counters Reported
☐ Configurable (attach explanation)
☒ Default Object _20,21____
Default Variation _____1_____
☐ Point-by-point list attached</td><td>Counters Roll Over at:

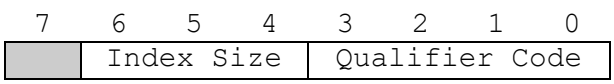
☐ No Counters Reported
☐ Configurable (attach explanation)
☐ 16 Bits
☐ 32 Bits
☒ Other Value ____31 Bits____
☐ Point-by-point list attached</td></tr>
<tr><td colspan="2">Sends Multi-Fragment Responses: ☒ Yes ☐ No</td></tr>
</table>

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QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS

Function Codes

1	Read
2	Write
3	Select
4	Operate
5	Direct Operate
6	Direct Operate-No ACK
7	Immediate Freeze
8	Immediate Freeze no ACK
13	Cold Start
14	Warm Start
20	Enable Unsol. Messages
21	Disable Unsol. Messages
23	Delay Measurement
129	Response
130	Unsolicited Message



Index Size

0- No Index, Packed
1- 1 byte Index
2- 2 byte Index
3- 4 byte Index
4- 1 byte Object Size
5- 2 byte Object Size
6- 4 byte Object Size

Qualifier Code

0- 8-Bit Start and Stop Indices
1- 16-Bit Start and Stop Indices
2- 32-Bit Start and Stop Indices
3- 8-Bit Absolute address Ident.
4- 16-Bit Absolute address Ident.
5- 32-Bit Absolute address Ident.
6- No Range Field (all)
7- 8-Bit Quantity
8- 16-Bit Quantity
9- 32-Bit Quantity
11-(0xB) Variable array

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IMPLEMENTATION TABLE

OBJECT			REQUEST (IRF will parse)		RESPONSE (IRF will respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
1	0	Binary Input – All variations	1	6			
1	1	Binary Input			129	1	Assigned to Class 0.
2	0	Binary Input Change – All variations	1	6,7,8			
2	1	Binary Input Change without Time	1	6,7,8	129		B
2	2	Binary Input Change with Time	1	6,7,8	129,130	28	Assigned to Class 1.
2	3	Binary Input Change with Relative Time	1	6,7,8	129		B
10	0	Binary Outputs – All variations	1	6	129		A
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	
20	0	Binary Counter – All variations	1	6	129		~~A~~
20	1	32 Bits Binary Counter			129	1	
21	0	Frozen Counter – All variations	1	6	129		~~A~~
21	1	32 Bits Frozen Counter			129	1	
22	0	Counter Change Event – All variations	1	6,7,8	129		B
30	0	Analog Input – All variations	1	6			
30	2	16-Bit Analog Input			129	1	Assigned to Class 0.
32	0	Analog Change Event – All variations	1	6,7,8			
32	4	16-Bit Analog Change Event with Time			129,130	28	Assigned to Class 2.
40	0	Analog Output Status – All variations	1	6	129		A
41	2	16-Bit Analog Output Block	3,4,5,6	17,28	129		A
50	1	Time and Date	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

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OBJECT			REQUEST (IRF will parse)		RESPONSE (IRF will respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	3	Class 2 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	4	Class 3 Data	1	6,7,8	N/A		B
			20,21	6			
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

A: Device implementation level does not support this group and variation of object or, for static objects, it has no objects with this group and variation. **OBJECT UNKNOWN** response (IIN2 bit 1 set).

B: No point range was specified, and device has no objects of this type. **NULL response** (no IIN bits set, but no objects of the specified type returned).

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1 and 2) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured "on", then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

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DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as** 50 Binary Input Changes **and** 50 Analog Input Changes**. If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- Configuration ➔ Binary Inputs/Outputs **menu: contains the default configuration (as shipped from factory or after a reset by means of F4 key), but customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus*® **software.**

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POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assigned to Class 1.		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 2048 points**	
1	***Configure by ZIVercomPlus®* 2048 points**	
2	***Configure by ZIVercomPlus®* 2048 points**	
3	***Configure by ZIVercomPlus®* 2048 points**	
4	***Configure by ZIVercomPlus®* 2048 points**	
5	***Configure by ZIVercomPlus®* 2048 points**	
6	***Configure by ZIVercomPlus®* 2048 points**	
7	***Configure by ZIVercomPlus®* 2048 points**	
8	***Configure by ZIVercomPlus®* 2048 points**	
9	***Configure by ZIVercomPlus®* 2048 points**	
10	***Configure by ZIVercomPlus®* 2048 points**	
11	***Configure by ZIVercomPlus®* 2048 points**	
12	***Configure by ZIVercomPlus®* 2048 points**	
13	***Configure by ZIVercomPlus®* 2048 points**	
14	***Configure by ZIVercomPlus®* 2048 points**	
15	***Configure by ZIVercomPlus®* 2048 points**	
16	***Configure by ZIVercomPlus®* 2048 points**	
17	***Configure by ZIVercomPlus®* 2048 points**	
...	***Configure by ZIVercomPlus®* 2048 points**	
253	***Configure by ZIVercomPlus®* 2048 points**	
254	***Configure by ZIVercomPlus®* 2048 points**	
255	***Configure by ZIVercomPlus®* 2048 points**	

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CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
0	***Configure by ZIVercomPlus*® 256 points**	
1	***Configure by ZIVercomPlus*® 256 points**	
2	***Configure by ZIVercomPlus*® 256 points**	
3	***Configure by ZIVercomPlus*® 256 points**	
4	***Configure by ZIVercomPlus*® 256 points**	
5	***Configure by ZIVercomPlus*® 256 points**	
6	***Configure by ZIVercomPlus*® 256 points**	
7	***Configure by ZIVercomPlus*® 256 points**	
8	***Configure by ZIVercomPlus*® 256 points**	
9	***Configure by ZIVercomPlus*® 256 points**	
10	***Configure by ZIVercomPlus*® 256 points**	
11	***Configure by ZIVercomPlus*® 256 points**	
12	***Configure by ZIVercomPlus*® 256 points**	
13	***Configure by ZIVercomPlus*® 256 points**	
14	***Configure by ZIVercomPlus*® 256 points**	
15	***Configure by ZIVercomPlus*® 256 points**	
16	***Configure by ZIVercomPlus*® 256 points**	
17	***Configure by ZIVercomPlus*® 256 points**	
...	***Configure by ZIVercomPlus*® 256 points**	
253	***Configure by ZIVercomPlus*® 256 points**	
254	***Configure by ZIVercomPlus*® 256 points**	
255	***Configure by ZIVercomPlus*® 256 points**	

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ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assigned to Class 2.		
Index	**Description**	**Deadband**
0	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_1.**
1	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_2.**
2	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_3.**
3	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_4.**
4	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_5.**
5	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_6.**
6	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_7.**
7	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_8.**
8	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_9.**
9	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_10.**
10	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_11.**
11	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_12.**
12	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_13.**
13	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_14.**
14	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_15.**
15	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_16.**

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Additional assign with *ZIVercomPlus*®:

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0.	
Index	**Description**
16	***Configure by ZIVercomPlus® 512 points***
17	***Configure by ZIVercomPlus® 512 points***
18	***Configure by ZIVercomPlus® 512 points***
19	***Configure by ZIVercomPlus® 512 points***
20	***Configure by ZIVercomPlus® 512 points***
21	***Configure by ZIVercomPlus® 512 points***
22	***Configure by ZIVercomPlus® 512 points***
23	***Configure by ZIVercomPlus® 512 points***
24	***Configure by ZIVercomPlus® 512 points***
25	***Configure by ZIVercomPlus® 512 points***
26	***Configure by ZIVercomPlus® 512 points***
27	***Configure by ZIVercomPlus® 512 points***
....	***Configure by ZIVercomPlus® 512 points***
254	***Configure by ZIVercomPlus® 512 points***
255	***Configure by ZIVercomPlus® 512 points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	**Full Scale Range**		
	Engineering units	**Counts**	
Currents (Phases, sequences, harmonics)	0 to 1,2 x In_{PHASE} A	0 to 32767	**Deadband**
Currents (Ground, polarizing)	0 to 1,2 x In_{GROUND} A	0 to 32767	**Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x In_{PHASE} x Vn/√3 W	-32768 to 32767	**Deadband**
Power factor	-1 to 1	-32768 to 32767	**Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**Deadband**
Thermal value	0 to 200%	0 to 32767	**Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**Deadband**

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With ***ZIVercomPlus®*** program it's possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*, which is the unit used by the protocol. There are three parameters to determine the distance range covered:

- **Offset:** minimum value of each magnitude to transmit 0 counts.
- **Limit:** it's the length of the magnitude range used to calculate the number of counts to transmit. If **offset** is 0, it's the same as the value of the magnitude for which the maximum number of counts defined by the protocol is sent (32767 counts).
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureComm = \frac{Measure - Offset}{RatedValue} \times \frac{32767}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureComm = (Measure - Offset) \times \frac{32767}{Limit}$$

Deadbands

- Deadbands are used for configuring *Analog Input Change* objects (Object 32).
- A Deadband is defined as a percentage over the **Full Scale Range (FSR)**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface), between 0.00% and 100.00%, in steps of 0.01%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Analog Input.

Energy counters

The range for the energy counters in primary values is from 100wh/varh to 99999Mwh/Mvarh, and these are the values transmitted by protocol.

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DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
DNP Port 1 Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Baud rate	**Integer**	**300**	**38400**	**38400**	**300 600 1200 2400 4800 9600 19200 38400**	**baud**
Stop Bits	**Integer**	**1**	**2**	**1**	**1**	
Parity	**Integer**	**None Odd Even**	**None Odd Even**	**None**	**None Odd Even**	
Rx Time btw. Char	**Float**	**1**	**60000**	**0.5**	**40**	**msec.**
Comms Fail Ind. Time	**Float**	**0**	**600**	**0.1**	**60**	**s**

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Advaced settings						
Flow control						
CTS Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Sensitive	Bool	No Yes	No Yes	No	No Yes	
DTR Control	Integer	Inactive Active Rec. Req.	Inactive Active Rec. Req.	Inactive	Inactive Active Rec. Req.	
RTS Control	Integer	Inactive Active Rec. Req. Sen. Req.	Inactive Active Rec. Req. Sen. Req.	Inactive	Inactive Active Rec. Req. Sen. Req.	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO DCD	NO ECHO DCD	NO	NO ECHO DCD	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.
DNP Port 2 Configuration						
Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step/ Select	Unit
Protocol Select	Uinteger	Procome Dnp3 Modbus	Procome Dnp3 Modbus	Procome	Procome Dnp3 Modbus	
Baud rate	Integer	300	38400	38400	300 600 1200 2400 4800 9600 19200 38400	baud
Stop Bits	Integer	1	2	1	1	
Parity	Integer	None Odd Even	None Odd Even	None	None Odd Even	
Rx Time btw. Char	Float	1	60000	0.5	40	msec.
Comms Fail Ind. Time	Float	0	600	0.1	60	s

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Advaced settings						
Operating Mode	**Integer**	**RS-232 RS-485**	**RS-232 RS-485**	**RS-232**	**RS-232 RS-485**	
Times						
Tx Time Factor	**Float**	**0**	**100**	**1**	**0.5**	
Tx Timeout Const	**Uinteger**	**0**	**60000**	**0**	**1**	
Wait N Bytes 485	**Integer**	**0**	**4**	**0**	**1**	
Message modification						
Number of Zeros	**Integer**	**0**	**255**	**0**	**1**	
collision						
Collision Type	**Integer**	**NO ECHO**	**NO ECHO**	**NO**	**NO ECHO**	
Max Retries	**Integer**	**0**	**3**	**0**	**1**	
Min Retry Time	**Uinteger**	**0**	**60000**	**0**	**1**	**msec.**
Max Retry Time	**Uinteger**	**0**	**60000**	**0**	**1**	**msec.**

Analog Inputs (Deadbands)

Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step	Unit
Deadband AI#0	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#1	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#2	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#3	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#4	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#5	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#6	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#7	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#8	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#9	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#10	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#11	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#12	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#13	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#14	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#15	Float	0 %	100 %	100 %	0.01 %	

✓ **All settings remain unchanged after a power loss.**

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DNP Protocol Configuration

- **Relay Number (RTU Address):**
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- **T Confirm Timeout (N7 Confirm Timeout) :**
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- **Max Retries (N7 Retries) :**
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- **Enable Unsolicited (Enable Unsolicited Reporting) :**
  Enables or disables Unsolicited reporting.
- **Enable Unsol. after Restart :**
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.

- **Unsolic. Master No. (MTU Address) :**
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- **Unsol. Grouping Time (Unsolicited Delay Reporting) :**
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- **Synchronization Interval**
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- **DNP 3.0 Rev.**
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)

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DNP Port 1 and Port 2 Configuration

- **Number of Zeros (Advice_Time) :**
  Number of zeros before the message.
- **Max Retries (N1 Retries) :**
  Number of retries of the Physical Layer after collision detection.
- **Min Retry Time (Fixed_delay) :**
  Minimum time to retry of the Physical Layer after collision detection.
- **Max Retry Time :**
  Maximum time to retry of the Physical Layer after collision detection.
- **Collision Type :**

  Port 1:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link).

  Port 2:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link.
  DCD (Data Carrier Detect) based on detecting out-of-band carrier.

  If the device prepares to transmit and finds the link busy, it waits until is no longer busy, and then waits a backoff_time as follows:
  backoff_time = Min Retry Time + random(Max Retry Time - Max Retry Time)
  and transmit. If the device has a collision in transmission the device tries again,up to a configurable number of retries (Max Retries) if has news collision.

- **Wait N Bytes 485:**

Number of wait bytes between Reception and transmission Use Port 2 Operate Mode RS-485.

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Dnp3 Basic Extended Profile

(Version 02.45.00 is the first Software Version that supports this Profile)

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DNP V3.00 Basic Extended Profile

DEVICE PROFILE DOCUMENT

This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**

Device Name: **IRF**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices
9) Supports respond to Multiple Read Request with multiple object types in the same Application Fragment .

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292 Received 292	Transmitted 2048 (if >2048, must be configurable) Received 249 (must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at _____ ☐ Configurable, range ___ to ____	☐ None ☒ Configurable, range 0 to 3 (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
_____
☐ Configurable. If 'Configurable', how?
_____

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Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always (not recommended)
- ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 and Class 2 responses that contain Event Data. (If there is no Event Data reported into a Class 1 or 2 response, Application Layer Confirmation is not requested)
- ☐ When sending multi-fragment responses (Slave devices only)
- ☐ Sometimes. If 'Sometimes', when?
- ☐ Configurable. If 'Configurable', how?

Timeouts while waiting for:

Data Link Confirm	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Complete Appl. Fragment	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm	☐ None	☐ Fixed at ____	☐ Variable	☒ Configurable
Complete Appl. Response	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable

Others

_____

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

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Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message 1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message 0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

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<table>
<tr><td colspan="2">FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:</td></tr>
<tr><td>Reports Binary Input Change Events when no specific variation requested:

☐ Never
☒ Only time-tagged
☐ Only non-time-tagged
☐ Configurable to send both, one or the other (attach explanation)</td><td>Reports time-tagged Binary Input Change Events when no specific variation requested:

☐ Never
☒ Binary Input Change With Time
☐ Binary Input Change With Relative Time
☐ Configurable (attach explanation)</td></tr>
<tr><td>Sends Unsolicited Responses:

☐ Never
☒ Configurable (See Note D)
☒ Only certain objects (Class 1 and 2)
☐ Sometimes (attach explanation)

☒ ENABLE/DISABLE UNSOLICITED Function codes supported</td><td>Sends Static Data in Unsolicited Responses:

☒ Never
☐ When Device Restarts
☐ When Status Flags Change

No other options are permitted.</td></tr>
<tr><td>Default Counter Object/Variation:

☐ No Counters Reported
☐ Configurable (attach explanation)
☒ Default Object _20,21____
Default Variation _____1_____
☐ Point-by-point list attached</td><td>Counters Roll Over at:

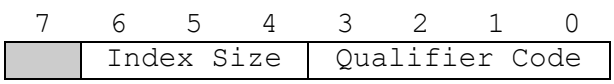
☐ No Counters Reported
☐ Configurable (attach explanation)
☐ 16 Bits
☐ 32 Bits
☒ Other Value ____31 Bits____
☐ Point-by-point list attached</td></tr>
<tr><td colspan="2">Sends Multi-Fragment Responses: ☒ Yes ☐ No</td></tr>
</table>

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QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS

Function Codes

1	Read
2	Write
3	Select
4	Operate
5	Direct Operate
9	Direct Operate-No ACK
10	Immediate Freeze
11	Immediate Freeze no ACK
13	Cold Start
14	Warm Start
20	Enable Unsol. Messages
21	Disable Unsol. Messages
23	Delay Measurement
129	Response
130	Unsolicited Message



Index Size

0- No Index, Packed
1- 1 byte Index
2- 2 byte Index
3- 4 byte Index
4- 1 byte Object Size
5- 2 byte Object Size
6- 4 byte Object Size

Qualifier Code

0- 8-Bit Start and Stop Indices
1- 16-Bit Start and Stop Indices
2- 32-Bit Start and Stop Indices
3- 8-Bit Absolute address Ident.
4- 16-Bit Absolute address Ident.
5- 32-Bit Absolute address Ident.
6- No Range Field (all)
7- 8-Bit Quantity
8- 16-Bit Quantity
9- 32-Bit Quantity
11-(0xB) Variable array

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IMPLEMENTATION TABLE

OBJECT			REQUEST (IRF will parse)		RESPONSE (IRF will respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
1	0	Binary Input – All variations	1	6			
1	1	Binary Input			129	1	Assigned to Class 0.
2	0	Binary Input Change – All variations	1	6,7,8			
2	1	Binary Input Change without Time	1	6,7,8	129		B
2	2	Binary Input Change with Time	1	6,7,8	129,130	28	Assigned to Class 1.
2	3	Binary Input Change with Relative Time	1	6,7,8	129		B
10	0	Binary Outputs – All variations	1	6	129		A
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	
20	0	Binary Counter – All variations	1	6	129		~~A~~
20	1	32 Bits Binary Counter			129	1	
21	0	Frozen Counter – All variations	1	6	129		~~A~~
21	1	32 Bits Frozen Counter			129	1	
22	0	Counter Change Event – All variations	1	6,7,8	129		B
30	0	Analog Input – All variations	1	6			
30	2	16-Bit Analog Input			129	1	Assigned to Class 0.
32	0	Analog Change Event – All variations	1	6,7,8			
32	4	16-Bit Analog Change Event with Time			129,130	28	Assigned to Class 2.
40	0	Analog Output Status – All variations	1	6	129		A
41	2	16-Bit Analog Output Block	3,4,5,6	17,28	129		A
50	1	Time and Date	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

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OBJECT			REQUEST (IRF will parse)		RESPONSE (IRF will respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	3	Class 2 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	4	Class 3 Data	1	6,7,8	N/A		B
			20,21	6			
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

A: Device implementation level does not support this group and variation of object or, for static objects, it has no objects with this group and variation. **OBJECT UNKNOWN** response (IIN2 bit 1 set).

B: No point range was specified, and device has no objects of this type. **NULL response** (no IIN bits set, but no objects of the specified type returned).

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1 and 2) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured "on", then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

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DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as** 50 Binary Input Changes **and** 50 Analog Input Changes**. If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- Configuration ➔ Binary Inputs/Outputs **menu: contains the default configuration (as shipped from factory or after a reset by means of F4 key), but customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus*® **software.**

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POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assigned to Class 1.		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 2048 points**	
1	***Configure by ZIVercomPlus®* 2048 points**	
2	***Configure by ZIVercomPlus®* 2048 points**	
3	***Configure by ZIVercomPlus®* 2048 points**	
4	***Configure by ZIVercomPlus®* 2048 points**	
5	***Configure by ZIVercomPlus®* 2048 points**	
6	***Configure by ZIVercomPlus®* 2048 points**	
7	***Configure by ZIVercomPlus®* 2048 points**	
8	***Configure by ZIVercomPlus®* 2048 points**	
9	***Configure by ZIVercomPlus®* 2048 points**	
10	***Configure by ZIVercomPlus®* 2048 points**	
11	***Configure by ZIVercomPlus®* 2048 points**	
12	***Configure by ZIVercomPlus®* 2048 points**	
13	***Configure by ZIVercomPlus®* 2048 points**	
14	***Configure by ZIVercomPlus®* 2048 points**	
15	***Configure by ZIVercomPlus®* 2048 points**	
16	***Configure by ZIVercomPlus®* 2048 points**	
17	***Configure by ZIVercomPlus®* 2048 points**	
...	***Configure by ZIVercomPlus®* 2048 points**	
253	***Configure by ZIVercomPlus®* 2048 points**	
254	***Configure by ZIVercomPlus®* 2048 points**	
255	***Configure by ZIVercomPlus®* 2048 points**	

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CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
0	***Configure by ZIVercomPlus*® 256 points**	
1	***Configure by ZIVercomPlus*® 256 points**	
2	***Configure by ZIVercomPlus*® 256 points**	
3	***Configure by ZIVercomPlus*® 256 points**	
4	***Configure by ZIVercomPlus*® 256 points**	
5	***Configure by ZIVercomPlus*® 256 points**	
6	***Configure by ZIVercomPlus*® 256 points**	
7	***Configure by ZIVercomPlus*® 256 points**	
8	***Configure by ZIVercomPlus*® 256 points**	
9	***Configure by ZIVercomPlus*® 256 points**	
10	***Configure by ZIVercomPlus*® 256 points**	
11	***Configure by ZIVercomPlus*® 256 points**	
12	***Configure by ZIVercomPlus*® 256 points**	
13	***Configure by ZIVercomPlus*® 256 points**	
14	***Configure by ZIVercomPlus*® 256 points**	
15	***Configure by ZIVercomPlus*® 256 points**	
16	***Configure by ZIVercomPlus*® 256 points**	
17	***Configure by ZIVercomPlus*® 256 points**	
...	***Configure by ZIVercomPlus*® 256 points**	
253	***Configure by ZIVercomPlus*® 256 points**	
254	***Configure by ZIVercomPlus*® 256 points**	
255	***Configure by ZIVercomPlus*® 256 points**	

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ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assigned to Class 2.		
Index	**Description**	**Deadband**
0	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_1.**
1	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_2.**
2	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_3.**
3	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_4.**
4	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_5.**
5	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_6.**
6	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_7.**
7	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_8.**
8	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_9.**
9	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_10.**
10	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_11.**
11	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_12.**
12	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_13.**
13	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_14.**
14	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_15.**
15	***Configure by ZIVercomPlus®*** **512 points**	**Deadband_16.**

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Additional assign with *ZIVercomPlus*®:

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0.	
Index	**Description**
16	***Configure by ZIVercomPlus® 512 points***
17	***Configure by ZIVercomPlus® 512 points***
18	***Configure by ZIVercomPlus® 512 points***
19	***Configure by ZIVercomPlus® 512 points***
20	***Configure by ZIVercomPlus® 512 points***
21	***Configure by ZIVercomPlus® 512 points***
22	***Configure by ZIVercomPlus® 512 points***
23	***Configure by ZIVercomPlus® 512 points***
24	***Configure by ZIVercomPlus® 512 points***
25	***Configure by ZIVercomPlus® 512 points***
26	***Configure by ZIVercomPlus® 512 points***
27	***Configure by ZIVercomPlus® 512 points***
....	***Configure by ZIVercomPlus® 512 points***
254	***Configure by ZIVercomPlus® 512 points***
255	***Configure by ZIVercomPlus® 512 points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	**Full Scale Range**		
	Engineering units	**Counts**	
Currents (Phases, sequences, harmonics)	0 to 1,2 x In_{PHASE} A	0 to 32767	**Deadband**
Currents (Ground, polarizing)	0 to 1,2 x In_{GROUND} A	0 to 32767	**Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x In_{PHASE} x Vn/√3 W	-32768 to 32767	**Deadband**
Power factor	-1 to 1	-32768 to 32767	**Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**Deadband**
Thermal value	0 to 200%	0 to 32767	**Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**Deadband**

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With ***ZIVercomPlus®*** program it's possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*, which is the unit used by the protocol. There are three parameters to determine the distance range covered:

- **Offset:** minimum value of each magnitude to transmit 0 counts.
- **Limit:** it's the length of the magnitude range used to calculate the number of counts to transmit. If **offset** is 0, it's the same as the value of the magnitude for which the maximum number of counts defined by the protocol is sent (32767 counts).
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureComm = \frac{Measure - Offset}{RatedValue} \times \frac{32767}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureComm = (Measure - Offset) \times \frac{32767}{Limit}$$

Deadbands

- Deadbands are used for configuring *Analog Input Change* objects (Object 32).
- A Deadband is defined as a percentage over the **Full Scale Range (FSR)**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface), between 0.00% and 100.00%, in steps of 0.01%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Analog Input.

Energy counters

The range for the energy counters in primary values is from 100wh/varh to 99999Mwh/Mvarh, and these are the values transmitted by protocol.

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DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
DNP Port 1 Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Baud rate	**Integer**	**300**	**38400**	**38400**	**300 600 1200 2400 4800 9600 19200 38400**	**baud**
Stop Bits	**Integer**	**1**	**2**	**1**	**1**	
Parity	**Integer**	**None Odd Even**	**None Odd Even**	**None**	**None Odd Even**	
Rx Time btw. Char	**Float**	**1**	**60000**	**0.5**	**40**	**msec.**
Comms Fail Ind. Time	**Float**	**0**	**600**	**0.1**	**60**	**s**

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Advaced settings						
Flow control						
CTS Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Sensitive	Bool	No Yes	No Yes	No	No Yes	
DTR Control	Integer	Inactive Active Rec. Req.	Inactive Active Rec. Req.	Inactive	Inactive Active Rec. Req.	
RTS Control	Integer	Inactive Active Rec. Req. Sen. Req.	Inactive Active Rec. Req. Sen. Req.	Inactive	Inactive Active Rec. Req. Sen. Req.	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO DCD	NO ECHO DCD	NO	NO ECHO DCD	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.
DNP Port 2 Configuration						
Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step/ Select	Unit
Protocol Select	Uinteger	Procome Dnp3 Modbus	Procome Dnp3 Modbus	Procome	Procome Dnp3 Modbus	
Baud rate	Integer	300	38400	38400	300 600 1200 2400 4800 9600 19200 38400	baud
Stop Bits	Integer	1	2	1	1	
Parity	Integer	None Odd Even	None Odd Even	None	None Odd Even	
Rx Time btw. Char	Float	1	60000	0.5	40	msec.
Comms Fail Ind. Time	Float	0	600	0.1	60	s

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Advaced settings						
Operating Mode	**Integer**	**RS-232 RS-485**	**RS-232 RS-485**	**RS-232**	**RS-232 RS-485**	
Times						
Tx Time Factor	**Float**	**0**	**100**	**1**	**0.5**	
Tx Timeout Const	**Uinteger**	**0**	**60000**	**0**	**1**	
Wait N Bytes 485	**Integer**	**0**	**4**	**0**	**1**	
Message modification						
Number of Zeros	**Integer**	**0**	**255**	**0**	**1**	
collision						
Collision Type	**Integer**	**NO ECHO**	**NO ECHO**	**NO**	**NO ECHO**	
Max Retries	**Integer**	**0**	**3**	**0**	**1**	
Min Retry Time	**Uinteger**	**0**	**60000**	**0**	**1**	**msec.**
Max Retry Time	**Uinteger**	**0**	**60000**	**0**	**1**	**msec.**

Analog Inputs (Deadbands)

Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step	Unit
Deadband AI#0	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#1	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#2	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#3	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#4	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#5	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#6	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#7	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#8	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#9	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#10	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#11	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#12	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#13	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#14	Float	0 %	100 %	100 %	0.01 %	
Deadband AI#15	Float	0 %	100 %	100 %	0.01 %	

✓ **All settings remain unchanged after a power loss.**

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DNP Protocol Configuration

- **Relay Number (RTU Address):**
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- **T Confirm Timeout (N7 Confirm Timeout) :**
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- **Max Retries (N7 Retries) :**
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- **Enable Unsolicited (Enable Unsolicited Reporting) :**
  Enables or disables Unsolicited reporting.
- **Enable Unsol. after Restart :**
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.

- **Unsolic. Master No. (MTU Address) :**
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- **Unsol. Grouping Time (Unsolicited Delay Reporting) :**
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- **Synchronization Interval**
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- **DNP 3.0 Rev.**
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)

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DNP Port 1 and Port 2 Configuration

- **Number of Zeros (Advice_Time) :**
  Number of zeros before the message.
- **Max Retries (N1 Retries) :**
  Number of retries of the Physical Layer after collision detection.
- **Min Retry Time (Fixed_delay) :**
  Minimum time to retry of the Physical Layer after collision detection.
- **Max Retry Time :**
  Maximum time to retry of the Physical Layer after collision detection.
- **Collision Type :**

  Port 1:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link).

  Port 2:
  NO
  ECHO based on detection of transmitted data (monitoring all data transmitted on the link.
  DCD (Data Carrier Detect) based on detecting out-of-band carrier.

  If the device prepares to transmit and finds the link busy, it waits until is no longer busy, and then waits a backoff_time as follows:
  backoff_time = Min Retry Time + random(Max Retry Time - Max Retry Time)
  and transmit. If the device has a collision in transmission the device tries again,up to a configurable number of retries (Max Retries) if has news collision.

- **Wait N Bytes 485:**
  Number of wait bytes between Reception and transmission Use Port 2 Operate Mode RS-485.

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Dnp3 Profile II

(Version 02.46.00 is the first Software Version that supports this Profile)

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DNP V3.00 Profile II

DEVICE PROFILE DOCUMENT

This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**

Device Name: **IRF**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices
9) Supports assign event Class for Binary, Analog and Counter events:
   Class 1 , Class 2, Class 3, None
10) Supports respond to Multiple Read Request with multiple object types in the same Application Fragment .

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292 Received 292	Transmitted 2048 (if >2048, must be configurable) Received 249 (must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at _____ ☐ Configurable, range ___ to ___	☐ None ☒ Configurable, range 0 to 3 (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
_____
☐ Configurable. If 'Configurable', how?
_____

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Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always (not recommended)
- ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 Class 2 and Class 3 responses that contain Event Data. (If there is no Event Data reported into a Class 1 2 or 3 response, Application Layer Confirmation is not requested)
- ☐ When sending multi-fragment responses (Slave devices only)
- ☐ Sometimes. If 'Sometimes', when?
- ☐ Configurable. If 'Configurable', how?

Timeouts while waiting for:

Data Link Confirm	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Complete Appl. Fragment	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm	☐ None	☐ Fixed at ____	☐ Variable	☒ Configurable
Complete Appl. Response	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable

Others _____

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

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Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message 1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message 0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

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<table>
<tr><td colspan="2">FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:</td></tr>
<tr><td>Reports Binary Input Change Events when no specific variation requested:

☐ Never
☒ Only time-tagged
☐ Only non-time-tagged
☐ Configurable to send both, one or the other (attach explanation)</td><td>Reports time-tagged Binary Input Change Events when no specific variation requested:

☐ Never
☒ Binary Input Change With Time
☐ Binary Input Change With Relative Time
☐ Configurable (attach explanation)</td></tr>
<tr><td>Sends Unsolicited Responses:

☐ Never
☒ Configurable (See Note D)
☒ Only certain objects (Class 1 2 and 3)
☐ Sometimes (attach explanation)

☒ ENABLE/DISABLE UNSOLICITED Function codes supported</td><td>Sends Static Data in Unsolicited Responses:

☒ Never
☐ When Device Restarts
☐ When Status Flags Change

No other options are permitted.</td></tr>
<tr><td>Default Counter Object/Variation:

☐ No Counters Reported
☐ Configurable (attach explanation)
☒ Default Object _20,21____
Default Variation _____1_____
☐ Point-by-point list attached</td><td>Counters Roll Over at:

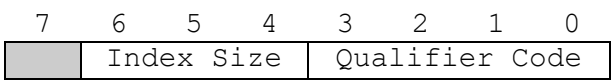
☐ No Counters Reported
☐ Configurable (attach explanation)
☐ 16 Bits
☐ 32 Bits
☒ Other Value ____31 Bits____
☐ Point-by-point list attached</td></tr>
<tr><td colspan="2">Sends Multi-Fragment Responses: ☒ Yes ☐ No</td></tr>
</table>

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QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS

Function Codes

1	Read
2	Write
3	Select
4	Operate
5	Direct Operate
6	Direct Operate-No ACK
7	Immediate Freeze
8	Immediate Freeze no ACK
13	Cold Start
14	Warm Start
20	Enable Unsol. Messages
21	Disable Unsol. Messages
23	Delay Measurement
129	Response
130	Unsolicited Message



Index Size

0- No Index, Packed
1- 1 byte Index
2- 2 byte Index
3- 4 byte Index
4- 1 byte Object Size
5- 2 byte Object Size
6- 4 byte Object Size

Qualifier Code

0- 8-Bit Start and Stop Indices
1- 16-Bit Start and Stop Indices
2- 32-Bit Start and Stop Indices
3- 8-Bit Absolute address Ident.
4- 16-Bit Absolute address Ident.
5- 32-Bit Absolute address Ident.
6- No Range Field (all)
7- 8-Bit Quantity
8- 16-Bit Quantity
9- 32-Bit Quantity
11-(0xB) Variable array

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IMPLEMENTATION TABLE

OBJECT			REQUEST (IRF parse)		RESPONSE (IRF respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
1	0	Binary Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
1	1	Binary Input	1	0,1,6,7,8	129	0,1	
2	0	Binary Input with Status	1	0,1,6,7,8	129	0,1	
2	0	Binary Input Change – All variations	1	6,7,8			
2	2	Binary Input Change with Time	1	6,7,8	129,130	17,,28	Assign to Event Class
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	Echo of request
20	0	Binary Counter – All variations	1	0,1,6,7,8			Assigned to Class 0.
20	1	32 Bits Binary Counter			129	0,1	
21	0	Frozen Counter – All variations	1	0,1,6,7,8			
21	1	32 Bits Frozen Counter			129	0,1	
22	0	Counter Change Event – All variations	1	6,7,8			
22	5	32 Bits Counter Change Event With Time			129,130	17,,28	Assign to Event Class
30	0	Analog Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
30	1	32-Bit Analog Input	1	0,1,6,7,8	129	1	
30	2	16-Bit Analog Input	1	0,1,6,7,8	129	1	
32	0	Analog Change Event – All variations	1	6,7,8			
32	3	32-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
32	4	16-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
50	1	Time and Date	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

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OBJECT			REQUEST (IRF parse)		RESPONSE (IRF respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	3	Class 2 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	4	Class 3 Data	1	6,7,8	129,130	28	D
			20,21	6			
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface ***ZIVercomPlus***). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1, 2 and 3) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured "on", then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

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DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as 128** Binary Input Changes**,** 64 Analog Input Changes and 64 Counter Input Change. **If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- **Customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus*® **software.**

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POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assign to Class.		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 2048 points**	
1	***Configure by ZIVercomPlus®* 2048 points**	
2	***Configure by ZIVercomPlus®* 2048 points**	
3	***Configure by ZIVercomPlus®* 2048 points**	
4	***Configure by ZIVercomPlus®* 2048 points**	
5	***Configure by ZIVercomPlus®* 2048 points**	
6	***Configure by ZIVercomPlus®* 2048 points**	
7	***Configure by ZIVercomPlus®* 2048 points**	
8	***Configure by ZIVercomPlus®* 2048 points**	
9	***Configure by ZIVercomPlus®* 2048 points**	
10	***Configure by ZIVercomPlus®* 2048 points**	
11	***Configure by ZIVercomPlus®* 2048 points**	
12	***Configure by ZIVercomPlus®* 2048 points**	
13	***Configure by ZIVercomPlus®* 2048 points**	
14	***Configure by ZIVercomPlus®* 2048 points**	
15	***Configure by ZIVercomPlus®* 2048 points**	
16	***Configure by ZIVercomPlus®* 2048 points**	
17	***Configure by ZIVercomPlus®* 2048 points**	
...	***Configure by ZIVercomPlus®* 2048 points**	
253	***Configure by ZIVercomPlus®* 2048 points**	
254	***Configure by ZIVercomPlus®* 2048 points**	
255	***Configure by ZIVercomPlus®* 2048 points**	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 256 points**	
1	***Configure by ZIVercomPlus®* 256 points**	
2	***Configure by ZIVercomPlus®* 256 points**	
3	***Configure by ZIVercomPlus®* 256 points**	
4	***Configure by ZIVercomPlus®* 256 points**	
5	***Configure by ZIVercomPlus®* 256 points**	
6	***Configure by ZIVercomPlus®* 256 points**	
7	***Configure by ZIVercomPlus®* 256 points**	
8	***Configure by ZIVercomPlus®* 256 points**	
9	***Configure by ZIVercomPlus®* 256 points**	
10	***Configure by ZIVercomPlus®* 256 points**	
11	***Configure by ZIVercomPlus®* 256 points**	
12	***Configure by ZIVercomPlus®* 256 points**	
13	***Configure by ZIVercomPlus®* 256 points**	

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CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
14	***Configure by ZIVercomPlus®* 256 points**	
15	***Configure by ZIVercomPlus®* 256 points**	
16	***Configure by ZIVercomPlus®* 256 points**	
17	***Configure by ZIVercomPlus®* 256 points**	
...	***Configure by ZIVercomPlus®* 256 points**	
253	***Configure by ZIVercomPlus®* 256 points**	
254	***Configure by ZIVercomPlus®* 256 points**	
255	***Configure by ZIVercomPlus®* 256 points**	

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assign to Class		
Index	**Description**	**Deadband**
0	***Configure by ZIVercomPlus®* 256 points**	**Deadband_1.**
1	***Configure by ZIVercomPlus®* 256 points**	**Deadband_2.**
2	***Configure by ZIVercomPlus®* 256 points**	**Deadband_3.**
3	***Configure by ZIVercomPlus®* 256 points**	**Deadband_4.**
4	***Configure by ZIVercomPlus®* 256 points**	**Deadband_5.**
5	***Configure by ZIVercomPlus®* 256 points**	**Deadband_6.**
6	***Configure by ZIVercomPlus®* 256 points**	**Deadband_7.**
7	***Configure by ZIVercomPlus®* 256 points**	**Deadband_8.**
8	***Configure by ZIVercomPlus®* 256 points**	**Deadband_9.**
9	***Configure by ZIVercomPlus®* 256 points**	**Deadband_10.**
10	***Configure by ZIVercomPlus®* 256 points**	**Deadband_11.**
11	***Configure by ZIVercomPlus®* 256 points**	**Deadband_12.**
12	***Configure by ZIVercomPlus®* 256 points**	**Deadband_13.**
13	***Configure by ZIVercomPlus®* 256 points**	**Deadband_14.**
14	***Configure by ZIVercomPlus®* 256 points**	**Deadband_15.**
15	***Configure by ZIVercomPlus®* 256 points**	**Deadband_16.**

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Additional assign with ***ZIVercomPlus***®:

Index	Description
16	***Configure by ZIVercomPlus® 256 points***
17	***Configure by ZIVercomPlus® 256 points***
18	***Configure by ZIVercomPlus® 256 points***
19	***Configure by ZIVercomPlus® 256 points***
20	***Configure by ZIVercomPlus® 256 points***
21	***Configure by ZIVercomPlus® 256 points***
22	***Configure by ZIVercomPlus® 256 points***
23	***Configure by ZIVercomPlus® 256 points***
24	***Configure by ZIVercomPlus® 256 points***
25	***Configure by ZIVercomPlus® 256 points***
26	***Configure by ZIVercomPlus® 256 points***
27	***Configure by ZIVercomPlus® 256 points***
....	***Configure by ZIVercomPlus® 256 points***
62	***Configure by ZIVercomPlus® 256 points***
63	***Configure by ZIVercomPlus® 256 points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	Full Scale Range		
	Engineering units	Counts	
Currents (Phases, sequences, harmonics)	0 to 1,2 x In_{PHASE} A	0 to 32767	**Deadband**
Currents (Ground, polarizing)	0 to 1,2 x In_{GROUND} A	0 to 32767	**Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x In_{PHASE} x Vn/√3 W	-32768 to 32767	**Deadband**
Power factor	-1 to 1	-32768 to 32767	**Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**Deadband**
Thermal value	0 to 200%	0 to 32767	**Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**Deadband**

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Communication Measure in Counts

With ***ZIVercomPlus*** program is possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de Magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Max Communication:** it's a constant that depend of the Number Bits of Analog Input.
  Max Communication=2(Number Bits Analog Input - 1)**
  For 16-Bit Analog Input (Obj 30 Var. 2) 2**(15) = 32.767 counts
  For 32-Bit Analog Input (Obj 30 Var. 1) 2**(31) = 2.147.483.647 counts
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** This *flag* defines if the **limit** is proportional to the **rated value** of the magnitude.
- **TR:** Secondary to Primary Transformation Ratio.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times \frac{MaxComunication}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times \frac{MaxComunication}{Limit}$$

Communication Measure in Engineering Units

With ***ZIVercomPlus*** program **also** it's possible to transmit each magnitude in Engineering Units. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the **rated value** of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.
- **TR:** Secondary to Primary Transformation Ratio.
- **Scaling Factor:** Multiply Factor of magnitude.

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Mathematical expression to obtain **Measure in Engineering Units** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times ScalingFactor$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times ScalingFactor$$

DeadBands

- Deadband is an area of a magnitude range or band where no generate magnitude change (the magnitude is dead). Meaning that no generation of Analogical Change Events if difference with value of generation of previous change is not equal or greater that DeadBand calculated. There is an independent setting for each 16 Measures with change.
- A Deadband is calculated as a percentage defined in DeadBand Setting over value of **parameter Limit**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 0.0000% and 100.00%, in steps of 0.0001%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Magnitude with change.

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BINARY COUNTER (OBJECT 20) -> Assigned to Class 0. FROZEN COUNTER (OBJECT 21) 32 BIT COUNTER CHANGE EVENT (OBJECT 22) -> Assign to Class		
Index	**Description**	**Deadband**
0	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_1.**
1	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_2.**
2	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_3.**
3	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_4.**
4	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_5.**
5	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_6**
6	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_7.**
7	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_8.**
8	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_9.**
9	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_10.**
10	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_11.**
11	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_12.**
12	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_13.**
13	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_14.**
14	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_15.**
15	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_16.**
16	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_17.**
17	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_18.**
18	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_19.**
19	***Configure by ZIVercomPlus*® 256 points**	**CounterDeadBand_20.**

CounterDeadBands

- CounterDeadband is an area of a counter magnitude range or band, where no generate counter magnitude change (the communication counter magnitude is dead).Meaning that no generation of Counter Change Events if difference with value of generation of previous change is not equal or greater that CounterDeadBand setting. There is an independent setting for each Counter.

- The CounterDeadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 1 and 32767, in steps of 1, default value is 1.

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DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
Binary Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 1	None Class 1 Class 2 Class 3	
Analog Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 2	None Class 1 Class 2 Class 3	
Counter Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 3	None Class 1 Class 2 Class 3	
Binary Status Change	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
32 Bits Analog Input	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
Analog Inputs (Deadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband AI#0	Float	0 %	100 %	100 %	0.0001 %	
Deadband AI#1	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#2	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#3	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#4	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#5	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#6	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#7	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#8	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#9	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#10	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#11	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#12	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#13	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#14	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#15	Float	0 %	100 %	100 %	0. 0001 %	

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Counter Inputs (CounterDeadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband Cont.I#0	Integer	1	32767	1	1	
Deadband Cont.I#1	Integer	1	32767	1	1	
Deadband Cont.I#2	Integer	1	32767	1	1	
Deadband Cont.I#3	Integer	1	32767	1	1	
Deadband Cont.I#4	Integer	1	32767	1	1	
Deadband Cont.I#5	Integer	1	32767	1	1	
Deadband Cont.I#6	Integer	1	32767	1	1	
Deadband Cont.I#7	Integer	1	32767	1	1	
Deadband Cont.I#8	Integer	1	32767	1	1	
Deadband Cont.I#9	Integer	1	32767	1	1	
Deadband Cont.I#10	Integer	1	32767	1	1	
Deadband Cont.I#11	Integer	1	32767	1	1	
Deadband Cont.I#12	Integer	1	32767	1	1	
Deadband Cont.I#13	Integer	1	32767	1	1	
Deadband Cont.I#14	Integer	1	32767	1	1	
Deadband Cont.I#15	Integer	1	32767	1	1	
Deadband Cont.I#16	Integer	1	32767	1	1	
Deadband Cont.I#17	Integer	1	32767	1	1	
Deadband Cont.I#18	Integer	1	32767	1	1	
Deadband Cont.I#19	Integer	1	32767	1	1	

DNP Port 1 Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Baud rate	**Integer**	**300**	**38400**	**38400**	**300 600 1200 2400 4800 9600 19200 38400**	**baud**
Stop Bits	**Integer**	**1**	**2**	**1**	**1**	
Parity	**Integer**	**None Odd Even**	**None Odd Even**	**None**	**None Odd Even**	
Rx Time btw. Char	**Float**	**1**	**60000**	**0.5**	**40**	**msec.**
Comms Fail Ind. Time	**Float**	**0**	**600**	**0.1**	**60**	**s**

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Advanced Settings						
Flow control						
CTS Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Flow	Bool	No Yes	No Yes	No	No Yes	
DSR Sensitive	Bool	No Yes	No Yes	No	No Yes	
DTR Control	Integer	Inactive Active Rec. Req.	Inactive Active Rec. Req.	Inactive	Inactive Active Rec. Req.	
RTS Control	Integer	Inactive Active Rec. Req. Sen. Req.	Inactive Active Rec. Req. Sen. Req.	Inactive	Inactive Active Rec. Req. Sen. Req.	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO DCD	NO ECHO DCD	NO	NO ECHO DCD	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.

DNP Port 2 and 3 Configuration

Setting Name	Type	Minimum Value	Maximum Value	Default Value	Step/ Select	Unit
Protocol Select	Uinteger	Procome Dnp3 Modbus	Procome Dnp3 Modbus	Procome	Procome Dnp3 Modbus	
Baud rate	Integer	300	38400	38400	300 600 1200 2400 4800 9600 19200 38400	baud
Stop Bits	Integer	1	2	1	1	
Parity	Integer	None Odd Even	None Odd Even	None	None Odd Even	
Rx Time btw. Char	Float	1	60000	0.5	40	msec.
Comms Fail Ind. Time	Float	0	600	0.1	60	s

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Advanced Settings						
Operating Mode	Integer	RS-232 RS-485	RS-232 RS-485	RS-232	RS-232 RS-485	
Times						
Tx Time Factor	Float	0	100	1	0.5	
Tx Timeout Const	Uinteger	0	60000	0	1	
Wait N Bytes 485	Integer	0	4	0	1	
Message modification						
Number of Zeros	Integer	0	255	0	1	
collision						
Collision Type	Integer	NO ECHO	NO ECHO	NO	NO ECHO	
Max Retries	Integer	0	3	0	1	
Min Retry Time	Uinteger	0	60000	0	1	msec.
Max Retry Time	Uinteger	0	60000	0	1	msec.

✓ **All settings remain unchanged after a power loss.** F4

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DNP Protocol Configuration

- **Relay Number** (**RTU Address**):
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- **T Confirm Timeout (N7 Confirm Timeout) :**
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- **Max Retries (N7 Retries) :**
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- **Enable Unsolicited (Enable Unsolicited Reporting) :**
  Enables or disables Unsolicited reporting.
- **Enable Unsol. after Restart :**
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.
- **Unsolic. Master No.** (**MTU Address**) **:**
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- **Unsol. Grouping Time (Unsolicited Delay Reporting) :**
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- **Synchronization Interval**
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- **DNP 3.0 Rev.**
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)
- **Binary Changes CLASS.**
  Selection to send Binary Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Analog Changes CLASS.**
  Selection to send Analog Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Counter Changes CLASS.**
  Selection to send Counter Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Binary Status .**
  Send Binary with status otherwise without status
- **32 Bits Analog Input .**
  Send Analog All Variations and Analog Change Event Binary Changes with 32 bits otherwise with 16 bits

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DNP Port 1 Port 2 and Port 3 Configuration

- **Number of Zeros (Advice Time) :**
  Number of zeros before the message.
- **Max Retries (N1 Retries) :**
  Number of retries of the Physical Layer after collision detection.
- **Min Retry Time (Fixed_delay) :**
  Minimum time to retry of the Physical Layer after collision detection.
- **Max Retry Time :**
  Maximum time to retry of the Physical Layer after collision detection.
- **Collision Type :**

  Port 1:

  NO

  ECHO based on detection of transmitted data (monitoring all data transmitted on the link).

  Port 2:

  NO

  ECHO based on detection of transmitted data (monitoring all data transmitted on the link.

  DCD (Data Carrier Detect) based on detecting out-of-band carrier.

  If the device prepares to transmit and finds the link busy, it waits until is no longer busy, and then waits a backoff_time as follows:

  backoff_time = Min Retry Time + random(Max Retry Time - Max Retry Time)

  and transmit. If the device has a collision in transmission the device tries again ,up to a configurable number of retries (Max Retries) if has news collision.

- **Wait N Bytes 485:**
  Number of wait bytes between Reception and transmission Use Port 2 Operate Mode RS-485 .

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Dnp3 Profile II Ethernet

(Version 02.60.00 is the first Software Version that supports this Profile)

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DNP V3.00 Dnp3 Profile II Ethernet

DEVICE PROFILE DOCUMENT
This document must be accompanied by: **Implementation Table** and **Point List**.

Vendor Name:	**ZIV Aplicaciones y Tecnología S.A.**
Device Name:	**IRF**

Highest DNP Level Supported:	Device Function:
For Requests 2 For Responses 2	☐ Master ☒ Slave

Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):

1) Supports Enable/Disable Unsolicited Responses (FC=20 and 21), for classes 1 and 2.
2) Supports Write operations (FC=2) on Time and Date objects.
3) Supports Delay measurement Fine (FC=23).
4) Supports Warm Start command (FC=14).
5) Supports **Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998)**
6) Supports selection of DNP3 Revision.
7) Supports indication of no **synchronization in time.**
8) Supports simultaneous communications with two different Master devices
9) Supports assign event Class for Binary, Analog and Counter events:
   Class 1 , Class 2, Class 3, None
10) Supports respond to Multiple Read Request with multiple object types in the same Application Fragment .

Maximum Data Link Frame Size (octets):	Maximum Application Fragment Size (octets):
Transmitted 292 Received 292	Transmitted 2048 (if >2048, must be configurable) Received 249 (must be <= 249)

Maximum Data Link Re-tries:	Maximum Application Layer Re-tries:
☒ None ☐ Fixed at _____ ☐ Configurable, range ___ to ___	☐ None ☒ Configurable, range 0 to 3 (Fixed is not permitted)

Requires Data Link Layer Confirmation:

☒ Never
☐ Always
☐ Sometimes. If 'Sometimes', when?
_____
☐ Configurable. If 'Configurable', how?

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Requires Application Layer Confirmation:

- ☐ Never
- ☐ Always (not recommended)
- ☒ When reporting Event Data (Slave devices only) For unsolicited, Class 1 Class 2 and Class 2 responses that contain Event Data. (If there is no Event Data reported into a Class 1 2 or 3 response, Application Layer Confirmation is not requested)
- ☐ When sending multi-fragment responses (Slave devices only)
- ☐ Sometimes. If 'Sometimes', when?
- ☐ Configurable. If 'Configurable', how?

Timeouts while waiting for:

Data Link Confirm	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Complete Appl. Fragment	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable
Application Confirm	☐ None	☐ Fixed at ____	☐ Variable	☒ Configurable
Complete Appl. Response	☒ None	☐ Fixed at ____	☐ Variable	☐ Configurable

Others _____

Attach explanation if 'Variable' or 'Configurable' was checked for any timeout

Application Confirm timeout setting (***MMI***): Range 50 ms. 65.535 ms.

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Sends/Executes Control Operations:

- Maximum number of CROB (obj. 12, var. 1) objects supported in a single message 1
- Maximum number of Analog Output (obj. 41, any var.) supported in a single message 0

☐ Pattern Control Block and Pattern Mask (obj. 12, var. 2 and 3 respectively) supported.

☐ CROB (obj. 12) and Analog Output (obj. 41) permitted together in a single message.

WRITE Binary Outputs	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
SELECT (3) / OPERATE (4)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE (5)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
DIRECT OPERATE - NO ACK (6)	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Count > 1	☐ Never	☐ Always	☒ Sometimes	☐ Configurable
Pulse On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Pulse Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch On	☐ Never	☒ Always	☐ Sometimes	☐ Configurable
Latch Off	☐ Never	☒ Always	☐ Sometimes	☐ Configurable

Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	☒ Never	☐ Always	☐ Sometimes	☐ Configurable

Attach explanation:

- All points support the same Function Codes: (3) Select, (4) Operate, (5) Direct Operate and (6) Direct Operate - No ACK.
- Maximum Select/Operate Delay Time: 60 seconds.
- Count can be >1 only for PULSE ON and PULSE OFF

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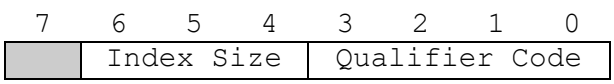
FILL OUT THE FOLLOWING ITEMS FOR SLAVE DEVICES ONLY:	
Reports Binary Input Change Events when no specific variation requested: ☐ Never ☒ Only time-tagged ☐ Only non-time-tagged ☐ Configurable to send both, one or the other (attach explanation)	Reports time-tagged Binary Input Change Events when no specific variation requested: ☐ Never ☒ Binary Input Change With Time ☐ Binary Input Change With Relative Time ☐ Configurable (attach explanation)
Sends Unsolicited Responses: ☐ Never ☒ Configurable (See Note D) ☒ Only certain objects (Class 1 2 and 3) ☐ Sometimes (attach explanation) ☒ ENABLE/DISABLE UNSOLICITED Function codes supported	Sends Static Data in Unsolicited Responses: ☒ Never ☐ When Device Restarts ☐ When Status Flags Change No other options are permitted.
Default Counter Object/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) ☒ Default Object 20,21 Default Variation 1 ☐ Point-by-point list attached	Counters Roll Over at: ☐ No Counters Reported ☐ Configurable (attach explanation) ☐ 16 Bits ☐ 32 Bits ☒ Other Value 31 Bits ☐ Point-by-point list attached
Sends Multi-Fragment Responses: ☒ Yes ☐ No	

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QUICK REFERENCE FOR DNP3.0 LEVEL 2 FUNCTION CODES & QUALIFIERS

Function Codes

1	Read
2	Write
3	Select
4	Operate
5	Direct Operate
9	Direct Operate-No ACK
10	Immediate Freeze
11	Immediate Freeze no ACK
13	Cold Start
14	Warm Start
20	Enable Unsol. Messages
21	Disable Unsol. Messages
23	Delay Measurement
24	Record Current Time
129	Response
130	Unsolicited Message



Index Size

0- No Index, Packed
1- 1 byte Index
2- 2 byte Index
3- 4 byte Index
4- 1 byte Object Size
5- 2 byte Object Size
6- 4 byte Object Size

Qualifier Code

0- 8-Bit Start and Stop Indices
1- 16-Bit Start and Stop Indices
2- 32-Bit Start and Stop Indices
3- 8-Bit Absolute address Ident.
4- 16-Bit Absolute address Ident.
5- 32-Bit Absolute address Ident.
6- No Range Field (all)
7- 8-Bit Quantity
8- 16-Bit Quantity
9- 32-Bit Quantity
11-(0xB) Variable array

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IMPLEMENTATION TABLE

OBJECT			REQUEST (IRF parse)		RESPONSE (IRF respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
1	0	Binary Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
1	1	Binary Input	1	0,1,6,7,8	129	0,1	
2	0	Binary Input with Status	1	0,1,6,7,8	129	0,1	
2	0	Binary Input Change – All variations	1	6,7,8			
2	2	Binary Input Change with Time	1	6,7,8	129,130	17,,28	Assign to Event Class
12	1	Control Relay Output Block	3,4,5,6	17,28	129	17,28	Echo of request
20	0	Binary Counter – All variations	1	0,1,6,7,8			Assigned to Class 0.
20	1	32 Bits Binary Counter			129	0,1	
21	0	Frozen Counter – All variations	1	0,1,6,7,8			
21	1	32 Bits Frozen Counter			129	0,1	
22	0	Counter Change Event – All variations	1	6,7,8			
22	5	32 Bits Counter Change Event With Time			129,130	17,,28	Assign to Event Class
30	0	Analog Input – All variations	1	0,1,6,7,8			Assigned to Class 0.
30	1	32-Bit Analog Input	1	0,1,6,7,8	129	1	
30	2	16-Bit Analog Input	1	0,1,6,7,8	129	1	
32	0	Analog Change Event – All variations	1	6,7,8			
32	3	32-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
32	4	16-Bit Analog Change Event with Time	1	6,7,8	129,130	28	Assign to Event Class
50	1	Time and Date	2	7 count=1	129		C
50	3	Time and Date at Last Recorded Time	2	7 count=1	129		C
52	2	Time Delay Fine	23		129	1	F,G

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OBJECT			REQUEST (IRF parse)		RESPONSE (IRF respond)		
Obj	Var	Description	Func Codes (dec)	Qual Codes (hex)	Func Codes (dec)	Qual Codes (hex)	Notes
60	1	Class 0 Data	1	6	129	1	
60	2	Class 1 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	3	Class 2 Data	1	6,7,8	129,130	28	D
			20,21	6			
60	4	Class 3 Data	1	6,7,8	129,130	28	D
			20,21	6			
80	1	Internal Indications	2	0 index=7			E
--	--	No Object (Cold Start)	13				F
--	--	No Object (Warm Start)	14				F
--	--	No Object (Delay Measurement)	23				G

NOTES

C: Device supports write operations on Time and Date objects. Time Synchronization-Required Internal Indication bit (IIN1-4) will be cleared on the response.

D: The device can be configured to send or not, unsolicited responses depending on a configuration option by means of ***MMI*** (Man-Machine Interface or front-panel user interface ***ZIVercomPlus***). Then, the Master can Enable or Disable Unsolicited messages (for Classes 1, 2 and 3) by means of requests (FC 20 and 21).
If the unsolicited response mode is configured "on", then upon device restart, the device will transmit an initial Null unsolicited response, requesting an application layer confirmation. While waiting for that application layer confirmation, the device will respond to all function requests, including READ requests.

E: Restart Internal Indication bit (IIN1-7) can be cleared explicitly by the master.

F: The outstation, upon receiving a ***Cold or Warm Start*** request, will respond sending a Time Delay Fine object message (which specifies a time interval until the outstation will be ready for further communications), restarting the DNP process, clearing events stored in its local buffers and setting IIN1-7 bit (Device Restart).

G: Device supports Delay Measurement requests (FC = 23). It responds with the Time Delay Fine object (52-2). This object states the number of milliseconds elapsed between Outstation receiving the first bit of the first byte of the request and the time of transmission of the first bit of the first byte of the response.

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DEVICE SPECIFIC FEATURES

- Internal Indication IIN1-6 (Device trouble): **Set to indicate a change in the current DNP configuration in the outstation. Cleared in the next response. Used to let the master station know that DNP settings have changed at the outstation. Note that some erroneous configurations could make impossible to communicate this condition to a master station.**

  This document also states the DNP3.0 settings currently available in the device. If the user changes whatever of these settings, it will set the *Device Trouble Internal Indication* bit on the next response sent.
- Event buffers**: device can hold as much as 128** Binary Input Changes**,** 64 Analog Input Changes and 64 Counter Input Change**. If these limits are reached the device will set the *Event Buffers Overflow Internal Indication* bit on the next response sent. It will be cleared when the master reads the changes, making room for new ones.**
- Configuration ➔ Operation Enable **menu: the device can enable or disable** permissions **for the operations over al Control Relay Output Block. In case permissions are configured off (disabled) the response to a command (issued as Control Relay Output Block) will have the Status code NOT_AUTHORIZED. In case the equipment is** blocked **the commands allowed are the configured when permitted. While blocked, the relay will accept commands over the configured signal. If the equipment is in** operation inhibited state**, the response to all commands over the configured signal will have the Status code NOT_AUTHORIZED.**
- **Customers can configure Inputs/Outputs to suit their needs, by means of** *ZIVercomPlus*® **software.**

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POINT LIST

BINARY INPUT (OBJECT 1) -> Assigned to Class 0. BINARY INPUT CHANGE (OBJECT 2) -> Assign to Class.		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 2048 points**	
1	***Configure by ZIVercomPlus®* 2048 points**	
2	***Configure by ZIVercomPlus®* 2048 points**	
3	***Configure by ZIVercomPlus®* 2048 points**	
4	***Configure by ZIVercomPlus®* 2048 points**	
5	***Configure by ZIVercomPlus®* 2048 points**	
6	***Configure by ZIVercomPlus®* 2048 points**	
7	***Configure by ZIVercomPlus®* 2048 points**	
8	***Configure by ZIVercomPlus®* 2048 points**	
9	***Configure by ZIVercomPlus®* 2048 points**	
10	***Configure by ZIVercomPlus®* 2048 points**	
11	***Configure by ZIVercomPlus®* 2048 points**	
12	***Configure by ZIVercomPlus®* 2048 points**	
13	***Configure by ZIVercomPlus®* 2048 points**	
14	***Configure by ZIVercomPlus®* 2048 points**	
15	***Configure by ZIVercomPlus®* 2048 points**	
16	***Configure by ZIVercomPlus®* 2048 points**	
17	***Configure by ZIVercomPlus®* 2048 points**	
...	***Configure by ZIVercomPlus®* 2048 points**	
253	***Configure by ZIVercomPlus®* 2048 points**	
254	***Configure by ZIVercomPlus®* 2048 points**	
255	***Configure by ZIVercomPlus®* 2048 points**	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
0	***Configure by ZIVercomPlus®* 256 points**	
1	***Configure by ZIVercomPlus®* 256 points**	
2	***Configure by ZIVercomPlus®* 256 points**	
3	***Configure by ZIVercomPlus®* 256 points**	
4	***Configure by ZIVercomPlus®* 256 points**	
5	***Configure by ZIVercomPlus®* 256 points**	
6	***Configure by ZIVercomPlus®* 256 points**	
7	***Configure by ZIVercomPlus®* 256 points**	
8	***Configure by ZIVercomPlus®* 256 points**	
9	***Configure by ZIVercomPlus®* 256 points**	
10	***Configure by ZIVercomPlus®* 256 points**	
11	***Configure by ZIVercomPlus®* 256 points**	
12	***Configure by ZIVercomPlus®* 256 points**	
13	***Configure by ZIVercomPlus®* 256 points**	

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CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
14	***Configure by ZIVercomPlus*® 256 points**	
15	***Configure by ZIVercomPlus*® 256 points**	
16	***Configure by ZIVercomPlus*® 256 points**	
17	***Configure by ZIVercomPlus*® 256 points**	
...	***Configure by ZIVercomPlus*® 256 points**	
253	***Configure by ZIVercomPlus*® 256 points**	
254	***Configure by ZIVercomPlus*® 256 points**	
255	***Configure by ZIVercomPlus*® 256 points**	

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assign to Class		
Index	**Description**	**Deadband**
0	***Configure by ZIVercomPlus*® 256 points**	**Deadband_1.**
1	***Configure by ZIVercomPlus*® 256 points**	**Deadband_2.**
2	***Configure by ZIVercomPlus*® 256 points**	**Deadband_3.**
3	***Configure by ZIVercomPlus*® 256 points**	**Deadband_4.**
4	***Configure by ZIVercomPlus*® 256 points**	**Deadband_5.**
5	***Configure by ZIVercomPlus*® 256 points**	**Deadband_6.**
6	***Configure by ZIVercomPlus*® 256 points**	**Deadband_7.**
7	***Configure by ZIVercomPlus*® 256 points**	**Deadband_8.**
8	***Configure by ZIVercomPlus*® 256 points**	**Deadband_9.**
9	***Configure by ZIVercomPlus*® 256 points**	**Deadband_10.**
10	***Configure by ZIVercomPlus*® 256 points**	**Deadband_11.**
11	***Configure by ZIVercomPlus*® 256 points**	**Deadband_12.**
12	***Configure by ZIVercomPlus*® 256 points**	**Deadband_13.**
13	***Configure by ZIVercomPlus*® 256 points**	**Deadband_14.**
14	***Configure by ZIVercomPlus*® 256 points**	**Deadband_15.**
15	***Configure by ZIVercomPlus*® 256 points**	**Deadband_16.**

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Additional assign with *ZIVercomPlus*®:

Index	Description
16	***Configure by ZIVercomPlus® 256 points***
17	***Configure by ZIVercomPlus® 256 points***
18	***Configure by ZIVercomPlus® 256 points***
19	***Configure by ZIVercomPlus® 256 points***
20	***Configure by ZIVercomPlus® 256 points***
21	***Configure by ZIVercomPlus® 256 points***
22	***Configure by ZIVercomPlus® 256 points***
23	***Configure by ZIVercomPlus® 256 points***
24	***Configure by ZIVercomPlus® 256 points***
25	***Configure by ZIVercomPlus® 256 points***
26	***Configure by ZIVercomPlus® 256 points***
27	***Configure by ZIVercomPlus® 256 points***
....	***Configure by ZIVercomPlus® 256 points***
62	***Configure by ZIVercomPlus® 256 points***
63	***Configure by ZIVercomPlus® 256 points***

The full scale ranges are adjustable and user's magnitudes can be created. It's possible to choose between primary and secondary values, considering CT and PT ratios. Typical ranges in secondary values are:

Description	Full Scale Range		
	Engineering units	Counts	
Currents (Phases, sequences, harmonics)	0 to 1,2 x In_{PHASE} A	0 to 32767	**Deadband**
Currents (Ground, polarizing)	0 to 1,2 x In_{GROUND} A	0 to 32767	**Deadband**
Currents (Ground sensitive, isolated neutral)	0 to 1,2 A	0 to 32767	**Deadband**
Voltages (Phase to ground, sequences, harmonics)	0 to 1,2 x Vn/√3 V	0 to 32767	**Deadband**
Voltages(Phase to phase, synchronizing)	0 to 1,2 x Vn V	0 to 32767	**Deadband**
Power (Real, reactive, apparent)	0 to 3 x 1,4 x In_{PHASE} x Vn/√3 W	-32768 to 32767	**Deadband**
Power factor	-1 to 1	-32768 to 32767	**Deadband**
Frequency	0 to 1,2 x Rated frequency (50/60 Hz)	0 to 32767	**Deadband**
Thermal value	0 to 200%	0 to 32767	**Deadband**
Distance to Fault - **Percentage of line length:** 100% sends 32767 counts (range from -100% to 100%) - **Distance in kilometers:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in km) - **Distance in miles:** with the "line length" sends 32767 counts (range from - "line length" to the "line length" set in miles)		-32768 to 32767	**Deadband**

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Communication Measure in Counts

With ***ZIVercomPlus*** program is possible to define the ***Full Scale Range*** that is desired to transmit each magnitude in *counts*. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de Magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Max Communication:** it's a constant that depend of the Number Bits of Analog Input.
  Max Communication=2(Number Bits Analog Input - 1)**
  For 16-Bit Analog Input (Obj. 30 Var. 2) 2**(15) = 32.767 counts
  For 32-Bit Analog Input (Obj. 30 Var. 1) 2**(31) = 2.147.483.647 counts
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** This *flag* defines if the **limit** is proportional to the **rated value** of the magnitude.
- **TR:** Secondary to Primary Transformation Ratio.

Mathematical expression to describe the ***Full Scale Range*** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times \frac{MaxComunication}{Limit}$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times \frac{MaxComunication}{Limit}$$

Communication Measure in Engineering Units

With ***ZIVercomPlus*** program **also** it's possible to transmit each magnitude in Engineering Units. Parameters necessary to configure the Mathematical expression are:

- **Offset:** A number indicating the compensation of de magnitude.
- **Limit:** it's the Maximum value of magnitude range.
- **Rated value:** Nominal Value of the magnitude.
- **Nominal Flag:** this *flag* defines if the **limit** is proportional to the **rated value** of the magnitude or not. The rated value of the new magnitudes defined by the user is a setting, while for the pre-defined magnitudes is a fix value.
- **TR:** Secondary to Primary Transformation Ratio.
- **Scaling Factor:** Multiply Factor of magnitude.

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Mathematical expression to obtain **Measure in Engineering Units** is:

- When **Nominal Flag** is actived,

$$MeasureCom = TR \times \frac{Measure - Offset}{RatedValue} \times ScalingFactor$$

- When **Nominal Flag** is NOT actived,

$$MeasureCom = TR \times (Measure - Offset) \times ScalingFactor$$

DeadBands

- Deadband is an area of a magnitude range or band where no generate magnitude change (the magnitude is dead). Meaning that no generation of Analogical Change Events if difference with value of generation of previous change is not equal or greater that DeadBand calculated. There is an independent setting for each 16 Measures with change.
- A Deadband is calculated as a percentage defined in DeadBand Setting over value of **parameter Limit**.
- The Deadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 0.0000% and 100.00%, in steps of 0.0001%. Default value is 100.00%, meaning that generation of Analog Change Events is **DISABLED** for that input. There is an independent setting for each Magnitude with change.

BINARY COUNTER (OBJECT 20) -> Assigned to Class 0.
FROZEN COUNTER (OBJECT 21)

32 BIT COUNTER CHANGE EVENT (OBJECT 22) -> Assign to Class

Index	Description	Deadband
0	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_1.**
1	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_2.**
2	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_3.**
3	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_4.**
4	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_5.**
5	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_6**
6	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_7.**
7	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_8.**
8	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_9.**
9	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_10.**
10	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_11.**
11	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_12.**
12	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_13.**
13	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_14.**
14	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_15.**
15	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_16.**
16	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_17.**
17	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_18.**
18	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_19.**
19	***Configure by ZIVercomPlus®*** **256 points**	**CounterDeadBand_20.**

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CounterDeadBands

- CounterDeadband is an area of a counter magnitude range or band, where no generate counter magnitude change (the communication counter magnitude is dead).Meaning that no generation of Counter Change Events if difference with value of generation of previous change is not equal or greater that CounterDeadBand setting. There is an independent setting for each Counter.

- The CounterDeadband can be adjusted to the device by means of ***MMI*** (Man-Machine Interface or front-panel user interface *ZIVercomPlus*), between 1 and 32767, in steps of 1, default value is 1.

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DNP3 PROTOCOL SETTINGS

DNP3 Protocol Settings						
DNP Protocol Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step/ Select**	**Unit**
Relay Number	Integer	0	65519	1	1	
T Confirm Timeout	Integer	1000	65535	1000	1	msec.
Max Retries	Integer	0	65535	0	1	
Enable Unsolicited.	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Enable Unsol. after Restart	Boolean	0 (No)	1 (Yes)	0 (No)	1	
Unsolic. Master No.	Integer	0	65519	1	1	
Unsol. Grouping Time	Integer	100	65535	1000	1	msec.
Synchronization Interval	Integer	0	120	0	1	min.
DNP 3.0 Rev.	Integer	2003 ST.ZIV	2003 ST.ZIV	2003	2003 ST.ZIV	
Binary Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 1	None Class 1 Class 2 Class 3	
Analog Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 2	None Class 1 Class 2 Class 3	
Counter Changes CLASS	Integer	None Class 1 Class 2 Class 3	None Class 1 Class 2 Class 3	Class 3	None Class 1 Class 2 Class 3	
Binary Status Change	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
32 Bits Analog Input	Boolean	0 (No)	1 (Yes)	1 (Yes)	1	
Analog Inputs (Deadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband AI#0	Float	0 %	100 %	100 %	0.0001 %	
Deadband AI#1	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#2	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#3	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#4	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#5	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#6	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#7	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#8	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#9	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#10	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#11	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#12	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#13	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#14	Float	0 %	100 %	100 %	0. 0001 %	
Deadband AI#15	Float	0 %	100 %	100 %	0. 0001 %	

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Counter Inputs (CounterDeadbands)						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Deadband Cont.I#0	Integer	1	32767	1	1	
Deadband Cont.I#1	Integer	1	32767	1	1	
Deadband Cont.I#2	Integer	1	32767	1	1	
Deadband Cont.I#3	Integer	1	32767	1	1	
Deadband Cont.I#4	Integer	1	32767	1	1	
Deadband Cont.I#5	Integer	1	32767	1	1	
Deadband Cont.I#6	Integer	1	32767	1	1	
Deadband Cont.I#7	Integer	1	32767	1	1	
Deadband Cont.I#8	Integer	1	32767	1	1	
Deadband Cont.I#9	Integer	1	32767	1	1	
Deadband Cont.I#10	Integer	1	32767	1	1	
Deadband Cont.I#11	Integer	1	32767	1	1	
Deadband Cont.I#12	Integer	1	32767	1	1	
Deadband Cont.I#13	Integer	1	32767	1	1	
Deadband Cont.I#14	Integer	1	32767	1	1	
Deadband Cont.I#15	Integer	1	32767	1	1	
Deadband Cont.I#16	Integer	1	32767	1	1	
Deadband Cont.I#17	Integer	1	32767	1	1	
Deadband Cont.I#18	Integer	1	32767	1	1	
Deadband Cont.I#19	Integer	1	32767	1	1	
DNP Port 1 Port 2 and 3 DNP 3 Profile II Ethernet Configuration						
Setting Name	**Type**	**Minimum Value**	**Maximum Value**	**Default Value**	**Step**	**Unit**
Protocol Select	**Uinteger**	**Procome Dnp3 Modbus**	**Procome Dnp3 Modbus**	**Procome**	**Procome Dnp3 Modbus**	
Enable Ethernet Port	**Boolean**	**0 (No)**	**1 (Yes)**	**1 (Yes)**	**1**	
IP Address Port 1	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.51**	**1**	
IP Address Port 2	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.61**	**1**	
IP Address Port 3	**Byte[4]**	**ddd.ddd.ddd.ddd**	**ddd.ddd.ddd.ddd**	**192.168.1.71**	**1**	
Subnet Mask	**Byte[4]**	**128.0.0.0**	**255.255.255.254**	**255.255.255.0**	**1**	
Port Number	**Uinteger**	**0**	**65535**	**20000**	**1**	
Keepalive Time	**Float**	**0**	**65**	**30**	**60**	**s.**
Rx Time Characters	**Float**	**1**	**60000**	**1**	**0.5**	**ms.**
Comms Fail Timer	**Float**	**0**	**600**	**60**	**0.1**	**s.**

✓ **All settings remain unchanged after a power loss.**

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DNP Protocol Configuration

- **Relay Number** (**RTU Address**):
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- **T Confirm Timeout (N7 Confirm Timeout) :**
  Timeout while waiting for Application Layer Confirmation. It applies to Unsolicited messages and Class 1 and Class 2 responses with event data.
- **Max Retries (N7 Retries) :**
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- **Enable Unsolicited (Enable Unsolicited Reporting) :**
  Enables or disables Unsolicited reporting.
- **Enable Unsol. after Restart :**
  Enables or disables Unsolicited after Restart (for compatibility with terminals whose revision is before DNP3-1998). It has effect only if Enable Unsolicited after Restart is set.
- **Unsolic. Master No.** (**MTU Address**) **:**
  Destination address of the Master device to which the unsolicited responses are to be sent. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*. It is useful only when Unsolicited Reporting is enabled.
- **Unsol. Grouping Time (Unsolicited Delay Reporting) :**
  Delay between an event being generated and the subsequent transmission of the unsolicited message, in order to group several events in one message and to save bandwidth.
- **Synchronization Interval**
  Max interval time between two synchronization. If no synchronizing inside interval, indication IIN1-4 (NEED TIME). This setting has no effect if Synchronization Interval is zero.
- **DNP 3.0 Rev.**
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)
- **Binary Changes CLASS.**
  Selection to send Binary Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Analog Changes CLASS.**
  Selection to send Analog Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Counter Changes CLASS.**
  Selection to send Counter Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- **Binary Status .**
  Send Binary with status otherwise without status
- **32 Bits Analog Input .**
  Send Analog All Variations and Analog Change Event Binary Changes with 32 bits otherwise with 16 bits

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DNP PROFILE II ETHERNET Port 1 Port 2 and Port 3 Configuration

- **Enable Ethernet Port :**
  Enables or disables Ethernet Port.

- **IP Address :**
  Identification Number of Ethernet device.

- **Subnet Mask :**
  Indicate the part of IP Address is the Net Address and the part of IP Address is the Device Number.

- **Port Number :**
  Indicate to Destinatión Device the path to send the recived data.

- **Keepalive Time :**
  Number of second between Keepalive paquets, if zero no send packages Keepalive. These packages allow to Server know if a Client is present in the Net.

- **Rx Time Between Characters :**
  Maximum time between Characters.

- **Comm Fail Timer :**
  Maximum time between Messages without indicate Communication Fail.

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C. MODBUS RTU Documentation. Address Map

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C.1 Preliminary Information

This a reference document for implementing the MODBUS RTU protocol in the **DLF** IED.

This document provides a detailed MODBUS address map (input status, coil status, input registers and force single coil) and their equivalent in the **DLF** relay.

The functions that will be implemented are:

ModBus Function	Meaning
01	Read Coil Status
02	Read Input Status
04	Read Input Registers
05	Force Single Coil

Any other function not among those indicated will be considered illegal and will return exception code 01 (Illegal function).

C.2 Function 01: Read Coil Status

C.2.1 Modbus Address Map for DLF

The MODBUS coil status address map for the **DLF** relay will be:

Address	Description
Configurable through the *ZIV e-NET tool*®	Any input or output logic signal from the protection modules or generated by the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 1023 and they are assigned automatically by the ***ZIV e-NET tool***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

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C.3 Function 02: Read Input Status

C.3.1 Modbus Address Map for DLF

The MODBUS input status address map for the **DLF** relay will be:

Address	Description
Configurable through the *ZIV e-NET tool*®	Any input or output logic signal from the protection modules or generated by the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 1023 and they are assigned automatically by the ***ZIV e-NET tool***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.4 Function 03: Read Holding Registers

C.4.1 Modbus Address Map for DLF

The MODBUS read holding registers address map for the **DLF** relay will be:

Address	Description
Configurable through the *ZIV e-NET tool*®	Any input or output logic signal from the protection modules or generated by the programmable logic whose number of changes is to be measured.

Configurable through the ***ZIV e-NET tool***®: Counters can be created with any signal configured in the programmable logic or from the protection modules. The default counters are those of the real energies (positive and negative) and the reactive energies (capacitive and inductive).

The metering range of energies in primary values is from 100wh/varh to 6553.5 kWh/kVArh. This is the magnitude transmitted via communications. That is, one (1) count represents 100 wh/varh.

To obtain an energy counter with a higher maximum value, a “user magnitude” must be created using this counter. For example, dividing the value of the counter by 1000 and making the output of the divider the new magnitude yields an energy counter with a range from 100 kWh/kVArh to 6553.5 MWh/Mvarh; that is, one (1) count represents 100 kWh/varh.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZIV e-NET tool***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

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C.5 Function 04: Read Input Registers

C.5.1 Modbus Address Map for DLF

The MODBUS read input registers address map for the **DLF** relay will be:

Address	Description
Configurable through the *ZIV e-NET tool*®	Any magnitude measured or calculated by the protection or generated by the programmable logic. It is possible to select between primary and secondary values, taking into account the corresponding transformation ratios.

All the full scale values of the magnitudes are definable, and these magnitudes can be used to create *User Defined Values*. Some typical values are:

- Phase and sequence currents and harmonics: **Rated value I_{PHASE} + 20**% sends 4095 counts.
- Ground and synchronization currents: **Rated value I_{GROUND} + 20%** sends 4095 counts.
- Sensitive ground and directional ungrounded currents: **1.2 A** sends 4095 counts.
- Phase voltages, sequence and harmonics voltages: **(Rated value V / √3) + 20%** sends 4095 counts.
- Line and polarization voltages: **Rated value V + 20%** sends 4095 counts.
- Powers: 3 x 1.4 x Rated value I_{PHASE} x Rated value / √3 sends 4095 counts.
- Power factor: from **–1** to **1** sends from –4095 to 4095 counts.
- Frequency: from **0 Hz** to **1.2 x Frequency$_{RATED}$** (50Hz / 60Hz) sends 4095 counts.
- Thermal value: **240%** sends 4095 counts
- Distance to the fault:
  - Percentage value: **±100%** sends ±4095 counts (range from -100% to 100%).
  - Value in kilometers: with the ***Length*** of the line, it sends ±4095 counts (range from 0 km to the length of the line set in km. It can also send negative values).
  - Value in miles: with the ***Length*** of the line, it sends ±4095 counts (range from 0 km to the length of the line set in miles. It can also send negative values).

With the ***ZIV e-NET tool***® program, it is possible to define the full-scale value to be used to transmit this magnitude in counts, the unit that all the protocols use. There are three definable parameters that determine the range of distance covered:

- **Offset value**: the minimum value of the magnitude for which 0 counts are sent.
- **Limit**: the length of the range of the magnitude on which it is interpolated to calculate the number of counts to send. If the offset value is 0, it coincides with the value of the magnitude for which the defined maximum of counts (4095) is sent.
- **Nominal flag**: this flag allows determining whether the limit set is proportional to the rated value of the magnitude or not. The rated value of the new magnitudes defined by the user in the programmable logic can be configured, while the rest of the existing magnitudes are fixed.

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- When the Nominal flag is enabled,

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{32767}{Limit}$$

- When the Nominal flag is NOT enabled,

$$CommunicationsMeasurement = (Measurement - Offset) \times \frac{32767}{Limit}$$

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZIV e-NET tool***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.6 Function 05: Force Single Coil

C.6.1 Modbus Address Map for DLF

The MODBUS force single coil address map of the **DLF** relay will be:

Address	Description
Configurable through the *ZIV e-NET tool*®	A command can be made on any input from the protection modules and on any signal configured in the programmable logic.

The content of the addresses is variable (reflection of each relay's configuration). The range of addresses is from 0 to 255 and they are assigned automatically by the ***ZIV e-NET tool***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

Any value other than 00H or FFH will be considered illegal and will return exception code 03 (Illegal Data Value).

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D. IEC 61850 Ed.2

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D.1 IEC 61850 Standard

IEC 61850 relay models have an extra protection and control function defined by **IEC 61850** standard.

Extra services provided by **IEC 61850** relays are:

- Reporting relay data (pickups, trips, blockings, etc) to a higher level equipment (Central Unit, Remote Control, HMI, etc).
- Quick data reporting (GOOSE) to same level relay (protections, control equipment, auxiliary services) or, even to other higher level equipment.
- MMS communications allowing any MMS client to receive the relay data model, thus being able to interact with it for editing settings and parameters and carry out commands.
- Managing a single file (**CID**) that allows to have a *backup* containing all protection, control and communications parameters.
- FTP access to oscillograms, logs, etc.
- Web server providing information on the relay status, errors, status and measurements, subscription to GOOSE messages, etc.

Each protection element contains **IEC 61850** mapping information with regard to node name and settings, available digital signals, commanding data, measurements, etc.

IEC 61850 is a substation automation standard defined by the TC57 Technical Committee. The standard is segregated into 10 parts and deals with issues related to general system requirements, engineering project management and communications requirements, putting forward a data model on which IED capacities are described. This data model is developed through the substation description language (SCL) also defined in the standard. Relay functions are modelled from the so called Logic Nodes (LN) that, at the same time, are formed from *Common Data Classes* and *Common Data Attributes*, following an object abstraction philosophy. Together with these objects, the standard defines a set of services through the so called *Abstract Communication Service Interface* (ACSI). Sections 8 and 9 of the standard explain how these objects and services are mapped in terms of given protocols, specifically, MMS, GOOSE and Sampled Values. The last section of the standard deals with the conformity tests that a relay or architecture must pass in order to be approved according to the standard, thus covering all aspects.

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Therefore, the standard includes the chapters or parts below:

- *IEC 61850-1: Introduction and overview.*
- *IEC 61850-2: Glossary.*
- *IEC 61850-3: General requirements.*
- *IEC 61850-4: System and project management.*
- *IEC 61850-5: Communication requirements for functions and device models.*
- *IEC 61850-6: Configuration language for communication in electrical substations related to IEDs.*
- *IEC 61850-7: Basic communication structure for substation and feeder equipment.*
  IEC 61850-7-1: Principles and models.
  IEC 61850-7-2: Abstract communication service interface (ACSI).
  IEC 61850-7-3: Common Data Classes.
  IEC 61850-7-4: Compatible logical node classes and data classes.
- *IEC 61850-8-1: Specific communication service mapping (SCSM) Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2) and to ISO/IEC8802-3.*
- *IEC 61850-9: Specific communication service mapping (SCSM).*
  IEC 61850-9-1: Sampled values over serial unidirectional multidrop point to point link.
  IEC 61850-9-2: Sampled values over ISO/IEC 802-3.
- *IEC 61850-10: Conformance testing.*

D.2 Communications Stack

The IED will be based on the *Client-Server* model to give data contained in its data model in a vertical way. It is a connection oriented communications, always initiated by the client and, in this case, using the MMS (*Manufacturing Message Specification*) standard, specifically developed for industrial applications, specified according to ISO 9506 and used for data interchange in production environments. This protocol is independent of the type of network or connected devices and, therefore, can be maintained as physical communications technology evolves. The protocol defines communications messages transferred between controllers, as well as between the engineering station and the controller, so that the server (IED) will make available to the clients (central units, gateways, SCADAs, computers, etc.) the data selected in a *Data Set* that will have been allocated to a *Report Control Block*. The IEC 61850-8-1 part defines the mapping between the MMS protocol service and the IEC 61850 abstract services.

The IED also has the *Publisher-Subscriber* model that the GOOSE service is based on. In this case, it is a high speed non connection oriented communications, thus enabling horizontal communications between IEDs. The message sent by the publisher will be a *multicast* message that will propagate through the local network, thus reaching all the IEDs connected to the same.

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D.3 IEC 61850 Server and Data Model

The IED server and, thus, the physical device, contains four *Logical Devices*. Those *Logical Device* includes all the different *Logical Nodes* that, at the same time, contain *Data Objects* composed of *Data Attributes* and that, as a whole, form the relay data model. Services to carry out a number of functions, as they are reading and writing data, commands, reporting, etc., are available at every level.

The distribution of the Logical Nodes inside the Logical Devices is the following one:

- **SYS**: *Logical Device* of the System where the *Report Control Blocks, GOOSE Control Blocks, Setting Group Control Blocks, LOGs*, etc. are located. Data Set will appear also here once configured and this is the place where the *Logical Nodes* related to the hardware of the IED are located (inputs, outputs, communications, synchronization, etc.).
- **CTRL**: *Logical device* where are located all the control *Logical Nodes* that can be instantiated with the configuration tool.
- **PROT**: *Logical device* where are located the Logical Nodes of the IED.
- **MEA**: *Logical device* where are located the *Logical Nodes* related to measurements.

Apart from the protection nodes, such as PHSPIOC, PTOV, PTOF, PTUF, RREC, RBRF, PTRC, etc. that are defined in the applicable chapters where the relay protection functions are explained, the relay has the configurable control nodes described below. These control nodes will not be present in the relay data models unless they have been registered and configured with the configuration tool:

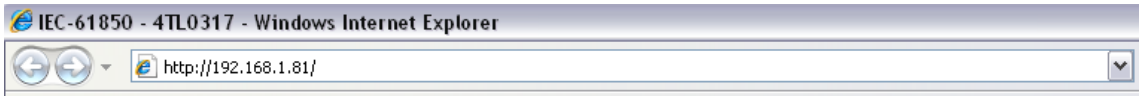
- XCBR: control node that features a double digital data used to map the status of a three pole breaker.
- XSWI: node that features a double digital data used to map the status of the disconnect switches.
- CSWI: this control node contains the double commands on the switchgear (breaker and disconnect switches).
- CILO: control node used to map the permits of the different commanding objects.
- GAPC: general control node with single and double general purpose states and commands except for switchgear elements (breakers and disconnect switches).
- GENGGIO: general control node with single and double status and integer and floating analog measurements used to have any relay data available in IEC 61850. Although there are up to a maximum of 4 nodes of this type, using as far as possible the relay own protection nodes is recommended, restricting the use of these nodes to own user data generated in the control logic.
- CALH: control node used to map bay alarms.
- SIMG: control node used to map SF6 alarm and trip.
- PLSMMTR: control node used to map energy meters calculated in control logic, normally from pulse inputs coming from external energy meters.
- SETGGIO: control node used to map and thus have user settings generated in the relay control logic available through MMS.
- LGOS: control node used to monitor the state of an input GOOSE.

The MICS file (Model Implementation Conformance Statement), which describes the extensions of the IEC 61850 data model in relation to the standard, is generated automatically by the configuration tool once defined the IED model.

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D.4 Web Server

Firmware versions, boot up status and useful relay data, can be accessed through the web server (using HTTP or HTTPS). To gain access, write the relay IP in a web browser:



Once authenticated (user data, password for only read access), the following data will be displayed:

- **Configuration**: relay identification data (hostname, location, contact, complete product model, firmware version, firmware reference and serial number) and access control data and certificates (see Cybersecurity Annex) are displayed. Additionally, it is allowed, only with the corresponding permission, to enable and disable Serial Log (option for analysis of internal anomalies by the manufacturer). Click ***Send*** and ***Apply*** to run this action.
- **Statistics**: this section shows the time the relay has been operating since the last boot up, the date and UTC time, the percentage of memory used and the percentage of CPU used. The relay date can be edit with permission to change settings.
  - **Routing**: traffic statistics can be accessed in case of using routers.
- **Log menu.** It is accessible with permission to manage logs. Shows the following information:
  - **System log:** register with boot up and system operation data that informs the user on the relay status where the reasons for CID rejection and other issues can be consulted. This register is stored in non-volatile memory. Click the button located at the top of the screen within section Download of System log, named Download File, to download the data into a text file.
  - **Security log**: see Cybersecurity Annex.
- **IEC-61850**. A number of data related to IEC 61850 standard are displayed.
  - **CID log**: register with loading data of new CID files. This register is stored in volatile memory since it stores data related to the last load. The history file may be obtained from System log.
  - **Analog signals list**: list of analog measurements available in IEC 61850 with the following data:
    - Description.
    - MMS path.
    - Value.
    - Quality: it consists of 3 fields:
      - Validity (**G**ood, **I**nvalid, **R**eserved, **Q**uestionable)
      - Quality Bit (**OV** overflow, **OR** out of range, **BR** bad reference, **OS** oscillatory, **FL** failure, **OD** old data, **ER** inconsistent, **IN** inaccurate)
      - Origin (**P** process, **S** substituted)/**T**est/Operator**B**locked.
    - Date of last update.
    - Information concerning maximum and minimum calculation (whether automatic or not).
    - Maximum value.
    - Minimum value.
    - Magnitude deadband setting.
    - Angle deadband setting.
  - **Digital signals list**: list of digital signals available in IEC 61850 with description, MMS path, value, quality and date of last update.

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- **GOOSE subscription list**: list of subscriptions to GOOSE messages where the configured subscription data can be seen (MAC, APPID, GOID, etc.) and the subscription status:
  - NOT FOUND: The configured GOOSE has never been received. The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA. It is the initial state of subscriptions.
  - OK: The GOOSE has been received perfectly and has been received before the TAL (TimeAllowedToLive). The quality of the data subscribed to that GOOSE (node GIGGIO1) will be either that contained in the GOOSE if the data is subscribed to the quality or GOOD if it is not.
  - TIME OUT: The GOOSE has ever been perfectly received and is no longer received in the TAL (TimeAllowedToLive). The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA.
  - STRUCT ERROR: The GOOSE has been received but the type of data does not match the expected type or the information is not present in the GOOSE. The quality of the data subscribed to that GOOSE (node GIGGIO1) whose type does not match the expected type will be INVALID and without cause. If any of the information expected in the GOOSE mapped to the data does not match or that information does not travel in the GOOSE, the quality of the data will be marked as INVALID (that is, if for the GIGGIO1.Ind1 data the stVal, q and t of the data is mapped and the t is received with a type that does not correspond or does not travel in the GOOSE, the GIGGIO1.Ind1.q quality will be INVALID, even though the stVal and q are being received OK). Within that GOOSE, data received correctly will be processed normally.
  - NDSCOM ERROR: The received GOOSE comes with the NdsCom field to TRUE. The GOOSE is ignored and the quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA.
  - ERROR HOLD TIME: The received GOOSE has TAL=0. In this case, the GOOSE is ignored.
  - CONFREV ERROR: The GOOSE has been received perfectly, but with ConfRev different from that configured. The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately passed to QUESTIONABLE by OLDDATA.
  - DATSET ERROR: The GOOSE has been received perfectly, but with a different DatSet than the one configured. The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately transferred to QUESTIONABLE by OLDDATA.
  - INTERRUPTED: The IED has stopped/interrupted the subscription to this GOOSE (for example, because the computer switches to Off mode). The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately switched to QUESTIONABLE by OLDDATA.
  - WAITING: Indicates that, having received and processed GOOSEs correctly, a change of LPHD1.Sim=FALSE has been detected. The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA. This status will only be changed when a change in LPHD1.Sim=FALSE is detected and LGOS[X].SimSt=TRUE has just been obtained.
- **Download file:** the name of the active CID file that the relay is operating with is displayed to the top as title. Click the Download File button located under it to download the file.

- **Actions menu** (only with administrator access).
  - **Apply**. After having been changed and sent, the parameters are applied to the relay.
  - **Clear Statistics**. Deletes statistics stored in the relay.
  - **Reboot**. Resets the relay.
  - **Reflash**. Updates the relay with a new firmware version.

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Taking into account the differences between the actions below (only available for administrator users) is very important.

- Send changed parameters to the relay. Click ***Send*** in the modified page to carry out this action.
- Once the desired parameters have been configured, the ***Apply*** action will activate these changes and the relay will commence to use the new applied configuration.
- Click ***Reboot*** to reset the relay.

D.5 Communications Port

The IEDs have two or four LAN ports for IEC 61850 communications. This LAN ports use the Ethernet network, using the TCP/IP protocol for MMS (standard used to pack the information in the network) communications, sending and receiving GOOSE messages, file transfer through FTP, etc. Therefore, regardless the physical media and the connection (fiber, copper, etc.), configuring the relay network IP configuration is necessary.

The relay can communicate in IEC 61850 with up to 10 clients and with 4 masters simultaneously, the port number and the protocol (PROCOME, DNP3 or MODBUS) being able to be configured. Also, the relay will always be able to communicate simultaneously with the manufacturer tool for relay remote management through the fixed port 32001.

The relay will therefore have a menu to configure the LAN ports:

- DHCP enable.
- IP address.
- Network mask.
- Routing configuration menu if required.
- Redundancy type.

And a menu to configure the TCP/IP protocols simultaneously enabled together with IEC 61850:

- PROCOME protocol: fixed connection to the TCP/IP 32001 port for remote relay management through the manufacturer tool.
- Protocols 1, 2, 3 and 4: settings to indicate protocol, TCP/IP port, etc. for simultaneous TCP/IP communications with the relay.

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D.6 File Transfer

File transfer access (using FTP or SFTP) will enable the availability of a number of relay folders. Different access levels will be obtained as a function of the user and password.

Accessing the equipment with user with visualization permission, read only access is gained to the following directories:

- COMTRADE: folder where the generated oscillograms are saved.
- SCL: folder containing the active CID that the relay is working with (SCL/active/).

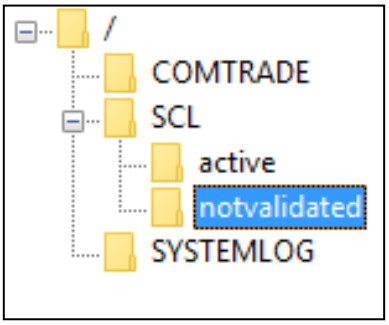


Figure D.1 Directory Structure for File Transfer.

Accessing the equipment with a user with permission to manage logs, you have read-only access to the following directory:

- **SYSTEM LOG**: folder containing *System.log* and *Security.log*.

Accessing the equipment with user with configuration loading permission, the equipment also offers write permission on the */SCL/notvalidated* folder, where the user can copy the new CID to load the equipment. When the new CID is copied to that location the equipment begins its validation.

In those cases where the relay is reset or has had a bad operation, the firmware automatically generates a file, *coredump,* where the status at the time of the failure is stored so as to be able to analyse the issue. Accessing by file transfer with a user with permission to manage logs, access to a read only folder with this information is gained.

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D.7 CID Configuration File

The standard defines the following files that will form part of the IED configuration process:

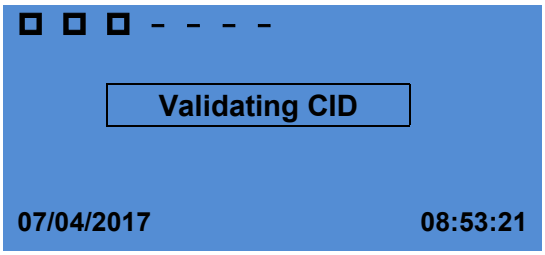
- ICD: file describing the IED capabilities. All nodes are extended and without configuration.
- CID: file containing a specific IED configuration at IED name, communications, Reports, etc. level

Both files allow knowing the relay data model in Logical Devices, Logical Nodes, Data and Attribute form. Once the relay has an IEC 61850 firmware, a file (**CID**) will be available in the format proposed by the **IEC 61850** standard according to section 6 (SCL) that can be downloadable by file transfer, web server or FileTransfer service of IEC 61850.

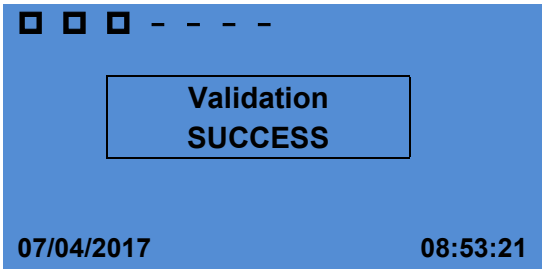
The CID file is used to configure send GOOSE message parameters, subscription to data of other GOOSE messages, create and allocate *datasets* to Report Control Blocks (RCBs) and GOOSE Control Blocks (GCBs), edit settings, control logic, descriptions, parameters etc.

The file can be edited using the program ***ZIV e-NET Tool***®. This program allows configuring the file that will later be sent to the relay through file transfer from the configuration tool. The starting CID file can be the file downloaded from the relay or a new file generated from the tool itself.

When a new CID file is loaded to the relay through file transfer (using a user with configuration loading permission), it is validated by the relay checking it is a correct SCL and that the configured IP in the file matches the IP configured in the relay, and the message **Validating CID** is displayed on the screen.

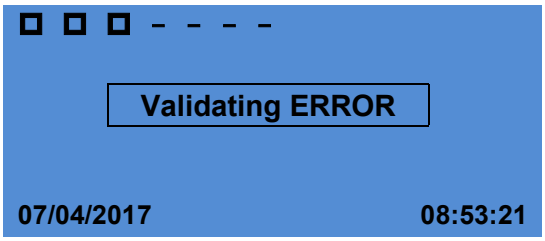


Once it has been validated, if the result is correct, the message **Validation SUCCESS** is displayed on the screen and the relay will be rebooted and reconfigured. The relay will be reset and will displayed the message **Configuring Device** and a progress bar on the screen. Upon completion of the reconfiguration process, the relay will be rebooted with the new configuration. The complete validation and reconfiguration process lasts about the minute.



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Upon failed validation, the CID file will be rejected and deleted from the loading directory (non validated), the message **Validation ERROR** being displayed on the screen. In this case, web server logs can be accessed (through the web server, file transfer or File Transfer service of IEC 61850) in order to know the reasons for file rejection. Therefore, the relay will keep operating with the CID file that was active and communications will never be lost.



D.8 Mod/Beh

The standard defines the following values in the Logical Nodes for the Mod and Beh.

Value	Status	LN Behaviour
1	On	The application represented by the LN works. All communication services work and get updated values. DOs will be transmitted with a relevant quality. Control commands with Test=false will be accepted. Control commands with Test=true will be rejected.
2	Blocked	The application represented by the LN works. No (wired) output data will be issued to the process. All communication services work and get updated values. DOs will be transmitted with a relevant quality. Control commands with Test=false will be accepted. Control commands with Test=true will be rejected.
3	Test	The application represented by the LN works. All communication services work and get updated values. DOs will be transmitted with q.test=true, except Mod, Beh and Health that have q.test=false. Control commands with Test=false will be rejected. Control commands with Test=true will be accepted.
4	Test/Blocked	The application represented by the LN works. No (wired) output data will be issued to the process. All communication services work and get updated values. DOs will be transmitted with q.test=true, except Mod, Beh and Health that have q.test=false. Control commands with Test=false will be rejected. Control commands with Test=true will be accepted.
5	Off	The application represented by the LN does not work. All communication services work (output with quality.validity=invalid, except Mod, Beh and Health that will have q.validity=good). No process output will be done. Control commands to the process will be rejected. Only Mod accepts control command with Test=false. Settings and configuration attributes are still modifiable.

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The complete IED (not by LN) supports the five modes. The LNs individually support ON and OFF modes and most of the protection related LNs also support the Blocked.

It is implemented a hierarchy management for the LDs (*GrRef* of LLN0). The format for the *GrRef.setSrcRef* in the SCL is: "@<*LDinst*>" or "<*IEDname*><*LDinst*>" and in the on-line data model is: "<*IEDname*><*LDinst*>" or "<*LDname*>".

The "root" is **SYS** and therefore all the other LDs will contain the *GrRef* in their LLN0 with "**@SYS**" value, which will be read only, so that all the LDs will inherit the status of **SYS** LD.

The IED will provide the following features related to the test mode:

- All the information sent/available in the IED will have test indication (q.test=true) and the following inputs will be considered as valid:
  - Data received by GOOSE message with *q*.test = true.
  - Commands received with Test=true attribute.
- Multicast signals used for simulation (GOOSE):
  - Suscription: Sim is the data object used to change the status/behaviour. It is present just in LPHD1 LN of **SYS** LD and will indicate the behaviour of the GOOSE simulation for all the IED. When the IED is receiving the same GOOSEin both ways, real (simulation bit=false) and simulated (simulation bit=true), the IED will take into account just to one of them depending on the value/status of *SYS/LPHD1.Sim.stVal.*
    - Real GOOSE if SYS/LPHD1.Sim.stVal=false.
    - Simulated GOOSE/SV if *SYS/LPHD1.Sim.stVal=false*. In this case, the SimSt of SYS/LGOS LN configured to monitor that GOOSE message will go to TRUE, showing that the IED is receiving and processing a simulated GOOSE message.
  - Publishing: The IED will have one setting per Goose Control Block (***Goose Control Block X Simulated***) that allows sending normal or simulated GOOSE messages. Therefore, depending on the settings, the IED will send the corresponding GOOSE message with the simulated bit in TRUE or FALSE.

D.9 Data Set

The relay supports a maximum of 35 Data Sets, each containing a maximum of 500 FCDAs.

The FC allowed in a Data Set which will be assigned to a RCB are the following ones: ST, MX, SP, CF, DC, SG, SR, OR, BL and EX.

The FC allowed in a Data Set which will be assigned to a GCB are the following ones: ST, MX and SP.

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D.10 Send GOOSE Messages

This service is defined in the standard and enables horizontal, fast and safe communications between IEDs. They are *multicast* messages and, thus, the emitter will place the data in the network and this will be received by any relay connected to the same. It has a message repeat algorithm, so that the data can be received by new relays connected to the network and, in this way, the receiving IEDs can detect communications or own emitter failures and act accordingly. The IEDs have 10 GCBs, so that they can be configured to send up to 10 different GOOSE messages. Each GCB has the following configurable parameters:

- MAC: send GOOSE message virtual MAC address
- VLAN ID: VLAN identifier
- AppID: application identifier. Parameter used to differentiate between GOOSE messages.
- VLAN Priority: message priority identifier.
- MinTime: minimum GOOSE message repeat time.
- MaxTime: maximum failure detection time on the part of the receiver (MaxTAL). The maximum GOOSE message repeat time will be MaxTime/2.
- GoID: string with a maximum size of 65 octets, which identifies the GOOSE message.
- GoRef: with a maximum size of 65 octets, which identifies the name of the GCB.
- Data Set: Data Set to be sent in the GOOSE message.
- Description: user-editable identifier to provide extra information.

Configuration version (ConfRev) is automatically calculated by the configuration tool and update at the time of generating the CID file.

Both *Data Attributes* and *Data Objects* (any FCD with a single FC ST/MX) can be sent through GOOSE and the same Data Set can be allocated to a GCB and a RCB. The relay can send both single and double digital signals, (SPS) and (DPS), integer data (INT) or analog measurements (FLOAT). When a measurement is allocated to a Data Set that will later be allocated to a GCB, it must be taken into account that, if the *deadband* associated to this measurement is configured to 0, this measurement will not be assessed, it will never generate a change and, therefore, will not cause GOOSE *trigger* by a change of value. If, otherwise, an instantaneous measurement is selected in the Data Set associated to a GOOSE message, every change of measurement will produce GOOSE sending.

In order to carry out the configuration, a Data Set must be first generated with the data to be sent in the GOOSE message. As a rule, attribute pairs (data, q) are sent but the relay can work with any type of Data Set. Later, this Data Set will be allocated to the desired GCB, any of the 10 existing in the relay model.

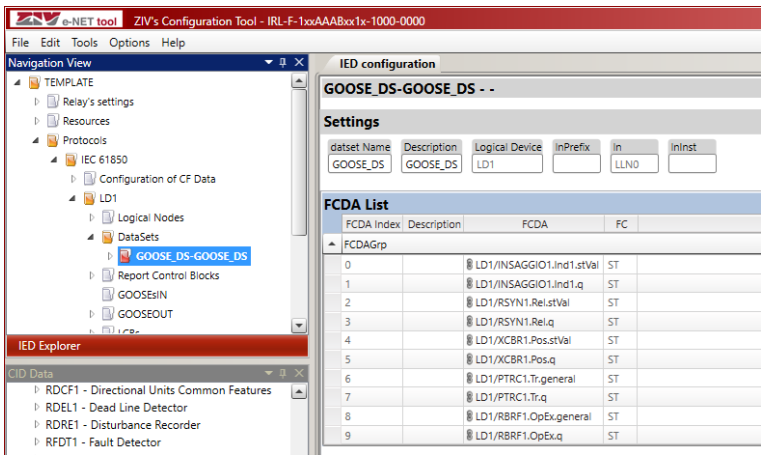


Figure D.2 Data Set configuration for GOOSE.

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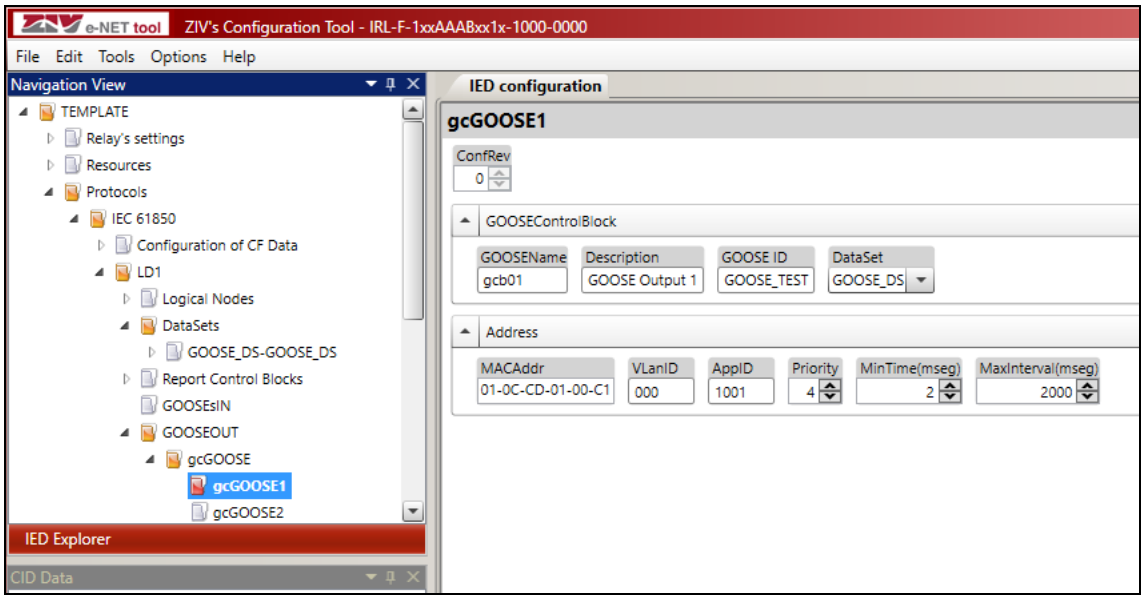


Figure D.3 GCB1 Configuration with Data Set Generated in Advance.

In this way, when a tool-generated CID is sent to the relay, after boot up, it will start sending a GOOSE message with the configured Data Set data.

If the Data Set allocated to the GCB is so large that the relay is not able to process and send, all relay services will be booted up normally, but the GOOSE message will not be sent, since it will have been disabled, the *NDSCom* attribute of the GCB having been set to TRUE. The *System Log* will display a message stating this condition:

ERR - [IEC61850ED1] Goose encoding error, setting GCB invalid (GoEna=False, NdsCom=True)

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D.11 Subscription to GOOSE Message Data

Subscription to GOOSE message data is carried out through the GIGGIO node.

Using the GIGGIO node, you can subscribe to a total of 400 elements using the *ExtRefs* of that node. The different attributes of GOOSE can be mapped to 200 single signal type data (*GIGGIO1.IndX* data), 100 double signal type data (*GIGGIO1.DPInX* data), 50 integer type data (*GIGGIO1.IntInX* data) and 50 floating type data (*GIGGIO1.AnInX* data). Each subscribed element (value, quality and/or timestamp) will occupy an independent *ExtRef*.

The device can receive GOOSEs containing both data (CDF) and attributes (FCDA), but the subscription has to be made only to final attributes of type boolean (assignable to *GIGGIO1.IndX* data), *DbPos* (assignable to *GIGGIO1.DPInX* data), int (assignable to *GIGGIO1.IntInX* data), float (assignable to *GIGGIO1.AnInX* data), quality and timestamp (assignable to any of the *GIGGIO1* data). For example, if an SPS data travels in the GOOSE, the equipment should subscribe to the *stVal* attribute, the *q* attribute and the *t* attribute (if desired), using three *ExtRefs*.

There is going to be just one GIGGIO *Logical Node* and it will appear always instantiated in the data model.

So, as defined before, the subscription is carried out through the GIGGIO node, where it will be mapped the internal data where the data received through the GOOSE service will be stored. Because of this, at the time of configuring a subscription, the required user resources (digital and/or analogue signals) must be generated. Those user resources will be the ones where mapped in the GIGGIO Logica Node and therefore where the data received through the GOOSE message will be stored.

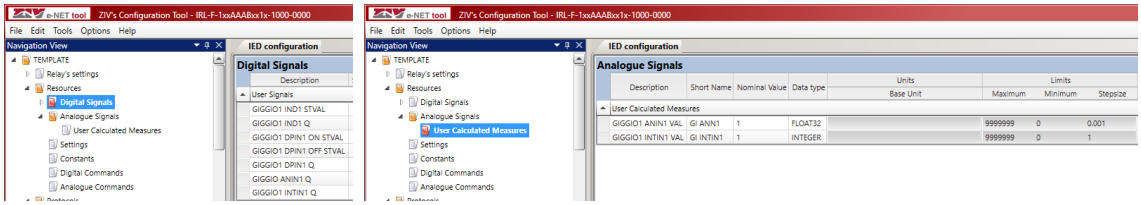


Figure D.4 Generation of User Signals (Digital and Analog) for Receiving the Subscribed Value.

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From the tools window, with the ***Referable*** data tab selected, map the user resources registered in advance in the GIGGIO node.

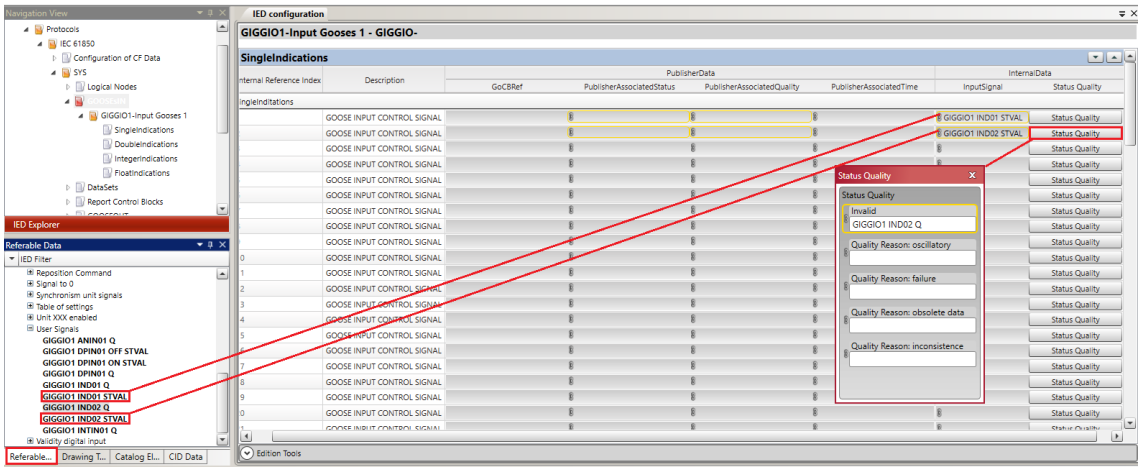


Figure D.5 Mapping for Receiving a Single Point Status Data (SPS) and its *Quality*.

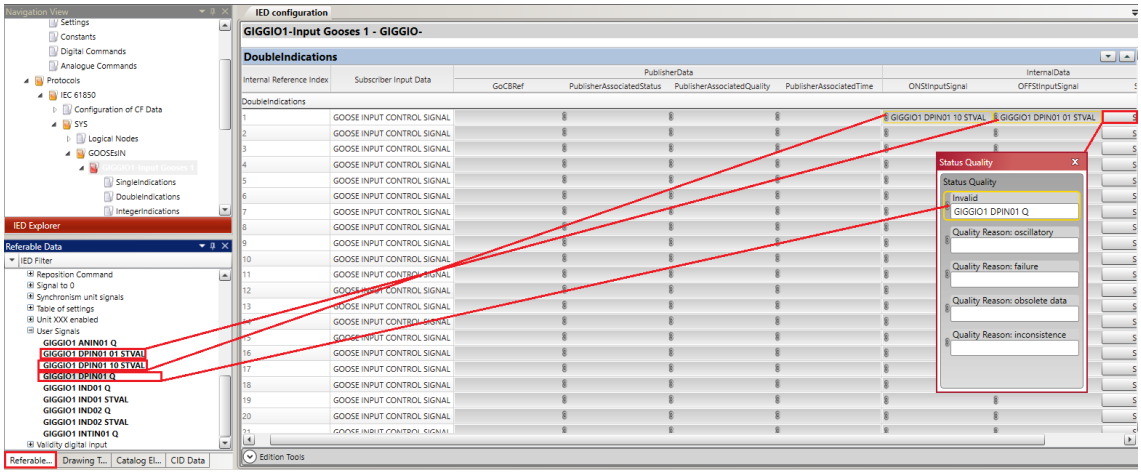


Figure D.6 Mapping for Receiving a Double Point Status Data (DPS) and its *Quality*.

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At the time of subscribing to a double point status data, the relay will receive the DPS data and will represent its value by means of two user signals.

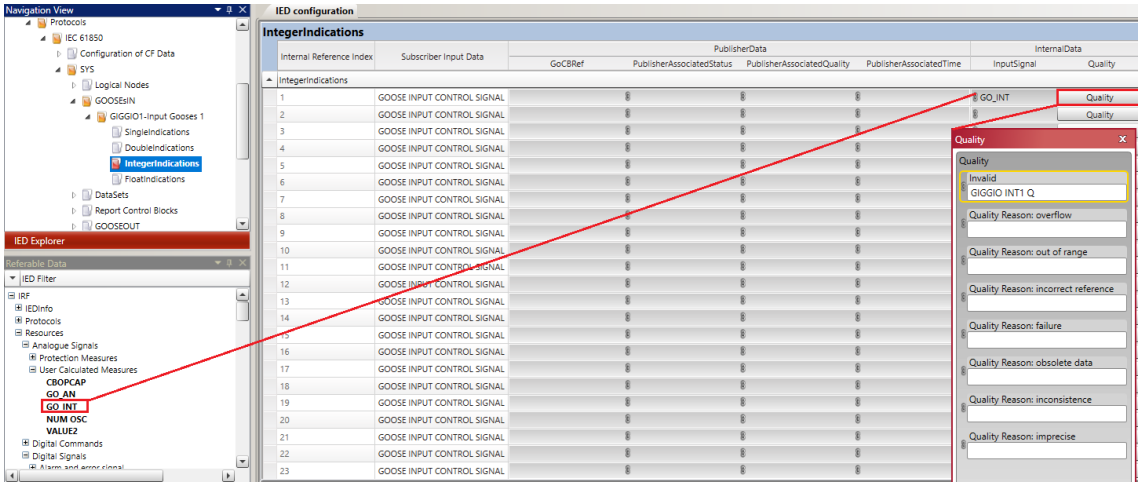


Figure D.7 Mapping for Receiving an Integer Data (INT) and its *Quality*.

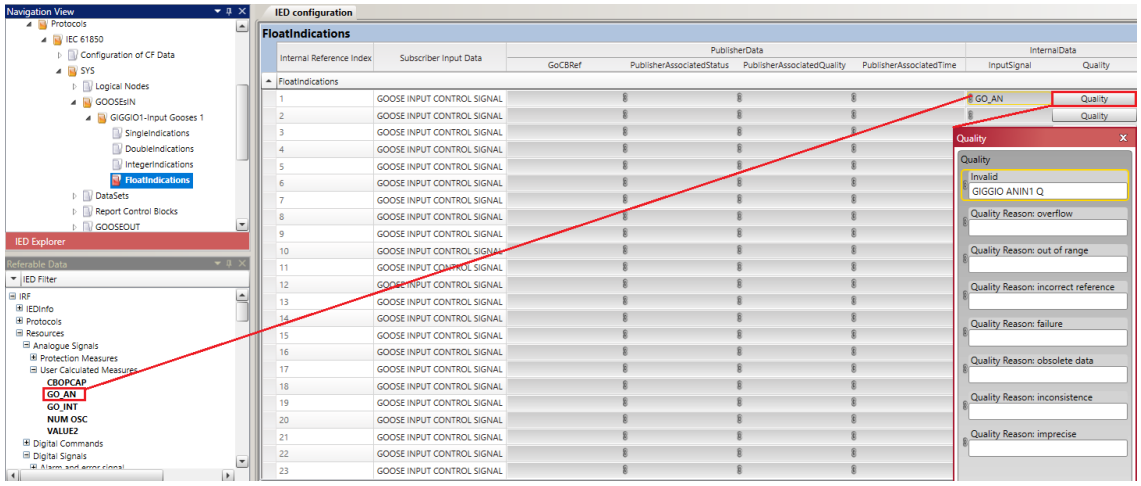


Figure D.8 Mapping for Receiving an Analog Data (FLOAT) and its *Quality*.

In the example, both the data value and its quality, in case both are sent through the GOOSE message, have been mapped to have this quality value in a user signal and be able to act accordingly, but this is not mandatory. When the GOOSE is being received correctly and the *quality* of the subscribed element is valid, the user signal mapped to the GIGGIO node in the ***Validity*** box will have a **TRUE** value. When the *quality* sent through the GOOSE is invalid or the relay is not receiving the GOOSE message, this signal will have a **FALSE** value, being able to use this signal in the relay logic to generate alarms, blockings or whatever is required. On the other hand, more user signals may be mapped if the reasons for a non valid quality must be known.

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Once the GIGGIO node has been mapped with all digital signals or measurements to be received through GOOSE message, the subscription can be configured. Right click ***Input GOOSEs*** to display the submenu ***Configure incoming GOOSE***. When selected, the program prompts to select the relay CID configured to send the GOOSE message, CID from which it will retrieve the data related to the configured GCB and Data Set. After selecting the file, in the ***Tools*** window, with the ***CID Data*** tab selected, the configured GCBs of the open CID will be shown.

To carry out the subscription of a single element (attributes type *boolean*, *quality* and / or *timestamp*), select single point data from the CID Data window and drag to the ***Publisher Associated Status*** field of the simple elements of the GIGGIO. When selecting the Data Attribute, if inside the Data Set its corresponding quality or timestamp is located, their subscription will also be done automatically. When making the subscription of a quality or timestamp just that subscription will be done.

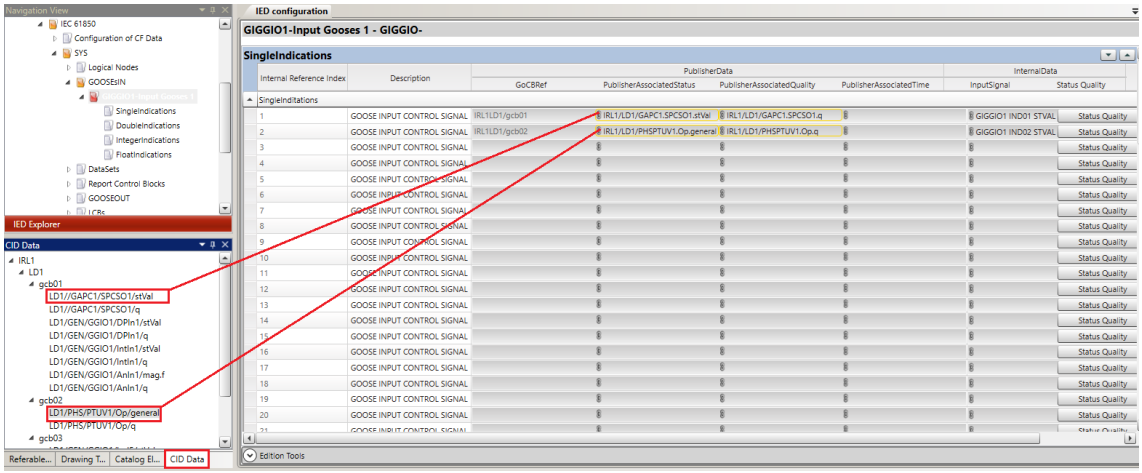


Figure D.9 Subscription to a Single Point Data.

In the example, the quality subscription of both elements has been done automatically by the configuration tool.

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To carry out the subscription of a double element (attributes type *DbPos*, *quality* and / or *timestamp*), select double point data from the ***CID Data*** window and drag to the ***Publisher Associated Status*** of the double elements of the GIGGIO.

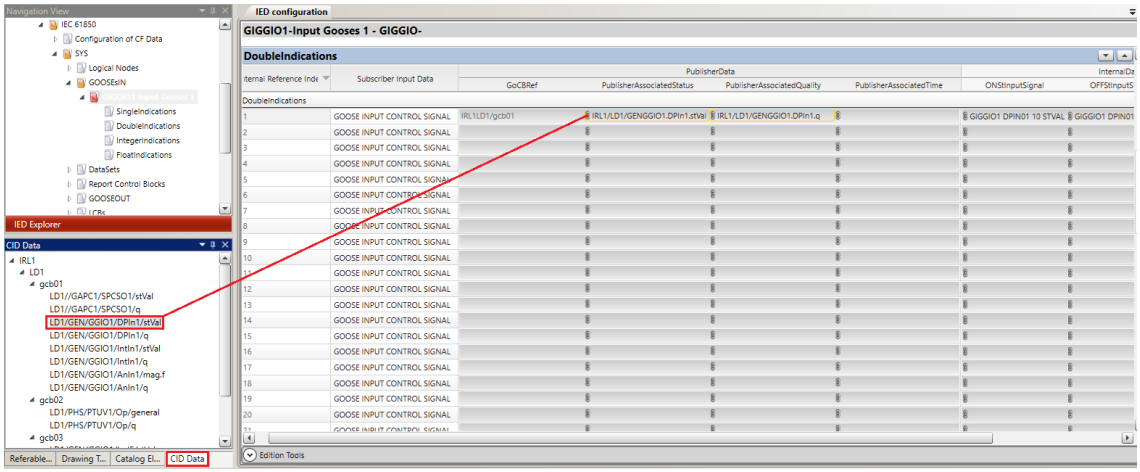


Figure D.10 Subscription to a Double Point Data.

To carry out the subscription of an integer element (attributes type *int, quality* and / or *timestamp*), select integer data from the ***CID Data*** window and drag to the ***Publisher Associated Status*** of the integer elements of the GIGGIO.

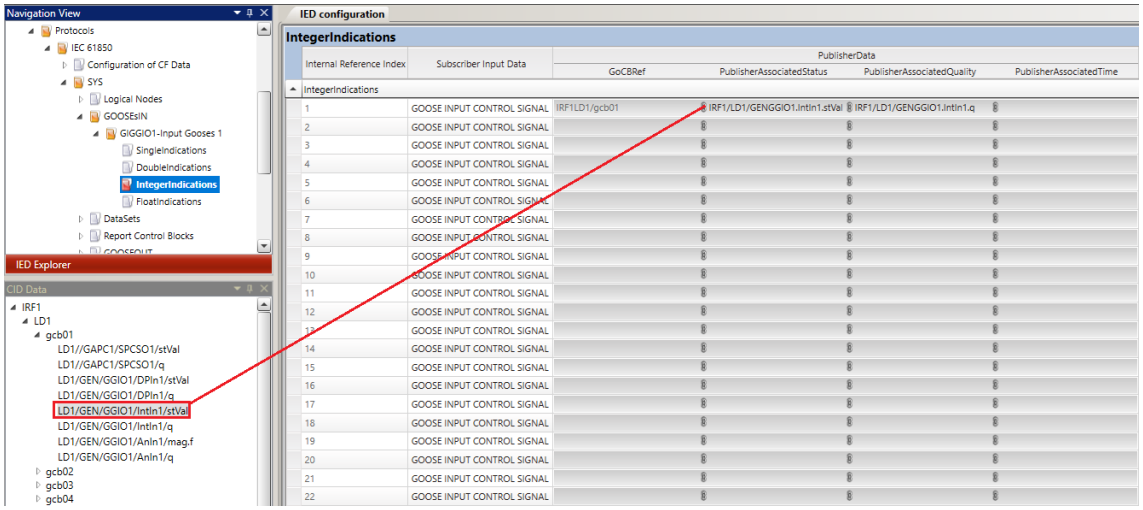


Figure D.11 Subscription to an Integer Data.

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To carry out the subscription of an analog element (attributes type *int, quality* and / or *timestamp*), select floating data from the ***CID Data*** window and drag to the ***Publisher Associated Status*** of the floating elements of the GIGGIO.

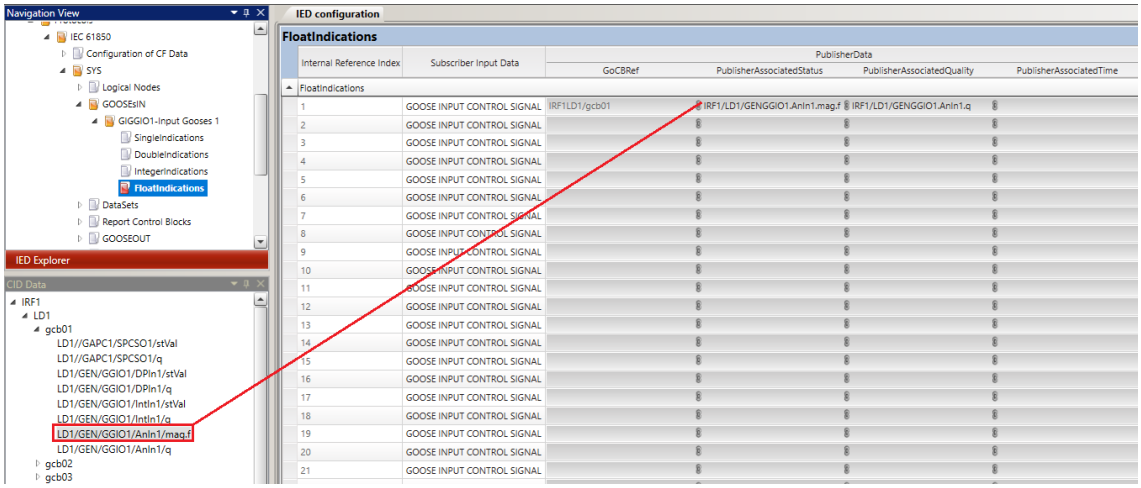


Figure D.12 Subscription to an Analogue Data.

If you try to subscribe to a wrong data type (for example, an integer data in a FLOAT), the tool displays the following message: ***Invalid Type!***, and does not allow subscription.

When configuring a subscription, the corresponding ExtRef with the information to be received will be automatically registered in the GIGGIO node and in the Communication field of the IED and in the *DataTypeTemplates* all the information of the IED who is sending that data in a GOOSE message so that the subscriptor IED can perform the subscription.

Once the relay is configured with the appropriate subscriptions to GOOSE messages, access to the status of each subscription can be gained from the web server.

Next, an example of subscription to a data (data object or FCD). As mentioned, subscriptions to attributes must always be made. The tool automatically displays the attributes of the FCD in the ***CID Data*** window and the user will individually configure the attributes as indicated above.

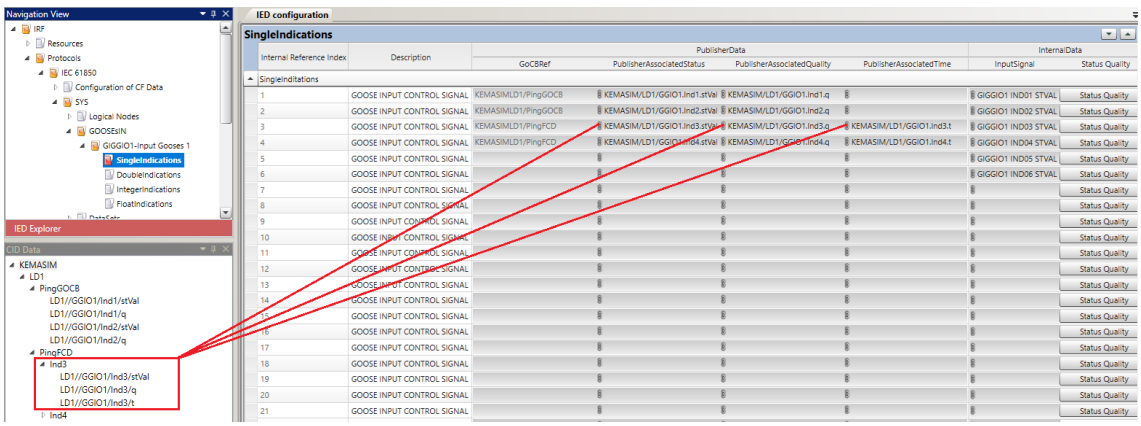


Figure D.13 Suscription to a Data Object.

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The Mod status of the IED (LD SYS.LLN0.Mod) will define the way the IED will process the GOOSE subscription elements.

GOOSE input value	on	blocked	test	test-blocked	off
value=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=good *detailQual*=0 *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=quest *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
GOOSE is no longer being received	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=false	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=false	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=true	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=true	*value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false

where:

(*) OD = OldData.
"Processed as valid" means that the application should react according to the quality and intended functionality of the LN.
"**Processed as invalid**" means the application should react as if the quality of the data had been invalid or as the data source has failed.
"**Processed as questionable**" means that the application should decide how to consider the status value.

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D.12 Report Control Blocks (RCBs)

This method is used in the standard for an effective vertical communication between the IED (server) and the clients (central units, gateways, SCADAs, etc.). The IEDs have 20 RCBs, 10 of them being Buffered RCBs and the other 10, Unbuffered RCBs. All 20 are always present in the data model and, the following parameters can be edited by configuration:

- BRCB:
  - Configuration revision.
  - Buffer time. Buffer size is 30 kbytes.
  - Description.
  - Data Set associated with BRCB.
  - rptID.
  - Integrity Period.
  - Trigger Options (Data Update is not supported by the relay).
  - Optional fields.
- URCB:
  - Configuration revision.
  - Description.
  - Data Set associated with URCB.
  - rptID.
  - Integrity Period.
  - Trigger Options (Data Update is not supported by the relay).
  - Optional fields.

The same Data Set may be allocated to different RCBs in order to be able to send the same data to different clients (for example, central units or redundant SCADAs).

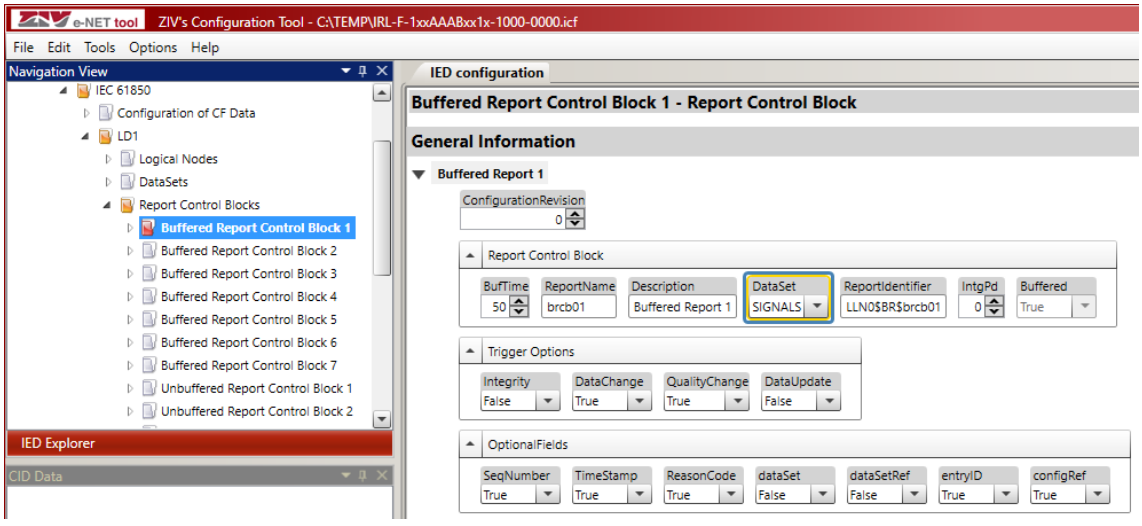


Figure D.14 Configuration of a BRCB.

The moment a client enables a RCB after having connected and associated with the relay, this RCB is then no longer available for other clients. Although all the configuration parameters are available in the tool, the client (once connected and prior to enabling the RCB) can edit the same according to its needs, except for the Data Set and ***Configuration Revision*** (***SqNum***, ***GI*** and ***TimeofEntry*** *cannot be edited either*).

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The IED supports the following ***Trigger Options***, apart from ***General Interrogation***:

- ***Integrity***: the relay will send periodically a *Report* with all the information of the Data Set, according to ***Integrity Period*** setting configuration.
- ***Data Change***: the relay will send a *Report* when a change in a the value of any Data Set element is detected and only this changed data will be sent.
- ***Quality Change***: the relay will send a *Report* when a change in Data Set element quality is detected and only this changed data will be sent.

The IED allows preconfiguring RCBs to specific clients so that those RCBs can just be configured and enabled by the preconfigured clients. In order to carry out that configuration it is necessary having the ICD/IID/CID/SCD file where the information of the client appears. Clicking with the right button of the mouse over the ***Report Control Blocks*** it appears a menu (***Open SCL file***) from where you can select the SCL file of the client. The tool will extract from that file the necessary information to preconfigure the desired RCB (LN and AccessPoint of the corresponding IED). Once selected the SCL file, it will appear in the ***Tools*** window, when being selected ***CID Data***, the information of the SCL file which will be used to configure the ***ClientLN*** and ***ClientAP*** fields of the desired RCB.

It is necessary that the SCL file of the client contains the Clientservices of the bufReport and/or unbufReport enabled (true) into the *Services* section so that the tool can preconfigure the RCBs.

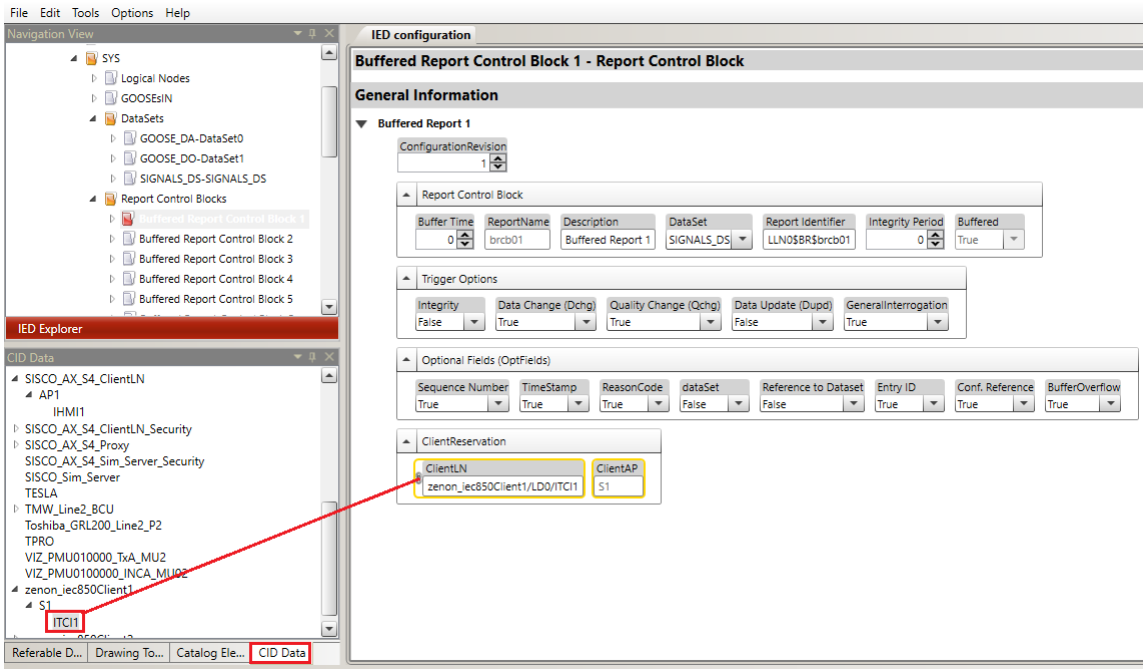


Figure D.15 Preconfiguration of a RCB.

In the hypothetical case in which a ***ClientLN*** has been configured without a ***ClientAp*** and the client IED has several *AccessPoints* with the same server (*ServerAt*), this is, when the tool can not determine the *AccessPoint* of the Logical Node selected of the client, the preconfiguration of the RCB will be refused. In this case, the ***ClientLN*** will be ignored and an error notification will be displayed.

When performing a preconfiguration of a RCB, the tool will automatically add to the CID the information of the client IED (Communications field, DataTypeTemplates, etc.).

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D.13 Measurement Configuration (Data CF)

When the automatic measurement range calculation setting is enabled (AutoRanMag data located in the logic node LPHD), the relay will carry out the automatic calculation of the 6 elements of the measurements *rangeC*. In this case, these elements will be *read only* type. The automatic calculation will be as follows:

- max: will be calculated as a function of the measurement, its nominal and corresponding transformation ratios.
- hhLim = min + ((max-min) * 80 / 100)
- hLim = min + ((max-min) * 60 / 100)
- lLim = min + ((max-min) * 40 / 100)
- llLim = min + ((max-min) * 20 / 100)
- min: will be calculated as a function of the measurement, its nominal and corresponding transformation ratios.

When the setting is disabled, the user can configure these *rangeC* elements as deemed appropriate, either from the configuration tool or through MMS, although the following checks will be carried out:

- rangeC.max > rangeC.min
- max>=hhLim>=hLim>=lLim>=llLim>=min

Any change in the *rangeC* values will be updated in the CID file.

On the other hand, each measurement has its *deadband* (***db*** attribute). *Deadband* represents the difference percentage between maximum and minimum values of a measurement in 1 per thousand (0.001). This setting is present in the data model since the measurements consist of two data: "**instMag/instCVal**" representing the instantaneous and continuous measurement value and "**mag/cVal**". This "**mag/cVal**" data is updated when the instantaneous measurement value is subject to a certain change, defined in the ***db*** setting and it is this "**mag/cVal**" data that is subject to the Reports and LOGS (*data change*) assessment function, namely, the data that is sent through communications in Reports and is stored in the LOG files.

Regarding GOOSE messages, both the instantaneous and the *deadband* data generate change and, thereby, the GOOSE message change *trigger*, so that instantaneous data selection in the Data Set associated with GOOSE messages is not recommended. Below is a graph with the relation between instantaneous and deadband data.

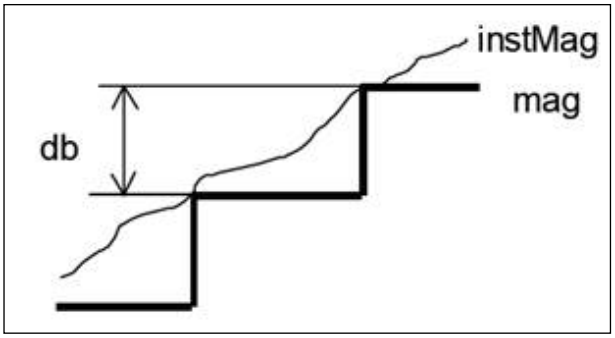


Figure D.16 Relation between Instantaneous and *Deadband* Measurement.

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As an example, below is shown the influence of the ***db*** data in the generation of changes of the measurement to be reported.

RangeC setting values max=30326402.0 and min=-30326402.
max-min= 60652804 W

db = 1000
1% del max-min => 606,5 kW
When the measurement varies 606.5 kW, a change is detected and the report is sent. In the graph above, the steps would be 606.5 kW.

db=10
0,01% del max-min => 6,065 kW
When the measurement varies 6.065, a change is detected and the report is sent. In the graph above, the steps would be 6.065 KW.

db=1
0,001% del max-min => 606,5 W
When the measurement varies 606.5, a change is detected and the report is sent. In the graph above, the steps would be 606.5 W.

D.14 Commands

Relays support SBO and direct commands, with or without enhanced safety as a function of the ***ctlModel*** setting value present in every relay commanding data:

- ***ctlModel*** = 0: non commanding data.
- ***ctlModel*** = 1: direct command with normal safety, which can be run after writing the applicable *Oper* attribute.
- ***ctlModel*** = 2: SBO command with normal safety. Before running it, first select the data by reading the *SBO* attribute. The IED will return the *path* of the selected data as indication of a good operation and “null” in case of error. Once selected, the data can be run after writing the corresponding Oper before the time ***sboTimeout*** times out, after which time the element is not longer selected.
- ***ctlModel*** = 3: direct command with enhanced safety that can be run after writing the corresponding *Oper* attribute. The IED will send information on how the command has been run: execution of the command rejected, failed termination or successful termination, indicating the cause of the failure in the first two situations
- ***ctlModel*** = 4: SBO command with enhanced safety. In order to run it, first select the data by writing the *SBOw* attribute. Once selected, the data can be run after writing the corresponding Oper with the same SBOw write parameters before the time ***sboTimeout*** times out, after which time the element is not longer selected. The IED will send information on how the command has been run: selection of the command rejected, execution of the command rejected, failed termination or successful termination, indicating the cause of the failure in the first three situations.

The device supports the *interlock-check* for any configurable command, so that, depending on the value of the mentioned *Check* attribute, the device will apply the information of the associated CILO Logical Node to the command to block it or to skip such blocking.

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D.15 SNTP Synchronization

The IED is able to synchronize through the communications network by SNTP protocol (*Simple Network Time Protocol*), as indicated by IEC 61850. The SNTP client of the equipment can be configured in *broadcast* or *unicast* mode: with one or two servers:

- *Broadcast*: the relay will wait to receive *broadcast* messages sent by the GPS clock for synchronizing.
- *Unicast*: the relay will send a date and time request to the GPS clock and will be synchronized with the message received.

The settings are detailed in the Physical Description section of the Description and Start-Up chapter.

D.15.1 SNTP Synchronism Status Calculation

The SNTP module recalculates its status every time any client (*unicast* or *broadcast*) calculates its own, which occurs with a change in its status (online/offline) due to timing, at the end of each interrogation cycle with response (correct structure) on the part of a server (*unicast client*) or with each received *broadcast* message (*broadcast* client).

The calculation method varies as a function of the ***Synchronism status calculation*** setting value:

- If the setting has been configured as ***Leap indicator***, the SNTP module status will be the latest status calculated by any of the *unicast* and *broadcast* clients.
- If the setting has been configured as ***Timing***, the SNTP module status will be a combined status of both *unicast* and *broadcast* clients, following two possible algorithms:
  - If ***broadcast error timing*** is set to 0, the SNTP module status is only a function of the *unicast* client status, except when the *broadcast* client switches from offline to online, at which time the SNTP module switches to the online status until a new *unicast* client status calculation.
  - If ***broadcast error timing*** is set to a value other than 0, the SNTP module status is a combination of the *unicast* and *broadcast* client statuses. In this mode, the SNTP module status will be:
    Synchronized if any client is in synchronized status.
    Non Synchronized if no client is synchronized and any client is not synchronized.
    Non calculated if all the clients are in non-calculated status.

D.15.1.a *Unicast* Client

A disabled *unicast* client does not make synchronization requests to servers. Therefore, when the IED client is enabled, it will interrogate the servers that have a configured IP address other than 0.0.0.0, which is the server identifier to be ignored.

Synchronization Period and ***Interval Between Retries*** settings define the time request interval to the servers when the client is in synchronized status and non-synchronized status respectively. The ***Number of Retries*** setting defines the maximum number of retries on a server if a valid response is not received. A 0 value indicates that retries will not be made, namely, only one connection attempt will be made. The ***SNTP Time Between Retries*** setting indicates the maximum waiting time between retries.

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As a function of these settings, the relay will send the appropriate messages and will wait for the answer on the part of the SNTP server. If ***Ignore leap indicator*** is set to **NO**, the received message will be process in terms of *leap indicator* field (less than 3), *stratum* field (from 0 to 16) and time difference between server and client (less than the ***Maximum Synchronization Time Difference*** *setting* except that the setting is 0), so that these received values must be within ranges in order to accept the synchronization, but when the ***Ignore leap indicator*** setting is set to **YES**, the message will be directly accepted. If the message is not accepted, the IED will interrogate the second server. The relay, in this way, will successively interrogate the servers until receiving a valid response from one of them. If, after going through all the servers, a correct response is not received, **non-synchronized** status will be shown. The relay will listen to NTP messages sent to its own IP address.

If the synchronized status calculation is set to timing, the ***Unicast Validity Timing*** setting specifies the time lapse from the first valid message received without receiving error messages or timeouts, so that the client switches to a synchronized Status. When the setting sets to 0, the waiting time is 0 seconds, so that the unicast client will switch to synchronized Status when the first correct message is received.

Unicast Error Timing enables selecting the time lapse from the last valid message received, so that the unicast client switches to non-synchronized Status. The timing also starts at the time when the client reaches the synchronized Status, since it could remain in this status without receiving any valid message.

D.15.1.b *Broadcast* Client

The *broadcast* client receives NTP synchronization *broadcast* messages, sets the time in accordance with the same, and calculates synchronism status at all times. When disabled, the IED will ignore the received synchronization messages. The synchronized status will be produced the moment a correct message is received, provided the time set in ***Broadcast Validity Timing,*** elapsed from the first correct message received, has run out, switching to non-synchronized when no valid messages are received within the time configured in ***Broadcast Error Timing***. The *broadcast* client will permanently be awaiting to receive NTP *broadcast* synchronization messages, listening to messages received with destination IP address 255.255.255.255 or *broadcast* address corresponding to the subnetwork that it belongs to. Listening to messages sent to its IP address in particular is also deemed correct.

Force unicast setting establishes whether a new *unicast* refresh must be sent at the time of receiving a *broadcast* message. The *unicast* client, when receiving the synchronization request, will cancel the refresh in progress if applicable and will immediately start a new refresh process with the servers.

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Protocol Implementation Conformance Statement for the IEC 61850 interface in RTF/DLF from ZIV Aplicaciones y Tecnología

10/04/2019, V. 0.0

UCA International Users Group
Testing Sub Committee

PICS template extracted from Server Test Procedures for Edition 2 TPCL 1.2.6

PICS Template for Server Ed1/Ed2

General

The following ACSI conformance statements are used to provide an overview and details about RTF/DLF, with firmware version 0.9.1:

- ACSI basic conformance statement,
- ACSI models conformance statement,
- ACSI service conformance statement

The statements specify the communication features mapped to IEC 61850-8-1 and IEC 61850-9-2.

ACSI basic conformance statement

The basic conformance statement is defined in Table A.1.

Table A.1 – Basic conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments
Client-Server roles				
B11	**Server** side (of TWO-PARTY-APPLICATION-ASSOCIATION)	—	Y	
B12	**Client** side of (TWO-PARTY-APPLICATION-ASSOCIATION)	N	—	
SCSMs supported				
B21	**SCSM**: IEC 61850-8-1 used	N	Y	
B22	**SCSM:** IEC 61850-9-1 used			Deprecated Ed2
B23	**SCSM**: IEC 61850-9-2 used			
B24	**SCSM**: other			
Generic substation event model (GSE)				
B31	**Publisher** side	—	Y	
B32	**Subscriber** side	Y	—	
Transmission of sampled value model (SVC)				
B41	**Publisher** side	—	N	
B42	**Subscriber** side	N	—	

– = not applicable
Y = supported
N or empty = not supported

ACSI models conformance statement

The ACSI models conformance statement is defined in Table A.2.

Table A.2 – ACSI models conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments
If **Server** side (B11) and/or **Client** side (B12) supported				
M1	**Logical device**	N	Y	
M2	**Logical node**	N	Y	
M3	**Data**	N	Y	
M4	**Data set**	N	Y	
M5	**Substitution**	N	N	
M6	**Setting group control**	N	Y	
	Reporting			
M7	**Buffered report control**	N	Y	
M7-1	sequence-number	N	Y	
M7-2	report-time-stamp	N	Y	
M7-3	reason-for-inclusion	N	Y	
M7-4	data-set-name	N	Y	
M7-5	data-reference	N	Y	
M7-6	buffer-overflow	N	Y	
M7-7	entryID	N	Y	
M7-8	BufTm	N	Y	
M7-9	IntgPd	N	Y	
M7-10	GI	N	Y	
M7-11	conf-revision	N	Y	
M8	**Unbuffered report control**	N	Y	
M8-1	sequence-number	N	Y	
M8-2	report-time-stamp	N	Y	
M8-3	reason-for-inclusion	N	Y	
M8-4	data-set-name	N	Y	
M8-5	data-reference	N	Y	
M8-6	BufTm	N	Y	
M8-7	IntgPd	N	Y	
M8-8	GI	N	Y	
M8-9	conf-revision	N	Y	
	Logging	N	N	
M9	**Log control**	N	N	
M9-1	IntgPd	N	N	
M10	**Log**	N	N	
M11	**Control**	N	Y	
M17	**File Transfer**	N	Y	
M18	**Application association**	N	Y	
M19	**GOOSE Control Block**	N	Y	
M20	**Sampled Value Control Block**	N	N	

		Client/ Subscriber	Server/ Publisher	Value/ Comments
If **GSE** (B31/32) is supported				
M12	**GOOSE**	N	Y	
M13	**GSSE**			Deprecated Ed2
If **SVC** (B41/42) is supported				
M14	Multicast SVC	N	N	
M15	Unicast SVC	N	N	
For all IEDs				
M16	**Time**	N	Y	Time source with required accuracy shall be available. Only Time Master are SNTP (Mode 4 response) time server. All other Client / Server devices require SNTP (Mode 3 request) clients
Y = service is supported N or empty = service is not supported				

ACSI service conformance statement

The ACSI service conformance statement is defined in Table A.4 (depending on the statements in Table A.1 and in Table A.3).

Table A.4 – ACSI service Conformance statement

	Ed.	Services	AA: TP/MC	Client ©	Server (S)	Comments
Server						
S1	1,2	GetServerDirectory (LOGICAL-DEVICE)	TP	N	Y	
Application association						
S2	1,2	Associate		N	Y	
S3	1,2	Abort		N	Y	
S4	1,2	Release		N	Y	
Logical device						
S5	1,2	GetLogicalDeviceDirectory	TP	N	Y	
Logical node						
S6	1,2	GetLogicalNodeDirectory	TP	N	Y	
S7	1,2	GetAllDataValues	TP	N	Y	
Data						
S8	1,2	GetDataValues	TP	N	Y	
S9	1,2	SetDataValues	TP	N	Y	
S10	1,2	GetDataDirectory	TP	N	Y	
S11	1,2	GetDataDefinition	TP	N	Y	
Data set						
S12	1,2	GetDataSetValues	TP	N	Y	
S13	1,2	SetDataSetValues	TP	N	N	
S14	1,2	CreateDataSet	TP	N	N	
S15	1,2	DeleteDataSet	TP	N	N	
S16	1,2	GetDataSetDirectory	TP	N	Y	
Substitution						
S17	1	SetDataValues	TP	N	N	
Setting group control						
S18	1,2	SelectActiveSG	TP	N	Y	
S19	1,2	SelectEditSG	TP	N	Y	
S20	1,2	SetEditSGValues	TP	N	Y	
S21	1,2	ConfirmEditSGValues	TP	N	Y	
S22	1,2	GetEditSGValues	TP	N	Y	
S23	1,2	GetSGCBValues	TP	N	Y	

	Ed.	Services	AA: TP/MC	Client ©	Server (S)	Comments
Reporting						
Buffered report control block (BRCB)						
S24	1,2	Report	TP	N	Y	
S24-1	1,2	data-change (dchg)		N	Y	
S24-2	1,2	quality-change (qchg)		N	Y	
S24-3	1,2	data-update (dupd)		N	N	
S25	1,2	GetBRCBValues	TP	N	Y	
S26	1,2	SetBRCBValues	TP	N	Y	
Unbuffered report control block (URCB)						
S27	1,2	Report	TP	N	Y	
S27-1	1,2	data-change (dchg)		N	Y	
S27-2	1,2	quality-change (qchg)		N	Y	
S27-3	1,2	data-update (dupd)		N	N	
S28	1,2	GetURCBValues	TP	N	Y	
S29	1,2	SetURCBValues	TP	N	Y	

Logging						
Log control block						
S30	1,2	GetLCBValues	TP	N	N	
S31	1,2	SetLCBValues	TP	N	N	
Log						
S32	1,2	QueryLogByTime	TP	N	N	
S33	1,2	QueryLogAfter	TP	N	N	
S34	1,2	GetLogStatusValues	TP	N	N	

Generic substation event model (GSE)						
GOOSE						
S35	1,2	SendGOOSEMessage	MC	N	Y	
GOOSE-CONTROL-BLOCK						
S36	1,2	GetGoReference	TP	N	Y	
S37	1,2	GetGOOSEElementNumber	TP	N	Y	
S38	1,2	GetGoCBValues	TP	N	Y	
S39	1,2	SetGoCBValues	TP	N	Y	
GSSE						
S40	1	SendGSSEMessage	MC			Deprecated in Edition 2
GSSE-CONTROL-BLOCK						
S41	1	GetReference	TP			Deprecated in Edition 2
S42	1	GetGSSEElementNumber	TP			Deprecated in Edition 2
S43	1	GetGsCBValues	TP			Deprecated in Edition 2
S44	1	SetGsCBValues	TP			Deprecated in Edition 2

	Ed.	Services	AA: TP/MC	Client ©	Server (S)	Comments
Transmission of sampled value model (SVC)						
Multicast SV						
S45	1,2	SendMSVMessage	MC	N	N	
Multicast Sampled Value Control Block						
S46	1,2	GetMSVCBValues	TP	N	N	
S47	1,2	SetMSVCBValues	TP	N	N	
Unicast SV						
S48	1,2	SendUSVMessage	TP	N	N	
Unicast Sampled Value Control Block						
S49	1,2	GetUSVCBValues	TP	N	N	
S50	1,2	SetUSVCBValues	TP	N	N	

Control						
S51	1,2	Select		N	Y	
S52	1,2	SelectWithValue	TP	N	Y	
S53	1,2	Cancel	TP	N	Y	
S54	1,2	Operate	TP	N	Y	
S55	1,2	CommandTermination	TP	N	Y	
S56	1,2	TimeActivatedOperate	TP	N	N	

File transfer						
S57	1,2	GetFile	TP	N	Y	
S58	1,2	SetFile	TP	N	Y	
S59	1,2	DeleteFile	TP	N	N	
S60	1,2	GetFileAttributeValues	TP	N	Y	
S61	1,2	GetServerDirectory (FILE-SYSTEM)	TP	N	Y	

Time						
T1	1,2	Time resolution of internal clock		xx	10 (1ms)	Nearest negative power of 2^{-n} in seconds (number 0 .. 24)
T2	1,2	Time accuracy of internal clock		Tx	T1	TL (ms) (low accuracy), T3 < 7) (only Ed2) T0 (ms) (<= 10 ms), 7 <= T3 < 10 T1 (µs) (<= 1 ms), 10 <= T3 < 13 T2 (µs) (<= 100 µS), 13 <= T3 < 15 T3 (µs) (<= 25 µS), 15 <= T3 < 18 T4 (µs) (<= 25 µS), 15 <= T3 < 18 T5 (µs) (<= 1 µS), T3 >= 20
T3	1,2	Supported TimeStamp resolution	-	xx	10	Nearest value of 2^{-n} in seconds (number 0 .. 24)

Protocol Implementation eXtra Information for Testing (PIXIT)
for the IEC 61850 interface in RTF/DLF
from ZIV Aplicaciones y Tecnología

10/04/2019, Version 0.1

UCA International Users Group
Testing Sub Committee

PIXIT template extracted from Server Test Procedures for Edition 2 TPCL 1.2.6

PIXIT Template for Server Ed1/Ed2

Introduction

This document specifies the protocol implementation extra information for testing (PIXIT) of the IEC 61850 interface in RTF/DLFF with firmware version 0.9.1.

Together with the PICS and the MICS the PIXIT forms the basis for a conformance test according to IEC 61850-10. The PIXIT entries contain information which is not available in the PICS, MICS, TICS documents or SCL file.

Each table specifies the PIXIT for applicable ACSI service model as structured in IEC 61850-10. The “Ed” column indicates if the entry is applicable for IEC 61850 Edition 1 and/or Edition 2.

PIXIT for Association model

ID	Ed	Description	Value / Clarification
As1	1	Maximum number of clients that can set-up an association simultaneously	10
As2	1,2	TCP_KEEPALIVE value. The recommended range is 1..20s	20 seconds
As3	1,2	Lost connection detection time	120 seconds (5 times KEEPALIVE)
As4	-	Authentication is not supported yet	
As5	1,2	What association parameters are necessary for successful association	Transport selector N Session selector N Presentation selector N AP Title N AE Qualifier N
As6	1,2	If association parameters are necessary for association, describe the correct values e.g.	Association parameters are not necessary for association
As7	1,2	What is the maximum and minimum MMS PDU size	Max MMS PDU size 65000 Min MMS PDU size Is determined by the size of the request.
As8	1,2	What is the maximum start up time after a power supply interrupt	35 seconds in normal situation (when no control configuration needs to be loaded)
As9	1,2	Does this device function only as test equipment? (test equipment need not have a non-volatile configuration; but it cannot be part of the substation automation system)	No. It has non-volatile configuration.
		<additional items>	

PIXIT for Server model

ID	Ed	Description	Value / Clarification
Sr1	1,2	Which analogue value (MX) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, N Reserved, Y Questionable N Overflow Y OutofRange N BadReference N Oscillatory N Failure Y OldData N Inconsistent N Inaccurate Source : Y Process N Substituted Y Test N OperatorBlocked
Sr2	1,2	Which status value (ST) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, N Reserved, Y Questionable N BadReference Y Oscillatory Y Failure Y OldData N Inconsistent N Inaccurate Source : Y Process N Substituted Y Test N OperatorBlocked
Sr3	-	What is the maximum number of data object references in one GetDataValues request	Deprecated
Sr4	-	What is the maximum number of data object references in one SetDataValues request	Deprecated

ID	Ed	Description	Value / Clarification
Sr5	1	Which Mode values are supported [1]	On Y [On-]Blocked Y Test Y Test/Blocked Y Off Y The supported Mode values are indicated by using different enumeration types for each case.
		<additional items>	

PIXIT for Data set model

ID	Ed	Description	Value / Clarification
Ds1	1	What is the maximum number of data elements in one data set (compare ICD setting)	Fixed in ICD to 500
Ds2	1	How many persistent data sets can be created by one or more clients (this number includes predefined datasets)	0
Ds3	1	How many non-persistent data sets can be created by one or more clients	0
		<additional items>	

PIXIT for Setting group control model

ID	Ed	Description	Value / Clarification
Sg1	1	What is the number of supported setting groups for each logical device	8
Sg2	1,2	What is the effect of when and how the non-volatile storage is updated (compare IEC 61850-8-1 $16.2.4)	If values are updated in a CID, these changes take effect after starting up. If values are updated by MMS services, these changes take effect immediately
Sg3	1	Can multiple clients edit the same setting group	N
Sg4	1	What happens if the association is lost while editing a setting group	The EditSG is reset to 0
Sg5	1	Is EditSG value 0 allowed	Y
Sg6	2	When ResvTms is not present how long is an edit setting group locked	ResvTms is present. Its default value is 3600 seconds
		<additional items>	

[1] IEC 61850-6:2009 clause 9.5.6 states that if only a subrange of the enumeration value set is supported, this shall be indicated within an ICD file by an enumeration type, where the unsupported values are missing

PIXIT for Reporting model

ID	Ed	Description	Value / Clarification
Rp1	1	The supported trigger conditions are (compare PICS)	integrity Y data change Y quality change Y data update N general interrogation Y
Rp2	1	The supported optional fields are	sequence-number Y report-time-stamp Y reason-for-inclusion Y data-set-name Y data-reference Y buffer-overflow Y entryID Y conf-rev Y segmentation Y
Rp3	1,2	Can the server send segmented reports (when not supported, it is allowed to refuse an association with a PDU smaller than the supported minimum PDU size)	Y
Rp4	1,2	Mechanism on second internal data change notification of the same analogue data value within buffer period (Compare IEC 61850-7-2 $14.2.2.9)	The DUT behaves as if BufTm has expired and sends the report immediately, restarts the timer with BufTm value and processes the second change
Rp5	1	Multi client URCB approach (compare IEC 61850-7-2:2003 $14.2.1)	Each URCB is visible to all clients
Rp6	-	What is the format of EntryID	Deprecated
Rp7	1,2	What is the buffer size for each BRCB or how many reports can be buffered	30 Kbytes
Rp8	-	Pre-configured RCB attributes that are dynamic, compare SCL report settings	Deprecated
Rp9	1	May the reported data set contain: - structured data objects - data attributes	 Y Y
Rp10	1,2	What is the scan cycle for binary events Is this fixed, configurable	2 ms Fixed
Rp11	1	Does the device support to pre-assign a RCB to a specific client in the SCL	Y

ID	Ed	Description	Value / Clarification
Rp12	2	After restart of the server is the value of ConfRev restored from the original configuration or retained prior to restart	Restored from original CID configuration
Rp13	1,2	Does the server accepts any client to configure/enable a BRCB with ResvTms=-1? What fields are used to do the identification?	N Client's IP Address
Rp14	2	When BRCB.ResvTms is exposed, what is default value for BRCB.ResvTms if client does not write (must be > 0) or When BRCB.ResvTms is not exposed, what is the internal reservation time (must be >= 0)	10 seconds N/A
Rp15	1,2	Each RCB should be configured with a different Data Set. In case of configuring the same Data Set in different RCBs those RCBs must be configured with the same trigger options and integrity period.	
		<additional items>	

PIXIT for Logging model

ID	Ed	Description	Value / Clarification
Lg1	1,2	What is the default value of LogEna (Compare IEC 61850-8-1 $17.3.3.2.1, the default value should be FALSE)	FALSE
Lg2	-	What is the format of EntryID	Deprecated
Lg3	1,2	Are there are multiple Log Control Blocks that specify the Journaling of the same MMS NamedVariable and TrgOps and the Event Condition (Compare IEC 61850-8-1 $17.3.3.3.2)	Single Journal Entry
Lg4	1	Pre-configured LCB attributes that cannot be changed online	LogRef and DatSet (DatSet is configurable by the IED tool)
		<additional items>	

PIXIT for GOOSE publish model

ID	Ed	Description	Value / Clarification
Gp1	1,2	Can the test (Ed1) / simulation (Ed2) flag in the published GOOSE be set	Y
Gp2	1	What is the behaviour when the GOOSE publish configuration is incorrect	If goose pdu is too large NdsCom=True and DUT keeps GoEna=False If no DatSet is configured NdsCom=True and DUT keeps GoEna=False CIDs with incorrect goose publish configuration are rejected
Gp3	1,2	Published FCD supported common data classes are	Any FCD with FC=ST/MX/SP Arrays are not supported
Gp4	1,2	What is the slow retransmission time Is it fixed or configurable	Max value: 2.147.483.647 ms Configured by GoCB MaxTime Default value: 2000 ms
Gp5	1,2	What is the fastest retransmission time Is it fixed or configurable	Min value: 2ms Configured by GoCB MinTime Default value: 2ms
Gp6	-	Can the GOOSE publish be turned on / off by using SetGoCBValues(GoEna)	Deprecated See PICS - SetGoCBValues
Gp7	1,2	What is the initial GOOSE sqNum after restart	1
Gp8	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y Y
		<additional items>	

PIXIT for GOOSE subscribe model

ID	Ed	Description	Value / Clarification
Gs1	1,2	What elements of a subscribed GOOSE message are checked to decide the message is valid and the allData values are accepted? If yes, describe the conditions. Notes: • the VLAN tag may be removed by a ethernet switch and shall not be checked • the simulation flag shall always be checked (Ed2)	Y destination MAC address Y APPID Y gocbRef Y timeAllowedtoLive Y datSet Y goID N t Y stNum N sqNum Y simulation / test Y confRev Y ndsCom Y numDatSetEntries Greater than expected: Not detected Less than expected: Detected Data-type mismatch in data set elements: Detected N out-of-order dataset members When Y (except datSet, confRev, simulation, ndsCom and numDatSetEntries): the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the GOOSE message indicating it by changing the quality (questionable-old data). When receiving a subscribed GOOSE with the simulate bit or the ndsCom flag activated or an incorrect dataset or confRev, the DUT will discard the GOOSE message without indicating it by changing the quality. In these cases, as soon as received a subscribed GOOSE with a data value change, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the message indicating it by changing the quality (questionable-old data).

ID	Ed	Description	Value / Clarification
			When receiving a subscribed GOOSE with numDatSetEntries less than expected or data-type mismatch, the DUT will discard the GOOSE message without indicating it by changing the quality. In these cases, as soon as received a subscribed GOOSE with a data value change, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the GOOSE message indicating it by changing the quality (invalid). When receiving a subscribed GOOSE with an incorrect confRev, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and immediatly the DUT will discard the GOOSE message indicating it by changing the quality (invalid).
Gs2	1,2	When is a subscribed GOOSE marked as lost (TAL = time allowed to live value from the last received GOOSE message)	Message does not arrive prior to TAL
Gs3	1,2	What is the behaviour when one or more subscribed GOOSE messages isn't received or syntactically incorrect (missing GOOSE)	If the TAL is expired the quality of the attribute in the database will be set to Questionable and Old Data and it will keep the last received value
Gs4	1,2	What is the behaviour when a subscribed GOOSE message is out-of-order	If there is a change of stNum (even with non zero sqNum) the new values are updated in the database. Otherwise, the message is ignored and the DUT keep holding the last received values in the database.
Gs5	1,2	What is the behaviour when a subscribed GOOSE message is duplicated	The DUT ignores the duplicated message.

ID	Ed	Description	Value / Clarification
Gs6	1	Does the device subscribe to GOOSE messages with/without the VLAN tag	Y, with the VLAN tag Y, without the VLAN tag
Gs7	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y Y
Gs8	1,2	Subscribed FCD supported common data classes are	SPS, DPS, INS, ENS, ACT, ACD, SEC, MV, CMV, WYE, DEL, SPC, DPC, INC, ENC, BSC, ISC, APC, BAC, SPG, ING, ENG, ASG, CURVE, CSG. Arrays are not supported
Gs9	1,2	Are subscribed GOOSE with test=T (Ed1) / simulation=T (Ed2) accepted in test/simulation mode	Y
Gs10	1,2	Max number of dataset members	Unlimited
		<additional items>	

PIXIT for Control model

ID	Ed	Description	Value / Clarification
Ct1	1	What control models are supported (compare ICD file enums for Ed2)	DOns: Y SBOns: Y DOes: Y SBOes: Y
Ct2	1,2	Is the control model fixed, configurable and/or dynamic	Dynamic
Ct3	-	Is TimeActivatedOperate supported (compare PICS or SCL)	Deprecated
Ct4	-	Is “operate-many” supported (compare sboClass)	Deprecated, see sboClass in datamodel (ICD)
Ct5	1	Will the DUT activate the control output when the test attribute is set in the SelectWithValue and/or Operate request (when N test procedure Ctl2 is applicable)	N
Ct6	-	What are the conditions for the time (T) attribute in the SelectWithValue and/or Operate request	Deprecated
Ct7	-	Is pulse configuration supported (compare pulseConfig)	Deprecated
Ct8	1	What is the behaviour of the DUT when the check conditions are set Is this behaviour fixed, configurable, online changeable	N synchrocheck Y interlock-check DUT ignores synchrocheck value. DUT uses interlock-check to perform or not the check. Fixed

ID	Ed	Description	Value / Clarification
Ct9	1,2	Which additional cause diagnosis are supported	Y Unknown Y Not-supported Y Blocked-by-switching-hierarchy Y Select-failed Y Invalid-position Y Position-reached Y Step-limit Y Blocked-by-Mode Y Blocked-by-process Y Blocked-by-interlocking N Blocked-by-synchrocheck Y Command-already-in-execution N Blocked-by-health Y 1-of-n-control N Abortion-by-cancel N Time-limit-over N Abortion-by-trip Y Object-not-selected **Edition 1 specific values:** N Parameter-change-in-execution (PCIE Ed1 semantics) **Edition 2 specific values:** Y Object-already-selected N No-access-authority N Ended-with-overshoot N Abortion-due-to-deviation N Abortion-by-communication-loss N Blocked-by-command N None Y Inconsistent-parameters Y Locked-by-other-client N Parameter-change-in-execution (PCIE Ed2 semantics)
Ct10	1,2	How to force a “test-not-ok” respond with SelectWithValue request	Invalid orCat value, orCat >= 9
Ct11	1,2	How to force a “test-not-ok” respond with Select request	The control is selected
Ct12	1,2	How to force a “test-not-ok” respond with Operate request	Invalid orCat value, orCat >= 9 DOns, SBOns, DOes: Operate value and actual position are the same SBOes: Operate values are different than selected

ID	Ed	Description	Value / Clarification
Ct13	1,2	Which origin categories are supported / accepted	Y bay-control Y station-control Y remote-control N automatic-bay Y automatic-station Y automatic-remote Y maintenance Y process
Ct14	1,2	What happens if the orCat value is not supported or invalid	DOns: command rejected SBOns: command rejected DOes: command rejected SBOes: command rejected The DUT sends reponse– with AccessResult=Object_access_denied and it sends, for enhanced security, CommandTermination with AddCause= Not-supported
Ct15	1,2	Does the IED accept a SelectWithValue / Operate with the same control value as the current status value Is this behaviour configurable	DOns: N SBOns: N DOes: N SBOes: Y/N Configurable N The DUT sends reponse– with AccessResult=Object_access_denied and it sends, for enhanced security, CommandTermination with AddCause= Position-reached
Ct16	1,2	Does the IED accept a select/operate on the same control object from 2 different clients at the same time	DOns: N SBOns: N DOes: N SBOes: N The DUT sends reponse– with AccessResult=temporarily-unavailable and it sends, for enhanced security, CommandTermination with AddCause= Object-already-selected / Command-already-in-execution

ID	Ed	Description	Value / Clarification
Ct17	1	Does the IED accept a Select/SelectWithValue from the same client when the control object is already selected (Tissue #334)	SBOns: N SBOes: N
Ct18	1,2	Is for SBOes the internal validation performed during the SelectWithValue and/or Operate step	The validation is performed during the Operate step
Ct19	-	Can a control operation be blocked by Mod=Off or [On-]Blocked (Compare PIXIT-Sr5)	Deprecated
Ct20	1,2	Does the IED support local / remote operation	Y
Ct21	1,2	Does the IED send an InformationReport with LastApplError as part of the Operate response-for control with normal security	SBOns: N DOns: N
Ct22	2	How to force a “parameter-change-in-execution”	N/A
Ct23	1,2	How many SBOns/SBOes control objects can be selected at the same time?	SBOns: multiple SBOes: multiple
Ct24	1,2	Can a controllable object be forced to keep its old state e.g. Internal Controllable Objects may not be accessible to force this, whereas a switch like Circuit Breaker outside the DUT can?	Y
Ct25	1,2	When CDC=DPC is supported, is it possible to have DPC (Controllable Double Point) go to the intermediate state? (00)	Y
Ct26	1,2	Name a DOes point (if any) with a finite operate timeout and specify the timeout (in milliseconds)	CTRL/CSWI1.Pos Timeout is configurable
Ct27	2	Does the IED support control objects with external signals?	DOns: Y SBOns: Y DOes: Y SBOes: Y
		<additional items>	

PIXIT for Time synchronisation model

ID	Ed	Description	Value / Clarification
Tm1	1	What time quality bits are supported (may be set by the IED)	Y LeapSecondsKnown N ClockFailure Y ClockNotSynchronized
Tm2	1,2	Describe the behaviour when the time server(s) ceases to respond What is the time server lost detection time	Wait for a configurable number of connection retries (unicast mode) or wait a configurable period of time (multicast mode). After that "Clock-not-synchronized" will be set. Configurable. Tested value: 10 seconds after the first request send to the time server without response.
Tm3	1,2	How long does it take to take over the new time from time server	Configurable Tested value: as soon as the new time from the time server is received.
Tm4	1,2	When is the time quality bit "ClockFailure" set	N/A
Tm5	1,2	When is the time quality bit "Clock not Synchronized" set	When connection to all time servers are lost (see PIXIT-Tm2)
Tm6	-	Is the timestamp of a binary event adjusted to the configured scan cycle	Deprecated
Tm7	1	Does the device support time zone and daylight saving	Y
Tm8	1,2	Which attributes of the SNTP response packet are validated	Y Leap indicator not equal to 3 N Mode is equal to SERVER N OriginateTimestamp is equal to value sent by the SNTP client as Transmit Timestamp N RX/TX timestamp fields are checked for reasonableness Y SNTP version 3 and/or 4 N other (describe)
Tm9	1,2	Do the COMTRADE files have local time or UTC time and is this configurable	Local Time Not configurable
		<additional items>	

PIXIT for File transfer model

ID	Ed	Description	Value / Clarification
Ft1	1	What is structure of files and directories Where are the COMTRADE files stored Are comtrade files zipped and what files are included in each zip file	/COMTRADE/ /SCL/active/ /SCL/notvalidated /SYSTEMLOG/ /COMTRADE/ Not zipped
Ft2	1,2	Directory names are separated from the file name by	"/"
Ft3	1	The maximum file name size including path (recommended 64 chars)	255 chars
Ft4	1,2	Are directory/file name case sensitive	Case sensitive
Ft5	1,2	Maximum file size for SetFile	N/A
Ft6	1	Is the requested file path included in the MMS fileDirectory respond file name	(Ed2: always complete path)
Ft7	1	Is the wild char supported MMS fileDirectory request	No
Ft8	1,2	Is it allowed that 2 clients get a file at the same time	Y same file Y different files
Ft9	1,2	Which files can be deleted	N/A
		<additional items>	

TISSUES Implementation Conformance Statement for the IEC 61850 Ed2 interface in RTF/DLF

03/04/2019, Version 0.0

UCA International Users Group
Testing Sub Committee

TICS template extracted from Server Test Procedures for Edition 2 TPCL 1.2.6

TICS Template Ed2 for TPCL 1.2.6

Introduction

This document provides a template for the Tissues conformance statement. According to the UCA IUG QAP the Tissue conformance statement is required to perform a conformance test and is referenced on the certificate.

This document is applicable for RTF/DLF with firmware version 0.9.1.

Mandatory Edition 2 Tissues

Below tables give an overview of the applicable mandatory Tissues.

Part 6 Tissue	Description	Implemented Y/na
658	Tracking related features	Y
1324	FCDA element cannot be a "functionally constrained logical node"	Y
668	Autotransformer modeling	Y
687	SGCB ResvTms	Y
719	ConfDataSet - maxAttributes definition is confusing	Y
721	Log element name	Y
768	bType VisString65 is missing	na
779	object references	Y
788	SICS S56 from optional to mandatory	na
789	ConfLdName as services applies to both server and client	Y
804	valKind and IED versus System configuration	Y
806	Max length of log name inconsistent between -6 and -7-2	Y
807	Need a way to indicate if "Owner" present in RCB	Y
823	ValKind for structured data attributes	Y
824	Short addresses on structured data attributes	Y
825	Floating point value	Y
845	SGCB ResvTms	Y
853	SBO and ProtNs	Y
855	Recursive SubFunction	na
856	VoltageLevel frequency and phases	na
857	Function/SubFunction for ConductingEquipment	na
886	Missing 8-1 P-types	na
901	tServices as AP or as IED element	Y

Part 6 Tissue	Description	Implemented Y/na
936	SupSubscription parameter usage is difficult	Y
1175	IPv6 address lowercase only	na

Part 7-1 Tissue	Description	Implemented Y/na
828	Data model namespace revision IEC 61850-7-4:2007[A]	Y
1151	simulated GOOSE disappears after 1st appearance when LPHD.Sim = TRUE	na
1468	Re-use DO from other LN	Y

Part 7-2 Tissue	Description	Implemented Y/na
778	AddCause values – add value not-supported	Y
780	What are unsupported trigger option at a control block?	Y
783	TimOper Resp- ; add Authorization check	Y
786	AddCause values 26 and 27 are switched	Y
820	Mandatory ACSI services (use for PICS template)	Y
858	typo in enumeration ServiceType	Y
861	dchg of ConfRev attribute	na
876	GenLogiclNodeClass and SGCB, GoCB, MsvCB, UsvCB	na
1038	Loss of Info Detection After Resynch	na
1050	GTS Phycomaddr definition in SCL	na
1062	Entrytime not used in CDC	na
1071	Length of DO name	Y
1091	The sentence "The initial value of EditSG shall be 0", has to be stated in part 7.2 not in 8.1	Y
1127	Missing owner attribute in BTS and UTS	na
1202	GI not optional	Y

Part 7-3 Tissue	Description	Implemented Y/na
697	persistent command / PulseConfig	na
698	Wrong case is BAC.dB attribute	Y
722	Units for 'h' and 'min' not in UnitKind enumeration.	Y

Part 7-3 Tissue	Description	Implemented Y/na
919	Presence Condition for sVC	na
925	Presence of i or f attribute - Problem with writing	Y
926	Presence Conditions within RangeConfig	Y

Part 7-4 Tissue	Description	Implemented Y/na
671	mistake in definition of Mod & Beh	Y
674	CDC of ZRRC.LocSta is wrong	na
676	Same data object name used with different CDC	Y
677	MotStr is used with different CDC in PMMS and SOPM LN classes	na
679	Remove CycTrMod Enum	na
680	SI unit for MHYD.Cndct	na
681	Enum PIDAlg	na
682	ANCR.ParColMod	na
683	Enum QVVR.IntrDetMth	na
685	Enum ParTraMod	na
686	New annex H - enums types in XML	Y
694	Data object CmdBlk	na
696	LSVS.St (Status of subscription)	na
712	interpretation of quality operatorBlocked	na
713	DO Naming of time constants in FFIL	na
724	ANCR.Auto	Y
725	Loc in LN A-group	na
734	LLN0.OpTmh vs. LPHD.OpTmh	na
736	PFSign	na
742	GAPC.Str, GAPC.Op and GAPC.StrVal	Y
743	CCGR.PmpCtl and CCGR.FanCtl	na
744	LN STMP, EEHealth and EEName	na
773	Loc, LocKey and LocSta YPSH and YLTC	na
774	ITCI.LocKey	na
800	Misspelling in CSYN	na
802	CCGR and Harmonized control authority	na
808	Presence condition of ZMoT.DExt and new DOs	na
831	Setting of ConfRevNum in LGOS	na
838	Testing in Beh=Blocked	na

Part 7-4 Tissue	Description	Implemented Y/na
844	MFLK.PhPiMax, MFLK.PhPiLoFil, MFLK.PhPiRoot DEL->WYE	na
849	Presence conditions re-assessing in case of derived statistical calculation	na
877	QVUB -settings should be optional	na
909	Remove ANCR.ColOpR and ColOpL	na
920	Resetable Counter is NOT resetable	na
932	Rename AVCO.SptVol to AVCO.VolSpt	na
939	Change CDC for ANCR.FixCol	na
991	LGOS: GoCBRef (as well as LSVS.SvCBRef) should be mandatory	na
1007	PTRC as fault indicator - Update of description required	na
1044	TapChg in AVCO	na
1077	Rename DOnames within LTIM	Y

Note: Tissues 675, 735, 772, 775, 776, 878 are not relevant for conformance testing

Part 8-1 Tissue	Description	Implemented Y/na
784	Tracking of control (CTS)	na
817	Fixed-length GOOSE float encoding	na
834	File dir name length 64	Y
951	Encoding of Owner attribute	Y
1040	More associate error codes	Y
1178	Select Response+ is non-null value	Y

Compare the TISSUE database for more details: www.tissues.iec61850.com

E. IEC 61850 Ed.2 Dynamic Model

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E.1 IEC 61850 Standard

IEC 61850 relay models have an extra protection and control function defined by **IEC 61850** standard.

Extra services provided by **IEC 61850** relays are:

- Reporting relay data (pickups, trips, blockings, etc) to a higher level equipment (Central Unit, Remote Control, HMI, etc).
- Quick data reporting (GOOSE) to same level relay (protections, control equipment, auxiliary services) or, even to other higher level equipment.
- MMS communications allowing any MMS client to receive the relay data model, thus being able to interact with it for editing settings and parameters and carry out commands.
- Managing a single file (**CID**) that allows to have a *backup* containing all protection, control and communications parameters.
- FTP access to oscillograms, logs, etc.
- Web server providing information on the relay status, errors, status and measurements, subscription to GOOSE messages, etc.

Each protection element contains **IEC 61850** mapping information with regard to node name and settings, available digital signals, commanding data, measurements, etc.

IEC 61850 is a substation automation standard defined by the TC57 Technical Committee. The standard is segregated into 10 parts and deals with issues related to general system requirements, engineering project management and communications requirements, putting forward a data model on which IED capacities are described. This data model is developed through the substation description language (SCL) also defined in the standard. Relay functions are modelled from the so called Logic Nodes (LN) that, at the same time, are formed from *Common Data Classes* and *Common Data Attributes*, following an object abstraction philosophy. Together with these objects, the standard defines a set of services through the so called *Abstract Communication Service Interface* (ACSI). Sections 8 and 9 of the standard explain how these objects and services are mapped in terms of given protocols, specifically, MMS, GOOSE and Sampled Values. The last section of the standard deals with the conformity tests that a relay or architecture must pass in order to be approved according to the standard, thus covering all aspects.

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Therefore, the standard includes the chapters or parts below:

- *IEC 61850-1: Introduction and overview.*
- *IEC 61850-2: Glossary.*
- *IEC 61850-3: General requirements.*
- *IEC 61850-4: System and project management.*
- *IEC 61850-5: Communication requirements for functions and device models.*
- *IEC 61850-6: Configuration language for communication in electrical substations related to IEDs.*
- *IEC 61850-7: Basic communication structure for substation and feeder equipment.*
  IEC 61850-7-1: Principles and models.
  IEC 61850-7-2: Abstract communication service interface (ACSI).
  IEC 61850-7-3: Common Data Classes.
  IEC 61850-7-4: Compatible logical node classes and data classes.
- *IEC 61850-8-1: Specific communication service mapping (SCSM) Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2) and to ISO/IEC8802-3.*
- *IEC 61850-9: Specific communication service mapping (SCSM).*
  IEC 61850-9-1: Sampled values over serial unidirectional multidrop point to point link.
  IEC 61850-9-2: Sampled values over ISO/IEC 802-3.
- *IEC 61850-10: Conformance testing.*

E.2 Communications Stack

The IED will be based on the *Client-Server* model to give data contained in its data model in a vertical way. It is a connection oriented communications, always initiated by the client and, in this case, using the MMS (*Manufacturing Message Specification*) standard, specifically developed for industrial applications, specified according to ISO 9506 and used for data interchange in production environments. This protocol is independent of the type of network or connected devices and, therefore, can be maintained as physical communications technology evolves. The protocol defines communications messages transferred between controllers, as well as between the engineering station and the controller, so that the server (IED) will make available to the clients (central units, gateways, SCADAs, computers, etc.) the data selected in a *Data Set* that will have been allocated to a *Report Control Block*. The IEC 61850-8-1 part defines the mapping between the MMS protocol service and the IEC 61850 abstract services.

The IED also has the *Publisher-Subscriber* model that the GOOSE service is based on. In this case, it is a high speed non connection oriented communications, thus enabling horizontal communications between IEDs. The message sent by the publisher will be a *multicast* message that will propagate through the local network, thus reaching all the IEDs connected to the same.

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E.3 IEC 61850 Server and Data Model

The IED server and, thus, the predefined physical device (default CID file generated by the configuration tool, eNET Tool), contains three *Logical Devices*. Those *Logical Device (LD)* includes all the different *Logical Nodes (LN)* that, at the same time, contain *Data Objects* (*DO*) composed of *Data Attributes* (*DA*) and that, as a whole, form the predefined relay data model (protection data). At each level, there are services available to carry out a number of functions, like reading and writing data, commands, reporting, etc.

The distribution of the predefined Logical Nodes inside the Logical Devices is the following one:

- **SYS**: *Logical Device* of the System where the *Setting Group Control Blocks, LOGs*, are located. This is also the place where the *Logical Nodes* related to the hardware of the IED are located (inputs, outputs, communications, synchronization, etc.).
- **PROT**: *Logical device* where are located the Logical Nodes of the IED.
- **MEA**: *Logical device* where are located the *Logical Nodes* related to measurements.

Apart from the protection nodes, such as PHSPIOC, PTOV, PTOF, PTUF, RREC, RBRF, PTRC, etc. that are defined in the applicable chapters where the relay protection functions are explained, the relay has the configurable control nodes described below. These control nodes will not be present in the relay data models unless they have been registered and configured with the configuration tool:

- XCBR: control node that features a double digital data used to map the status of a three pole breaker.
- XSWI: node that features a double digital data used to map the status of the disconnect switches.
- CSWI: this control node contains the double commands on the switchgear (breaker and disconnect switches).
- CILO: control node used to map the permits of the different commanding objects.
- GAPC: general control node with single and double general purpose states and commands except for switchgear elements (breakers and disconnect switches).
- GGIO: general control node with single and double status and integer and floating analog measurements used to have any relay data available in IEC 61850. Although there are up to a maximum of 4 nodes of this type, using as far as possible the relay own protection nodes is recommended, restricting the use of these nodes to own user data generated in the control logic.
- CALH: control node used to map bay alarms.
- SIMG: control node used to map SF6 alarm and trip.
- MMTR: control node used to map energy meters calculated in control logic, normally from pulse inputs coming from external energy meters.
- LGOS: control node used to monitor the state of an input GOOSE.

The MICS file (Model Implementation Conformance Statement), which describes the extensions of the IEC 61850 data model in relation to the standard, is generated automatically by the configuration tool once defined the IED model and the corresponding configuration.

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The Dynamic Data Model allows:

- Reorganizing the IEC 61850 information, this is, create or delete LDs, LNs or DOs or moving LNs from one LD to another LD or DOs from one LN to another LN.
- Carrying out internal mappings (relating IEC 61850 data to the internal data in the relay).
- The possibility of renaming LDs, LNs (prefix and/or instance) and Control Blocks (flexible naming).
- Adding new LNs according to the LNClass defined in the standard.

The IED will have a predefined data model that will include only those LNs and DOs with an associated protection functionality. This predefined data model will be obtained using the configuration tool, ***ZIV eNET Tool***®. A device with the manufacturing configuration will have just one LD (SYS) and two LNs (LN0 and LPHD).

The user will be able to create a specific data model with the required LDs and LNs, complying with the IEC 61850 rules and taking into account the limitations of the device which are defined in the configuration tool. The LDs and LNs can be created from scratch or using the elements provided in the predefined data model. The user will be able to:

- Add DOs.
- Delete DOs.
- Remap DOs which share the same CDC (Common Data Class).
- Rename extended DOs.
- Define new DOs. The new DOs can be optional or extended. In case of being extended, the CDC must be supported by the device.

The content of a DO of the reference data model (upper left corner of the tool) cannot be modified, but it can be used in other LNs, can be deleted or renamed in the user defined data model (configuration area). On the other hand, it must be taken into account that in case of DOs which represent settings, they are allowed to appear/exist just once.

Hereafter, it is described more in detail the configuration possibilities per each element.

E.3.1 AccesPoint

Depending on the model version of the IED, the functionality related to the AccessPoints changes. In those IEDs which operate only with one AccessPoint, it will only be allowed to modify the name attribute of the *AccessPoint*.

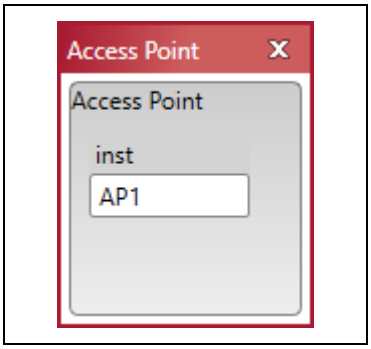


Figure E.1 AccessPoint Modification.

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The models that manage AccessPoints, inside the Communications menus the user has access to their configuration.

On the one hand they will be displayed the available SubNetWorks (by default 2 or 4 depending on the number of LAN ports of the IED) and on the other hand, the AccessPoings where it can be defined the type of redundancy and the SubNetWork that it will be associated with. When any of these parameters is modified, the information shown in the SubNewWorks scressn will be automatically updated.

It should be taken into account that, from a redundancy perspective, the LAN ports operate by pairs (LAN1-LAN2 and LAN3-LAN4). Therefore, when setting the redundancy parameter with a value different to “none”, one of the ports will disappear (LAN2 or LAN4) and with it the corresponding SubNetWork.

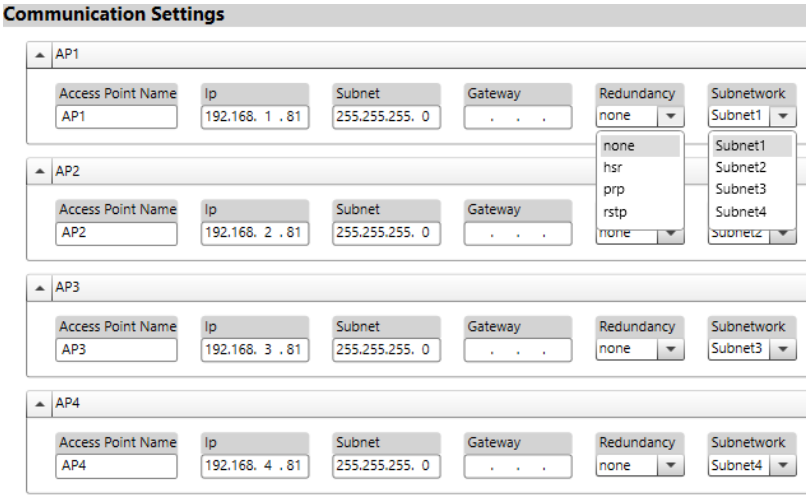


Figure E.2 AccessPoint Configuration.

Also, a new parameter will appear in the GOOSE Control Block configuration so that you can define to which AccessPoint the GCB will be associated with.

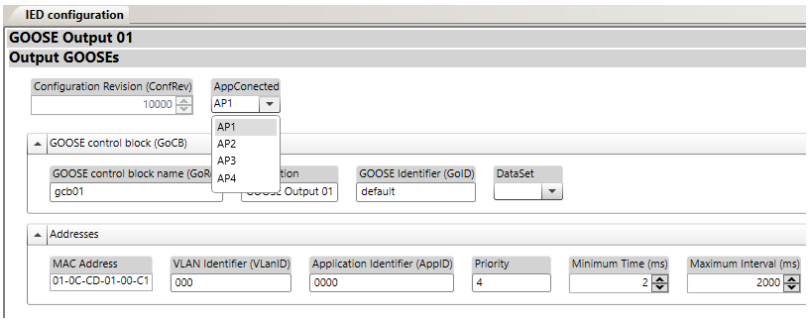


Figure E.3 AccessPoint Configuration inside the GCB.

If the user modifies the configuration of the AccessPoints once they have already been assigned to the different GCBs, and one AP that was been used disappears, automatically the tool will update the association of the GCB to the remaining AP (AP1/AP3). If later the AP configuration is changed again so that all of them are available again, the configuration tool will not proceed with any change and it will be the responsibility of the user to modify, if necessary, the assignation of the APs to the GCBs. On the other hand, the IED can receive GOOSE messages by any LAN port and therefore nothing specifically has to be configured.

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E.3.2 Logical Device

It will be allowed to rename, add or delete LDs from the predefined data model in the user defined data model (UDDM).

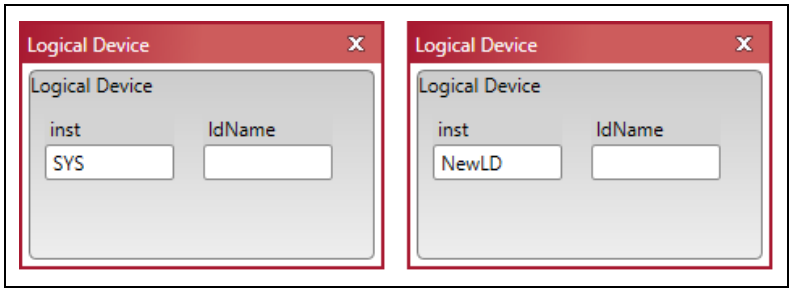


Figure E.4 Modification of LDs.

There will be a root LD where the LPHD LN will be located and the rest of LDs will have the *GrRef* DO to indicate the reference to the root LD which manages its behaviour.

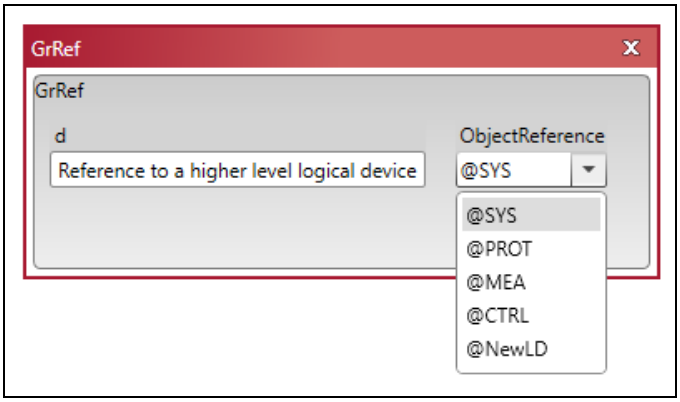


Figure E.5 Reference of LDs.

E.3.3 Logical Node

New LNs can be added selecting one *LNClass* available in the list shown by the configuration tool and defining the desired Prefix. Once added the user will have access to the DOs, being able to select the required optional DOs and with the possibility of adding new extended DOs if required. It is also possible to create new LNs with *LNClass* not defined in the standard.

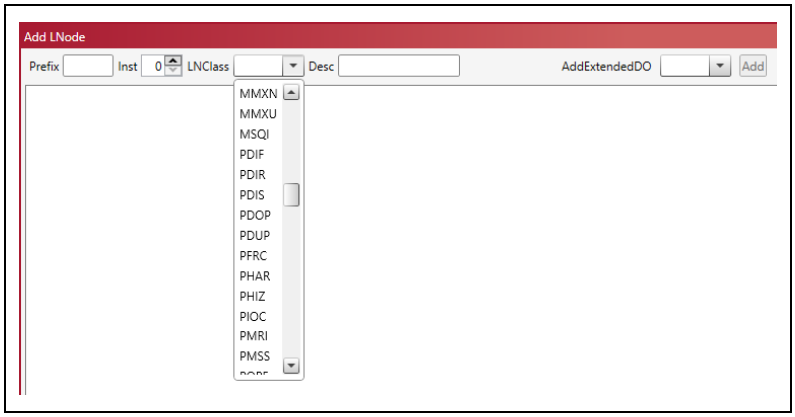


Figure E.6 New LN.

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The LNs that appear in the UDDM can be deleted or modified (*Prefix*, *Instance*, *Remove* optional DOs, *Add* optional or *Extended DOs*).

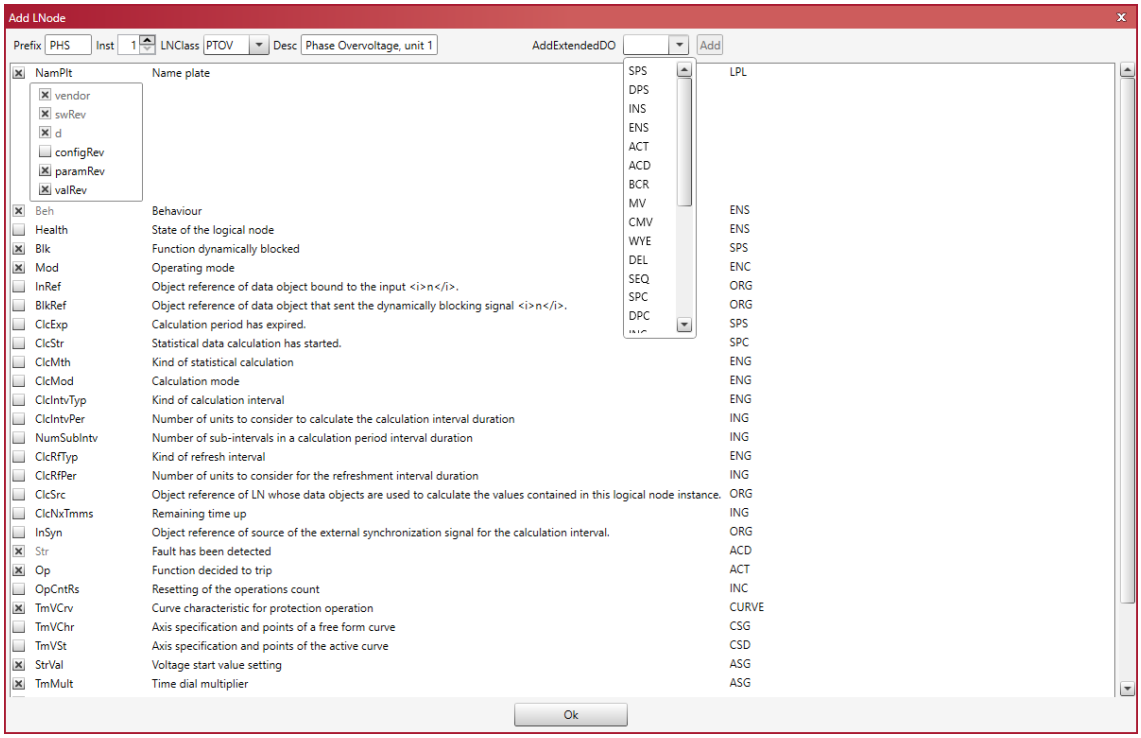


Figure E.7 Modification of LN.

It is also allowed moving one LN from one LD to another LD.

Once one DO is added inside a LN, the available resources of the IED will be used for the mapping.

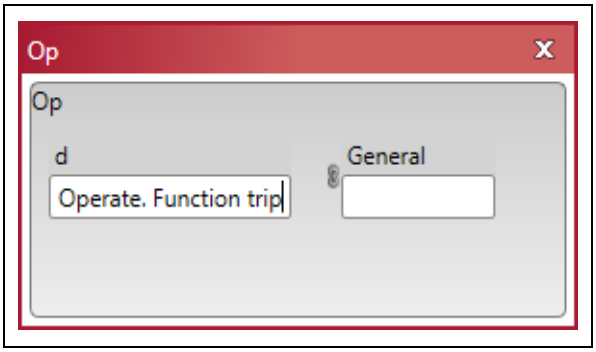
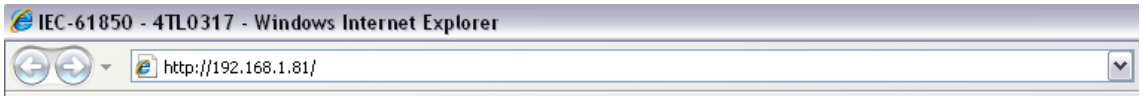


Figure E.8 Data Mapping.

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E.4 Web Server

Firmware versions, boot up status and useful relay data, can be accessed through the web server (using HTTP or HTTPS). To gain access, write the relay IP in a web browser:



Once authenticated (user admin, password Passwd@02 by default), the following data will be displayed:

- **Configuration**: relay identification data (hostname, location, contact, complete product model, firmware version, firmware reference and serial number) and access control data and certificates (see Cybersecurity Annex) are displayed. Additionally, it is allowed, only with the corresponding permission, to enable and disable Serial Log (option for analysis of internal anomalies by the manufacturer). Click ***Send*** and ***Apply*** to run this action.
- **Statistics**: this section shows the time the relay has been operating since the last boot up, the date and UTC time, the percentage of memory used and the percentage of CPU used. The relay date can be edit with permission to change settings.
  - **Routing**: traffic statistics can be accessed in case of using routers.
- **Log menu.** It is accessible with permission to manage logs. Shows the following information:
  - **System log:** register with boot up and system operation data that informs the user on the relay status where the reasons for CID rejection and other issues can be consulted. This register is stored in non-volatile memory. Click the button located at the top of the screen within section Download of System log, named Download File, to download the data into a text file.
  - **Security log**: see Cybersecurity Annex.
- **IEC-61850**. A number of data related to IEC 61850 standard are displayed.
  - **CID log**: register with loading data of new CID files. This register is stored in volatile memory since it stores data related to the last load. The history file may be obtained from System log.
  - **Analog signals list**: list of analog measurements available in IEC 61850 with the following data:
    - Description.
    - MMS path.
    - Value.
    - Quality: it consists of 3 fields:
      - Validity (**G**ood, **I**nvalid, **R**eserved, **Q**uestionable)
      - Quality Bit (**OV** overflow, **OR** out of range, **BR** bad reference, **OS** oscillatory, **FL** failure, **OD** old data, **ER** inconsistent, **IN** inaccurate)
      - Origin (**P** process, **S** substituted)/**T**est/Operator**B**locked.
    - Date of last update.
    - Information concerning maximum and minimum calculation (whether automatic or not).
    - Maximum value.
    - Minimum value.
    - Magnitude deadband setting.
    - Angle deadband setting.
  - **Digital signals list**: list of digital signals available in IEC 61850 with description, MMS path, value, quality and date of last update.

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- **GOOSE subscription list**: list of subscriptions to GOOSE messages where the configured subscription data can be seen (MAC, APPID, GOID, etc.) and the subscription status:
  - NOT FOUND: The configured GOOSE has never been received. The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA. It is the initial state of subscriptions.
  - OK: The GOOSE has been received perfectly and has been received before the TAL (*TimeAllowedToLive*). The quality of the data subscribed to that GOOSE (node GIGGIO1) will be either that contained in the GOOSE if the data is subscribed to the quality or GOOD if it is not.
  - TIME OUT: The GOOSE has ever been perfectly received and is no longer received in the TAL (*TimeAllowedToLive*). The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA.
  - STRUCT ERROR: The GOOSE has been received but the type of data does not match the expected type or the information is not present in the GOOSE. The quality of the data subscribed to that GOOSE whose type does not match the expected type will be INVALID and without cause. If any of the information expected in the GOOSE mapped to the data does not match or that information does not travel in the GOOSE, the quality of the data will be marked as INVALID
  - NDSCOM ERROR: The received GOOSE comes with the *NdsCom* field to TRUE. The GOOSE is ignored and the quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA.
  - ERROR HOLD TIME: The received GOOSE has TAL=0. In this case, the GOOSE is ignored.
  - CONFREV ERROR: The GOOSE has been received perfectly, but with *ConfRev* different from that configured. The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately passed to QUESTIONABLE by OLDDATA.
  - DATSET ERROR: The GOOSE has been received perfectly, but with a different *DatSet* than the one configured. The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately transferred to QUESTIONABLE by OLDDATA.
  - INTERRUPTED: The IED has stopped/interrupted the subscription to this GOOSE (for example, because the computer switches to Off mode). The quality of the data subscribed to that GOOSE (node GIGGIO1) is immediately switched to QUESTIONABLE by OLDDATA.
  - WAITING: Indicates that, having received and processed GOOSEs correctly, a change of LPHD1.Sim=FALSE has been detected. The quality of the data subscribed to that GOOSE (node GIGGIO1) will be QUESTIONABLE by OLDDATA. This status will only be changed when a change in LPHD1.Sim=FALSE is detected and LGOS[X].SimSt=TRUE has just been obtained.
- **Download file:** the name of the active CID file that the relay is operating with is displayed to the top as title. Click the Download File button located under it to download the file.

- **Actions menu** (only with administrator access).
  - **Apply**. After having been changed and sent, the parameters are applied to the relay.
  - **Clear Statistics**. Deletes statistics stored in the relay.
  - **Reboot**. Resets the relay.
  - **Reflash**. Updates the relay with a new firmware version.

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Taking into account the differences between the actions below (only available for administrator users) is very important.

- Send changed parameters to the relay. Click ***Send*** in the modified page to carry out this action.
- Once the desired parameters have been configured, the ***Apply*** action will activate these changes and the relay will commence to use the new applied configuration.
- Click ***Reboot*** to reset the relay.

E.5 Communications Port

The IEDs have two or four LAN ports for IEC 61850 communications. This LAN ports use the Ethernet network, using the TCP/IP protocol for MMS (standard used to pack the information in the network) communications, sending and receiving GOOSE messages, file transfer through FTP, etc. Therefore, regardless the physical media and the connection (fiber, copper, etc.), configuring the relay network IP configuration is necessary.

The relay can communicate in IEC 61850 with up to 10 clients and with 4 masters simultaneously, the port number and the protocol (PROCOME, DNP3 or MODBUS) being able to be configured. Also, the relay will always be able to communicate simultaneously with the manufacturer tool for relay remote management through the fixed port 32001.

The relay will therefore have a menu to configure the LAN ports:

- DHCP enable.
- IP address.
- Network mask.
- Routing configuration menu if required.
- Redundancy type.

And a menu to configure the TCP/IP protocols simultaneously enabled together with IEC 61850:

- PROCOME protocol: fixed connection to the TCP/IP 32001 port for remote relay management through the manufacturer tool.
- Protocols 1, 2, 3 and 4: settings to indicate protocol, TCP/IP port, etc. for simultaneous TCP/IP communications with the relay.

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E.6 File Transfer

File transfer access (using FTP or SFTP) will enable the availability of a number of relay folders. Different access levels will be obtained as a function of the user and password.

Accessing the equipment with user with visualization permission, read only access is gained to the following directories:

- COMTRADE: folder where the generated oscillograms are saved.
- SCL: folder containing the active CID that the relay is working with (SCL/active/).

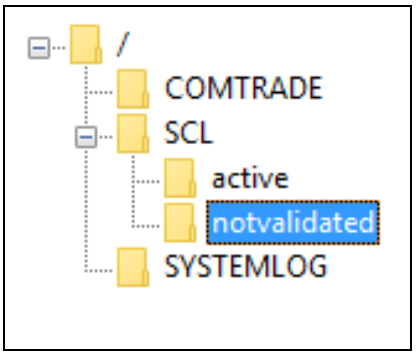


Figure E.9 Directory Structure for File Transfer.

Accessing the equipment with a user with permission to manage logs, you have read-only access to the following directory:

- **SYSTEM LOG**: folder containing *System.log* and *Security.log*.

Accessing the equipment with user with configuration loading permission, the equipment also offers write permission on the */SCL/notvalidated* folder, where the user can copy the new CID to load the equipment. When the new CID is copied to that location the equipment begins its validation.

In those cases where the relay is reset or has had a bad operation, the firmware automatically generates a file, *coredump,* where the status at the time of the failure is stored so as to be able to analyse the issue. Accessing by file transfer with a user with permission to manage logs, access to a read only folder with this information is gained.

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E.7 CID Configuration File

The standard defines the following files that will form part of the IED configuration process:

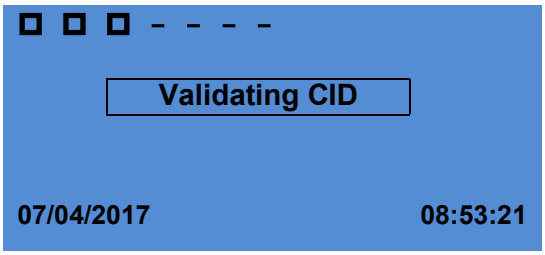
- ICD: file describing the IED capabilities. All nodes are extended and without configuration.
- CID: file containing a specific IED configuration at IED name, communications, Reports, etc. level

Both files allow knowing the relay data model in Logical Devices, Logical Nodes, Data and Attribute form. Once the relay has an IEC 61850 firmware, a basic file (**CID** with one LD and two LNs, LN0 and LPHD) will be available in the format proposed by the **IEC 61850** standard according to section 6 (SCL) that can be downloadable by file transfer, web server or FileTransfer service of IEC 61850. With the configuration tool, eNET Tool, a CID file can be generated with the complete predefined data model.

The CID file is used to configure send GOOSE message parameters, subscription to data of other GOOSE messages, create and allocate *datasets* to Report Control Blocks (RCBs) and GOOSE Control Blocks (GCBs), edit settings, control logic, descriptions, parameters etc.

The file can be edited using the program ***ZIV e-NET Tool***®. This program allows configuring the file that will later be sent to the relay through file transfer from the configuration tool. The starting CID file can be the file downloaded from the relay or a new file generated from the tool itself.

When a new CID file is loaded to the relay through file transfer (using a user with configuration loading permission), it is validated by the relay checking it is a correct SCL and that the configured IP in the file matches the IP configured in the relay, and the message **Validating CID** is displayed on the screen.



Once it has been validated, if the result is correct, the message **Validation SUCCESS** is displayed on the screen and the relay will be rebooted and reconfigured. The relay will be reset and will displayed the message **Configuring Device** and a progress bar on the screen. Upon completion of the reconfiguration process, the relay will be rebooted with the new configuration. The complete validation and reconfiguration process lasts about the minute.



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Upon failed validation, the CID file will be rejected and deleted from the loading directory (non validated), the message **Validation ERROR** being displayed on the screen. In this case, web server logs can be accessed (through the web server, file transfer or File Transfer service of IEC 61850) in order to know the reasons for file rejection. Therefore, the relay will keep operating with the CID file that was active and communications will never be lost.



E.8 Mod/Beh

The standard defines the following values in the Logical Nodes for the Mod and Beh.

Value	Status	LN Behaviour
1	On	The application represented by the LN works. All communication services work and get updated values. DOs will be transmitted with a relevant quality. Control commands with Test=false will be accepted. Control commands with Test=true will be rejected.
2	Blocked	The application represented by the LN works. No (wired) output data will be issued to the process. All communication services work and get updated values. DOs will be transmitted with a relevant quality. Control commands with Test=false will be accepted. Control commands with Test=true will be rejected.
3	Test	The application represented by the LN works. All communication services work and get updated values. DOs will be transmitted with q.test=true, except Mod, Beh and Health that have q.test=false. Control commands with Test=false will be rejected. Control commands with Test=true will be accepted.
4	Test/Blocked	The application represented by the LN works. No (wired) output data will be issued to the process. All communication services work and get updated values. DOs will be transmitted with q.test=true, except Mod, Beh and Health that have q.test=false. Control commands with Test=false will be rejected. Control commands with Test=true will be accepted.
5	Off	The application represented by the LN does not work. All communication services work (output with quality.validity=invalid, except Mod, Beh and Health that will have q.validity=good). No process output will be done. Control commands to the process will be rejected. Only Mod accepts control command with Test=false. Settings and configuration attributes are still modifiable.

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The IED (whether by LD or LN) supports the five modes.

It is implemented a hierarchy management for the LDs (*GrRef* of LLN0). The format for the *GrRef.setSrcRef* in the SCL is: "@<*LDinst*>" or "<*IEDname*><*LDinst*>" and in the on-line data model is: "<*IEDname*><*LDinst*>" or "<*LDname*>".

The "root" by default is **SYS** and therefore all the other LDs will contain the *GrRef* in their LLN0 with "**@SYS**" value, which will be read only, so that all the LDs will inherit the status of **SYS** LD. It is configurable.

The IED will provide the following features related to the test mode:

- All the information sent/available in the IED will have test indication (*q.test*=true) and the following inputs will be considered as valid:
  - Data received by GOOSE/SV message with *q*.test = true.
  - Commands received with Test=true attribute.
- Multicast signals used for simulation (GOOSE/SV):
  - Subscription: Sim is the data object used to change the status/behaviour. It is present just in LPHD1 LN of **SYS** LD and will indicate the behaviour of the GOOSE simulation for all the IED. When the IED is receiving the same GOOSE/SV in both ways, real (simulation bit=false) and simulated (simulation bit=true), the IED will take into account just to one of them depending on the value/status of *SYS/LPHD1.Sim.stVal.*
    - Real GOOSE/SV if SYS/LPHD1.Sim.stVal=false.
    - Simulated GOOSE/SV if *SYS/LPHD1.Sim.stVal=false*. In this case, the SimSt of SYS/LGOS and SYS/LSVS LN configured to monitor that GOOSE/SV message will go to TRUE, showing that the IED is receiving and processing a simulated GOOSE/SV message.
  - Publishing: The IED will have one setting that allows sending normal or simulated GOOSE messages (***LPHD1.GoTxSim***) and another one for the SV (***LPHD1.SVTxSim***). Therefore, depending on these settings, the IED will send all the GOOSE/SV messages with the simulated bit in TRUE or FALSE.

Moreover, the configuration tool will allow configurin the Beh of any LN manually, so that the user can define it as per any specific requirement:

- A user Beh can take On, Off and Blocked values base don the activation and blocking signals defined by the user.

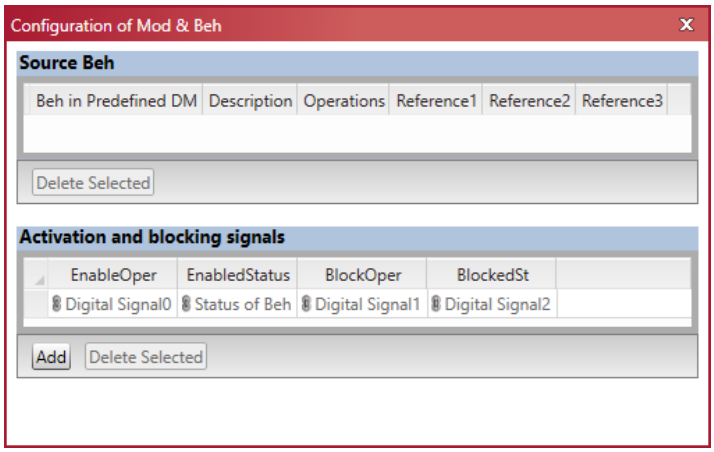


Figure E.10 Beh Configuration Depending on Signals.

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- A user Beh can be calculated as a combination of Behs of different LNs of the predefined data model.

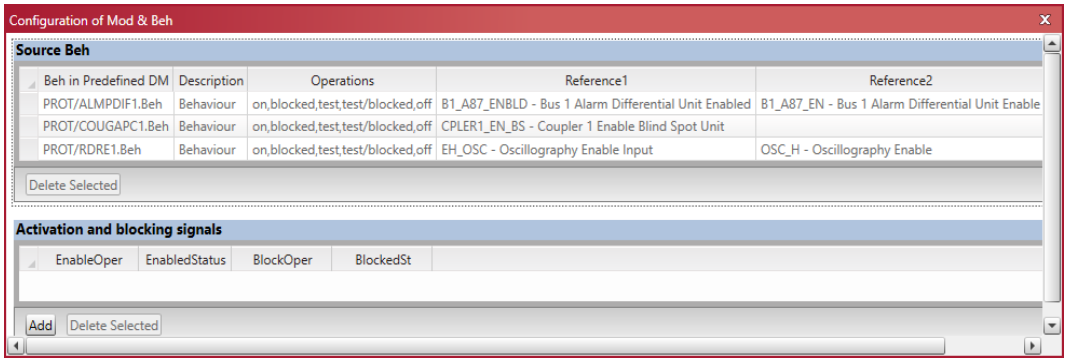


Figure E.11 Configuration of Beh as a Combination of Different LN Behs.

E.9 Data Set

The relay supports a maximum of 35 Data Sets, each containing a maximum of 500 FCDAs.

The FC allowed in a Data Set which will be assigned to a RCB are the following ones: ST, MX, SP, CF, DC, SG, SR, OR, BL and EX.

The FC allowed in a Data Set which will be assigned to a GCB are the following ones: ST, MX and SP.

Datasets can be located inside the LD and LN selected.



Figure E.12 Configuration of Datasets.

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E.10 GOOSE Messages Publishing

This service is defined in the standard and enables horizontal, fast and safe communications between IEDs. They are *multicast* messages and, thus, the emitter will place the data in the network and this will be received by any relay connected to the same. It has a message repeat algorithm, so that the data can be received by new relays connected to the network and, in this way, the receiving IEDs can detect communications or own emitter failures and act accordingly.

The type of the Performance class (according to IEC 61850-5 and IEC 61850-10) is P2/P3 performance class. The IEDs have 10 GCBs, so that they can be configured to send up to 10 different GOOSE messages. Each GCB has the following configurable parameters:

- MAC: send GOOSE message virtual MAC address
- VLAN ID: VLAN identifier
- AppID: application identifier. Parameter used to differentiate between GOOSE messages.
- VLAN Priority: message priority identifier.
- MinTime: minimum GOOSE message repeat time.
- MaxTime: maximum failure detection time on the part of the receiver (MaxTAL). The maximum GOOSE message repeat time will be MaxTime/2.
- GoID: string with a maximum size of 65 octets, which identifies the GOOSE message.
- GoRef: with a maximum size of 65 octets, which identifies the name of the GCB.
- Data Set: Data Set to be sent in the GOOSE message.
- Description: user-editable identifier to provide extra information.

Configuration version (*ConfRev*) is automatically calculated by the configuration tool and update at the time of generating the CID file.

Both *Data Attributes* and *Data Objects* (any FCD with a single FC ST/MX) can be sent through GOOSE and the same Data Set can be allocated to a GCB and a RCB. The relay can send both single and double digital signals, (SPS) and (DPS), integer data (INT) or analog measurements (FLOAT). When a measurement is allocated to a Data Set that will later be allocated to a GCB, it must be taken into account that, if the *deadband* associated to this measurement is configured to 0, this measurement will not be assessed, it will never generate a change and, therefore, will not cause GOOSE *trigger* by a change of value. If, otherwise, an instantaneous measurement is selected in the Data Set associated to a GOOSE message, every change of measurement will produce GOOSE sending.

In order to carry out the configuration, a Data Set must be first generated with the data to be sent in the GOOSE message. As a rule, attribute pairs (data, q) are sent but the relay can work with any type of Data Set. Later, this Data Set will be allocated to the desired GCB, any of the 10 existing in the relay model.

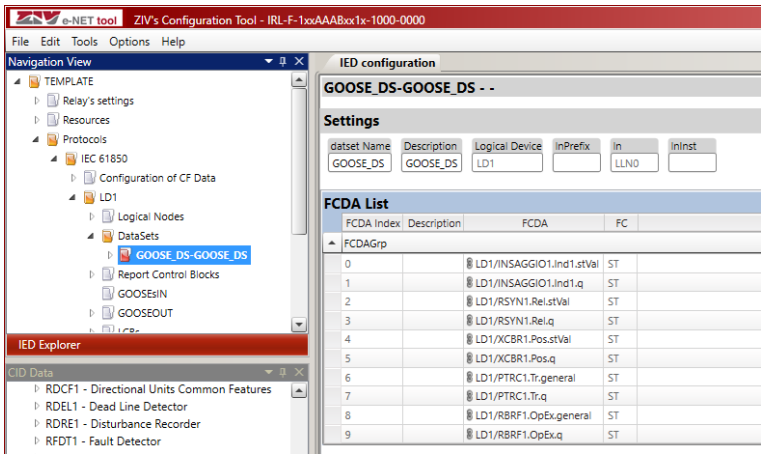


Figure E.13 Data Set Configuration for GOOSE.

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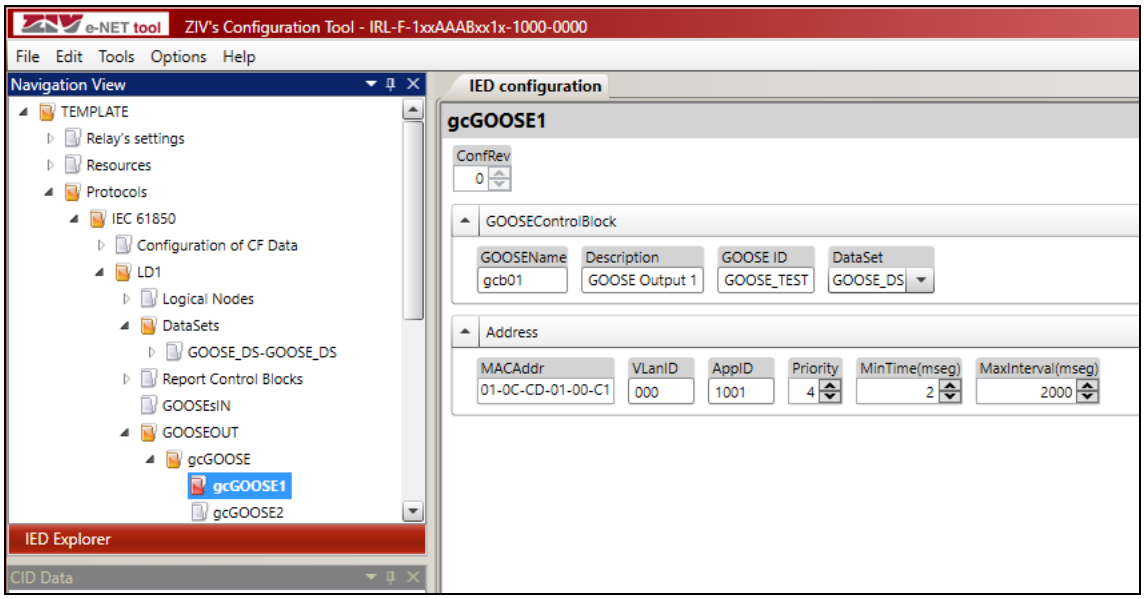


Figure E.14 GCB1 Configuration with Data Set Generated in Advance.

In this way, when a tool-generated CID is sent to the relay, after boot up, it will start sending a GOOSE message with the configured Data Set data.

The GCB can be added inside any LD.



Figure E.15 Configuration of GCBs in Different LDs.

If the Data Set allocated to the GCB is so large that the relay is not able to process and send, all relay services will be booted up normally, but the GOOSE message will not be sent, since it will have been disabled and the *NDSCom* attribute of that GCB set to TRUE. The *System Log* will display a message stating this condition:

ERR - [IEC61850ED1] Goose encoding error, setting GCB invalid (GoEna=False, NdsCom=True)

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E.11 Subscription to GOOSE Message Data

Subscription to GOOSE message data is carried out through *ExtRef*, that can be located inside any LD and any LN.

You can subscribe to a total of 400 elements using the *ExtRefs*. Each subscribed element (value and / or quality) will occupy an independent *ExtRef*.

The device can receive GOOSEs containing both data (CDF) and attributes (FCDA), but the subscription has to be made only to final attributes of type boolean, *DbPos*, int, float and quality. For example, if an SPS data travels in the GOOSE, the equipment should subscribe to the *stVal* attribute and the *q* attribute (if desired), using two *ExtRefs*.

So, as defined before, the subscription is carried out through any LN in the data model, where it will be mapped to internal data where the data received through the GOOSE service will be stored. Because of this, at the time of configuring a subscription, the required user resources (digital and/or analogue signals) must be generated. Those user resources will be the ones where the data received through the GOOSE message will be stored.

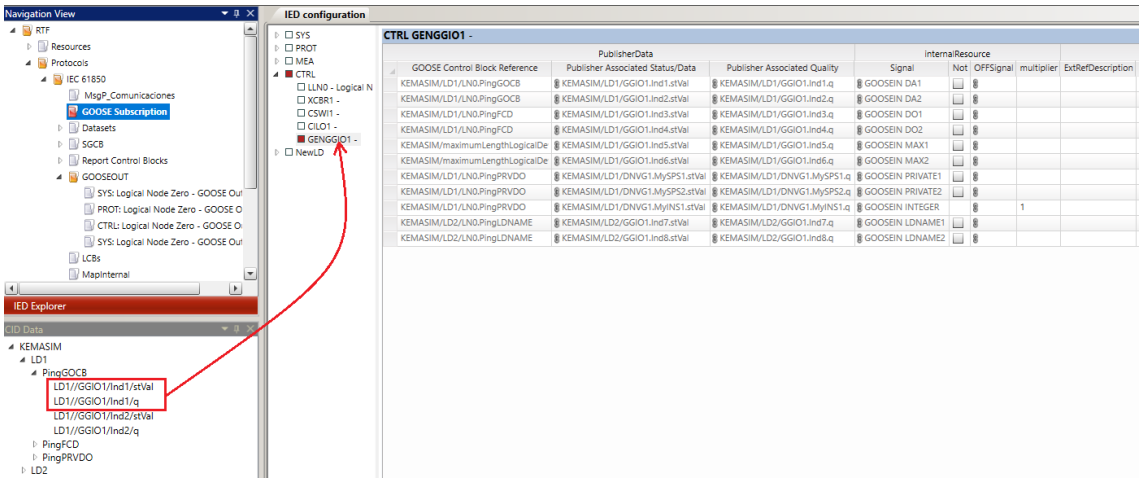


Figure E.16 Subscription to GOOSE Messages inside CTRL/GENGGIO1.

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The tool also allows adding non-complete subscriptions so that the corresponding ExtRef will be added inside the desired LN just with the internal resource configured. This way the tool will generate one file (*.IID) that the SCT will use to complete all the information related to the publishers (later binding). For that purpose, the internal resource where the information of the subscribed element will be stored has to be selected and drag into the LN where the ExtRef will be added. The configuration tool will not allow generating a CID file this way, because the configuration of that type of subscriptions is not completed and the IED would reject it, but it allows generating one IID file so that the SCT will be the one in charge of finishing the configuration. Due to the fact that there is pending information related to the publisher, the tool will show the corresponding LN marked in grey instead of red.

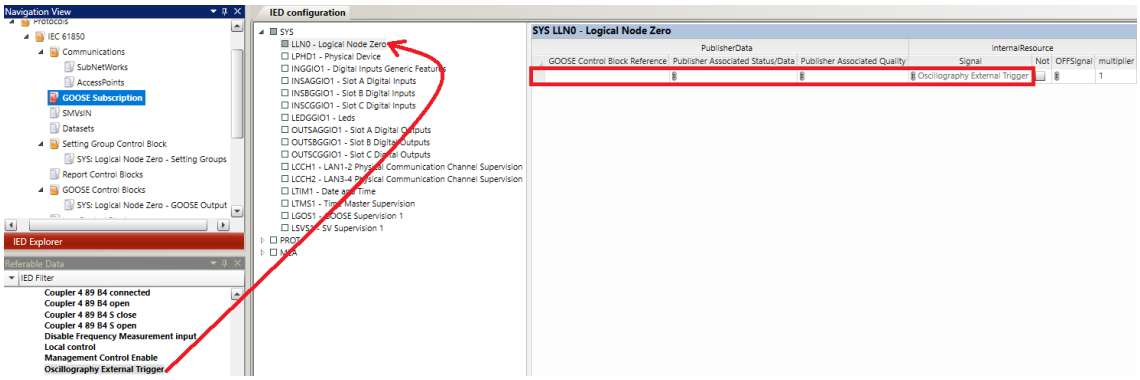


Figure E.17 GOOSE Subscription using Later Binding

The Mod status of the IED (LD SYS.LLN0.Mod) will define the way the IED will process the GOOSE subscription elements.

GOOSE input value	on	blocked	test	test-blocked	off
value=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=false	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=false	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=good *detailQual*=0 *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Processed as valid** *value*=X *validity*=good *detailQual*=0 *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=quest *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Processed as questionable** *value*=X *validity*=quest *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=false	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
value=X *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Processed as invalid** *value*=latest valid value *validity*=invalid *detailQual*=Y *test*=true	**Not Processed** *value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false
GOOSE is no longer being received	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=false	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=false	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=true	*value*=latest valid value *validity*=quest *detailQual*=OD(*) *test*=true	*value*=latest valid value *validity*=invalid *detailQual*=0 *test*=false

Where:

(*) OD = *OldData*.
“Processed as valid” means that the application should react according to the quality and intended functionality of the LN.
“**Processed as invalid**” means the application should react as if the quality of the data had been invalid or as the data source has failed.
“**Processed as questionable**” means that the application should decide how to consider the status value.

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E.12 Report Control Blocks (RCBs)

This method is used in the standard for an effective vertical communication between the IED (server) and the clients (central units, gateways, SCADAs, etc.). The IEDs have 20 indexed RCBs. The user will define per each RCB added the maximum number of indexed RCBs that will be available and per RCB it will be defined:

- Configuration revision.
- RCB:
  - Buffer time. (the buffer size is 30 kbytes).
  - Report Name.
  - Description.
  - Data Set associated to the RCB.
  - Report Identifier (*rptID*).
  - Integrity Period. The minimum configuration value is 500ms.
- Trigger Options:
  - Data Change (*Dchg*).
  - Quality Change (*Qchg*).
  - Data Update (*Dupd*): configurable but not supported by the IED.
  - Integrity.
  - General Interrogation.
- Optional fields: Sequence number, TimeStamp, ReasonCode, dataSet, Reference to Dataset, Entry ID, Configuration Reference y BufferOverflow.
- Client Reservation:
  - Max: number of indexed RCBs.
  - ClientAP and ClientLN per each indexed RCB to configure the reservation.

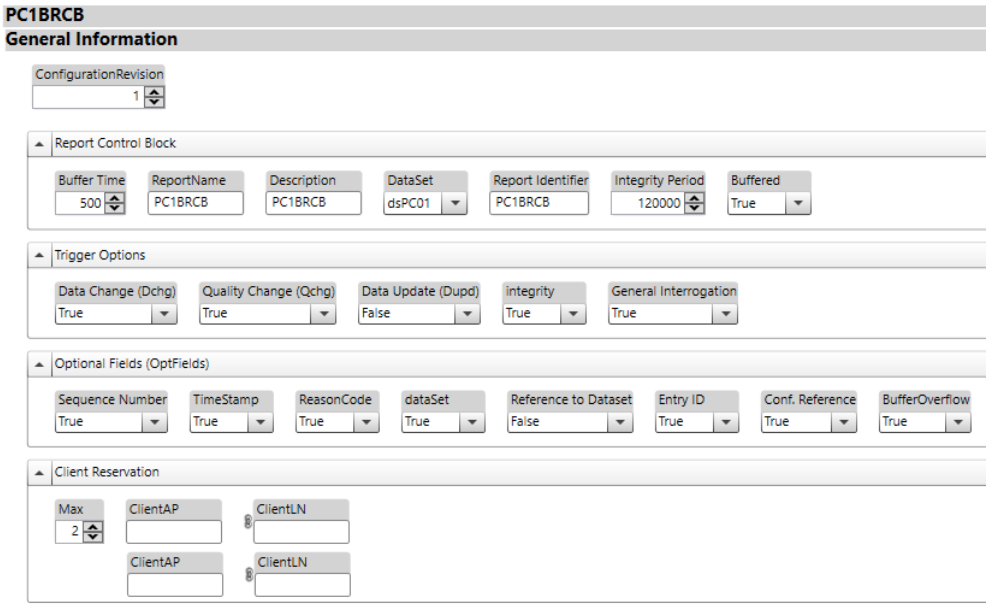


Figure E.18 Configuration of a BRCB.

The moment a client enables a RCB after having connected and associated with the relay, this RCB is then no longer available for other clients. Although all the configuration parameters are available in the tool, the client (once connected and prior to enabling the RCB) can edit the same according to its needs, except for the Data Set and ***Configuration Revision*** (***SqNum***, ***GI*** and ***TimeofEntry*** *cannot be edited either*).

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The IED supports the following ***Trigger Options***, apart from ***General Interrogation***:

- ***Integrity***: the relay will send periodically a *Report* with all the information of the Data Set, according to ***Integrity Period*** setting configuration.
- ***Data Change***: the relay will send a *Report* when a change in a the value of any Data Set element is detected and only this changed data will be sent.
- ***Quality Change***: the relay will send a *Report* when a change in Data Set element quality is detected and only this changed data will be sent.

The IED allows preconfiguring RCBs to specific clients so that those RCBs can just be configured and enabled by the preconfigured clients. In order to carry out that configuration it is necessary having the ICD/IID/CID/SCD file where the information of the client appears. Clicking with the right button of the mouse over the ***Report Control Blocks*** it appears a menu (***Open SCL file***) from where you can select the SCL file of the client. The tool will extract from that file the necessary information to preconfigure the desired RCB (LN and *AccessPoint* of the corresponding IED). Once selected the SCL file, it will appear in the ***Tools*** window, when being selected ***CID Data***, the information of the SCL file which will be used to configure the ***ClientLN*** and ***ClientAP*** fields of the desired RCB.

It is necessary that the SCL file of the client contains the *Clientservices* of the *bufReport* and/or *unbufReport* enabled (true) into the *Services* section so that the tool can preconfigure the RCBs.

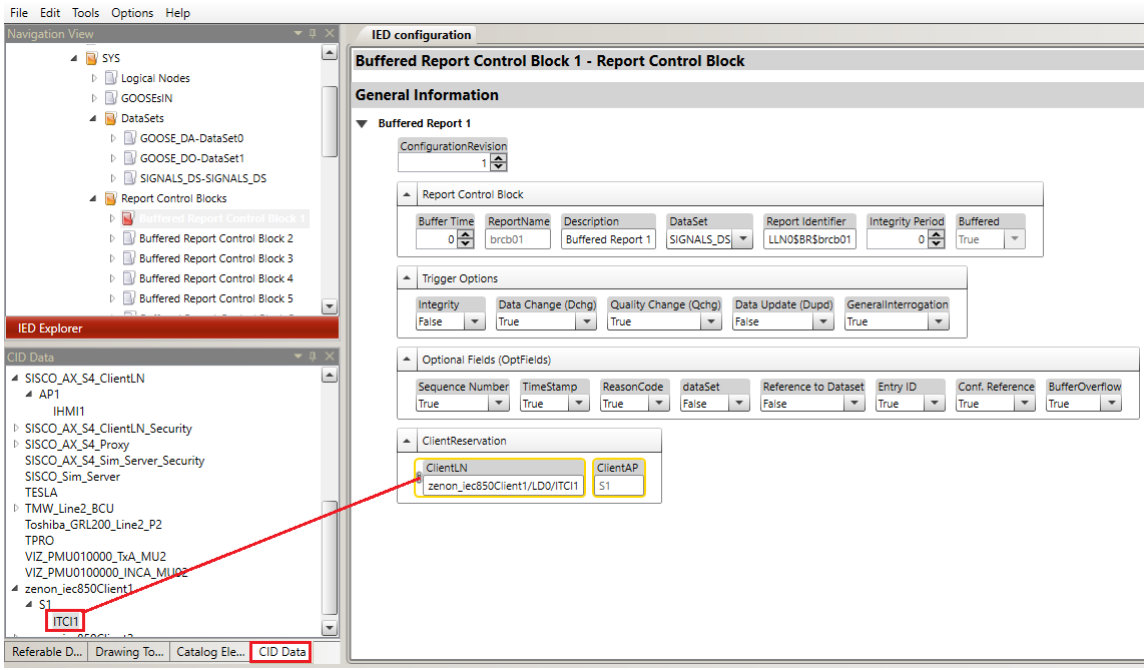


Figure E.19 Preconfiguration of a RCB.

In the hypothetical case in which a ***ClientLN*** has been configured without a ***ClientAp*** and the client IED has several *AccessPoints* with the same server (*ServerAt*), this is, when the tool can not determine the *AccessPoint* of the Logical Node selected of the client, the preconfiguration of the RCB will be refused. In this case, the ***ClientLN*** will be ignored and an error notification will be displayed. When performing a preconfiguration of a RCB, the tool will automatically add to the CID the information of the client IED (Communications field, *DataTypeTemplates*, etc.).

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E.13 Measurement Configuration (Data CF)

When the automatic measurement range calculation setting is enabled (*AutoRanMag* data located in the logic node LPHD), the relay will carry out the automatic calculation of the 6 elements of the measurements *rangeC*. In this case, these elements will be *read only* type. The automatic calculation will be as follows:

- max: will be calculated as a function of the measurement, its nominal and corresponding transformation ratios.
- hhLim = min + ((max-min) * 80 / 100)
- hLim = min + ((max-min) * 60 / 100)
- lLim = min + ((max-min) * 40 / 100)
- llLim = min + ((max-min) * 20 / 100)
- min: will be calculated as a function of the measurement, its nominal and corresponding transformation ratios.

When the setting is disabled, the user can configure these *rangeC* elements as deemed appropriate, either from the configuration tool or through MMS, although the following checks will be carried out:

- rangeC.max > rangeC.min
- max>=hhLim>=hLim>=lLim>=llLim>=min

Any change in the *rangeC* values will be updated in the CID file.

On the other hand, each measurement has its *deadband* (***db*** attribute). *Deadband* represents the difference percentage between maximum and minimum values of a measurement in 1 per thousand (0.001). This setting is present in the data model since the measurements consist of two data: "**instMag/instCVal**" representing the instantaneous and continuous measurement value and "**mag/cVal**". This "**mag/cVal**" data is updated when the instantaneous measurement value is subject to a certain change, defined in the ***db*** setting and it is this "**mag/cVal**" data that is subject to the Reports and LOGS (*data change*) assessment function, namely, the data that is sent through communications in Reports and is stored in the LOG files.

Regarding GOOSE messages, both the instantaneous and the *deadband* data generate change and, thereby, the GOOSE message change *trigger*, so that instantaneous data selection in the Data Set associated with GOOSE messages is not recommended. Below is a graph with the relation between instantaneous and deadband data.

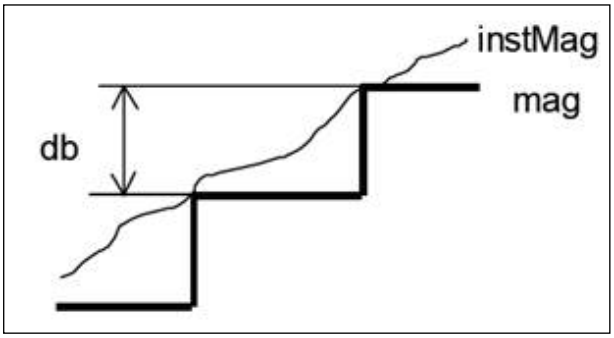


Figure E.20 Relation between Instantaneous and *Deadband* Measurement.

The measures contained in elements of Common Data Class: WYE, DEL or SEQ are a collection of simultaneous measurements in a three-phase system that represent phase to ground values, and their respective time stamps hold the same value "t". In addition, as indicated in the standard (IEC61850-7-3): *The actualization of one of the component due to a dead band calculation results in the actualization of all other components and a restart of the dead band calculation for all the components*.

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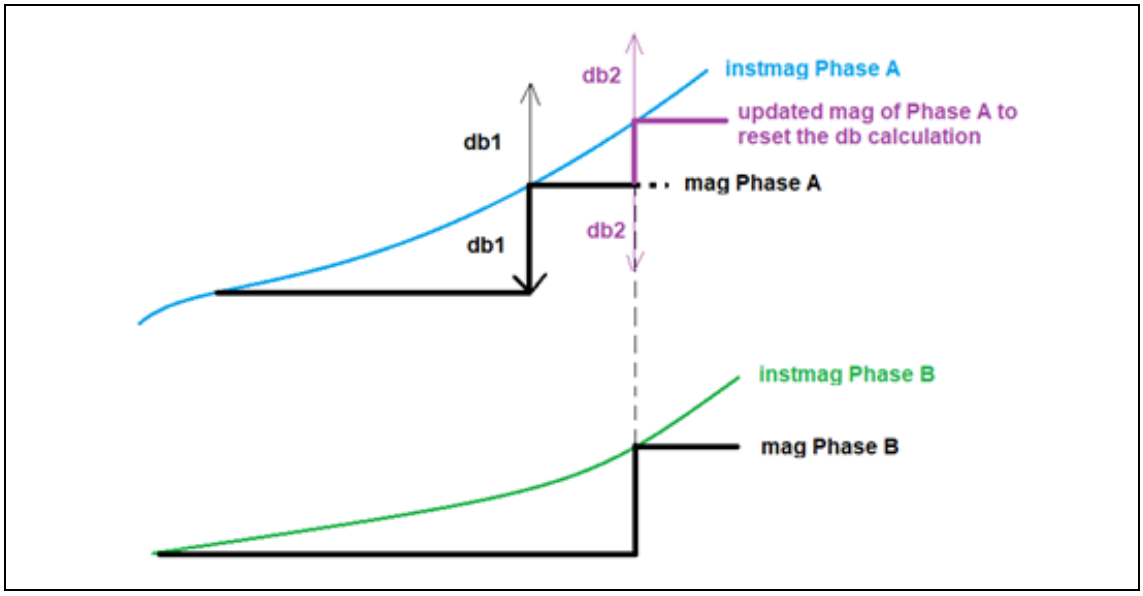


Figure E.21 Deadband actualization of simultaneous measurements.

So, in these cases, whenever a single phase is to be tested, it is recommended to set all db and zerodb parameters of the rest of phases to their highest possible values. In other words, when injecting and so when modifying the value of all phases, t and mag of all phases will be updated when the lowest db value between all phases has been reached or crossed (and then, the reference of all the rest of phases is modified too). It should also be tested, that whenever one changes the rest are updated (to do that, set db and zerodb to different values).

In the same way, the change in the angle will update the whole group of measurements. Therefore the dbAng must be also taken into account.

As an example, below is shown the influence of the ***db*** data in the generation of changes of the measurement to be reported.

RangeC setting values max=30326402.0 and min=-30326402.
max-min= 60652804 W

db = 1000
1% del max-min => 606,5 kW
When the measurement varies 606.5 kW, a change is detected and the report is sent. In the graph above, the steps would be 606.5 kW.

db=10
0,01% del max-min => 6,065 kW
When the measurement varies 6.065, a change is detected and the report is sent. In the graph above, the steps would be 6.065 KW.

db=1
0,001% del max-min => 606,5 W
When the measurement varies 606.5, a change is detected and the report is sent. In the graph above, the steps would be 606.5 W.

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E.14 Commands

IEDs support SBO and direct commands, with or without enhanced safety as a function of the ***ctlModel*** setting value present in every relay commanding data:

- ***ctlModel*** = 0: non commanding data.
- ***ctlModel*** = 1: direct command with normal safety, which can be run after writing the applicable *Oper* attribute.
- ***ctlModel*** = 2: SBO command with normal safety. Before running it, first select the data by reading the *SBO* attribute. The IED will return the *path* of the selected data as indication of a good operation and "null" in case of error. Once selected, the data can be run after writing the corresponding Oper before the time ***sboTimeout*** times out, after which time the element is not longer selected.
- ***ctlModel*** = 3: direct command with enhanced safety that can be run after writing the corresponding *Oper* attribute. The IED will send information on how the command has been run: execution of the command rejected, failed termination or successful termination, indicating the cause of the failure in the first two situations.
- ***ctlModel*** = 4: SBO command with enhanced safety. In order to run it, first select the data by writing the *SBOw* attribute. Once selected, the data can be run after writing the corresponding Oper with the same SBOw write parameters before the time ***sboTimeout*** times out, after which time the element is not longer selected. The IED will send information on how the command has been run: selection of the command rejected, execution of the command rejected, failed termination or successful termination, indicating the cause of the failure in the first three situations.

The device supports the *interlock-check* for any configurable command, so that, depending on the value of the mentioned *Check* attribute, the device will apply the information of the associated CILO Logical Node to the command to block it or to skip such blocking.

The commands hierarchy in the IEDs with dynamic data model has been defined at the level of the element which can receive commands (DO by DO independently) and following what it is declared in the standard. Each element can be associated to the LocKey, Loc and LocSta DOs at LN level. Depending on the value of them (plus the heritage of the LLN0 of the LD where it is located and the possible LDs that this LD belongs to) the element will calculate the hierarchy status. Logically, the value of the MltLev setting that allows working with several hierarchy levels at a time or just with one has to be taken into account and also the LocMntnc DO (device in maintenance) that will block any command except the ones generated with orCat 7 (maintenance).

Therefore, based on the status of those DOs, the commands will be accepted or rejected depending on the origin they are coming from. The combination is described in the following table which shows the same information of table B.1 of the 7-4 part of the IEC 61850 standard.

If those DOs are not appearing in the data model (from the point of view of the LN), the IED will use the internal signals (Local/Panel-Controlled/Remote) that were being used before with the previous models (check the Programmable Logic chapter).

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IED		Signal from each commandable element			IEC 61850 Origin							
					1	2	3	4	5	6	7	8
MltLev	Maintenance Control	Local Control	Station Control	Remote Control	Bay-ctrl	Station-ctrl	Remote-ctrl	Auto-bay	Auto-station	Auto-remote	maintenance	process
0	0	0	0	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK
0	0	0	0	1	BLOCK	BLOCK	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK
0	0	0	1	0	BLOCK	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK
0	0	0	1	1	BLOCK	PERM	PERM	BLOCK	PERM	PERM	BLOCK	BLOCK
0	1	0	0	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
0	1	0	0	1	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
0	1	0	1	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
0	1	0	1	1	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
0	0	1	0	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	0	1	0	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	0	1	1	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	0	1	1	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	1	1	0	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	1	1	0	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	1	1	1	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
0	1	1	1	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	0	0	0	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK
1	0	0	0	1	PERM	PERM	PERM	PERM	PERM	PERM	BLOCK	BLOCK
1	0	0	1	0	PERM	PERM	BLOCK	PERM	PERM	BLOCK	BLOCK	BLOCK
1	0	0	1	1	PERM	PERM	PERM	PERM	PERM	PERM	BLOCK	BLOCK
1	1	0	0	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
1	1	0	0	1	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
1	1	0	1	0	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
1	1	0	1	1	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	PERM	BLOCK
1	0	1	0	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	0	1	0	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	0	1	1	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	0	1	1	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	1	1	0	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	1	1	0	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	1	1	1	0	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK
1	1	1	1	1	PERM	BLOCK	BLOCK	PERM	BLOCK	BLOCK	BLOCK	BLOCK

Exceptions:

- If LockKey = True, commands received by communications will not be accepted no matter which is the status of the input signals “Local Control”, “Station Control”, “Remote control”, “Maintenance Control” or the value of the MltLev. Commands received by communications will be rejected with AddCause=Blocked-by-switching-hierarchy.
- All the internal commands with orCat “4” will be accepted.
- When being in orCat “1”, the IED will accept commands received by communications but only if they are coming from origin 1.

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E.15 SNTP Synchronization

The IED is able to synchronize through the communications network by SNTP protocol (*Simple Network Time Protocol*), as indicated by IEC 61850. The SNTP client of the equipment can be configured in *broadcast* or *unicast* mode: with one or two servers:

- *Broadcast*: the relay will wait to receive *broadcast* messages sent by the GPS clock for synchronizing.
- *Unicast*: the relay will send a date and time request to the GPS clock and will be synchronized with the message received.

The settings are detailed in the Physical Description section of the Description and Start-Up chapter.

E.15.1 SNTP Synchronism Status Calculation

The SNTP module recalculates its status every time any client (*unicast* or *broadcast*) calculates its own, which occurs with a change in its status (online/offline) due to timing, at the end of each interrogation cycle with response (correct structure) on the part of a server (*unicast client*) or with each received *broadcast* message (*broadcast* client).

The calculation method varies as a function of the ***Synchronism status calculation*** setting value:

- If the setting has been configured as ***Leap indicator***, the SNTP module status will be the latest status calculated by any of the *unicast* and *broadcast* clients.
- If the setting has been configured as ***Timing***, the SNTP module status will be a combined status of both *unicast* and *broadcast* clients, following two possible algorithms:
  - If ***broadcast error timing*** is set to 0, the SNTP module status is only a function of the *unicast* client status, except when the *broadcast* client switches from offline to online, at which time the SNTP module switches to the online status until a new *unicast* client status calculation.
  - If ***broadcast error timing*** is set to a value other than 0, the SNTP module status is a combination of the *unicast* and *broadcast* client statuses. In this mode, the SNTP module status will be:
    Synchronized if any client is in synchronized status.
    Non Synchronized if no client is synchronized and any client is not synchronized.
    Non calculated if all the clients are in non-calculated status.

E.15.1.a *Unicast* Client

A disabled *unicast* client does not make synchronization requests to servers. Therefore, when the IED client is enabled, it will interrogate the servers that have a configured IP address other than 0.0.0.0, which is the server identifier to be ignored.

Synchronization Period and ***Interval Between Retries*** settings define the time request interval to the servers when the client is in synchronized status and non-synchronized status respectively. The ***Number of Retries*** setting defines the maximum number of retries on a server if a valid response is not received. A 0 value indicates that retries will not be made, namely, only one connection attempt will be made. The ***SNTP Time Between Retries*** setting indicates the maximum waiting time between retries.

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As a function of these settings, the relay will send the appropriate messages and will wait for the answer on the part of the SNTP server. If ***Ignore leap indicator*** is set to **NO**, the received message will be process in terms of *leap indicator* field (less than 3), *stratum* field (from 0 to 16) and time difference between server and client (less than the ***Maximum Synchronization Time Difference*** *setting* except that the setting is 0), so that these received values must be within ranges in order to accept the synchronization, but when the ***Ignore leap indicator*** setting is set to **YES**, the message will be directly accepted. If the message is not accepted, the IED will interrogate the second server. The relay, in this way, will successively interrogate the servers until receiving a valid response from one of them. If, after going through all the servers, a correct response is not received, **non-synchronized** status will be shown. The relay will listen to NTP messages sent to its own IP address.

If the synchronized status calculation is set to timing, the ***Unicast Validity Timing*** setting specifies the time lapse from the first valid message received without receiving error messages or timeouts, so that the client switches to a synchronized Status. When the setting sets to 0, the waiting time is 0 seconds, so that the unicast client will switch to synchronized Status when the first correct message is received.

Unicast Error Timing enables selecting the time lapse from the last valid message received, so that the unicast client switches to non-synchronized Status. The timing also starts at the time when the client reaches the synchronized Status, since it could remain in this status without receiving any valid message.

E.15.1.b *Broadcast* Client

The *broadcast* client receives NTP synchronization *broadcast* messages, sets the time in accordance with the same, and calculates synchronism status at all times. When disabled, the IED will ignore the received synchronization messages. The synchronized status will be produced the moment a correct message is received, provided the time set in ***Broadcast Validity Timing,*** elapsed from the first correct message received, has run out, switching to non-synchronized when no valid messages are received within the time configured in ***Broadcast Error Timing***. The *broadcast* client will permanently be awaiting to receive NTP *broadcast* synchronization messages, listening to messages received with destination IP address 255.255.255.255 or *broadcast* address corresponding to the subnetwork that it belongs to. Listening to messages sent to its IP address in particular is also deemed correct.

Force unicast setting establishes whether a new *unicast* refresh must be sent at the time of receiving a *broadcast* message. The *unicast* client, when receiving the synchronization request, will cancel the refresh in progress if applicable and will immediately start a new refresh process with the servers.

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Protocol Implementation Conformance Statement for the IEC 61850 interface in IRF/IDF/ZLF/DLF/RTF from ZIV Aplicaciones y Tecnología

Version 0.0, Date 15/05/2021

based upon UCAIug PICS Template version 3.0

UCA International Users Group
Testing Sub Committee

Date: January 19, 2021

1. General

The following ACSI conformance statements are used to provide an overview and details about IRF/IDF/ZLF/DLF/RTF, with firmware version 0.10.0:

- ACSI basic conformance statement,
- ACSI models conformance statement,
- ACSI service conformance statement

The statements specify the communication features mapped to IEC 61850-8-1 and IEC 61850-9-2.

2. ACSI basic conformance statement

The basic conformance statement is defined in Table A.1.

Table A.1 – Basic conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments	Client	Server
Client-Server roles						
B11	**Server** side (of TWO-PARTY-APPLICATION-ASSOCIATION)	N/A	Yes			C1
B12	**Client** side (of TWO-PARTY-APPLICATION-ASSOCIATION)	No	N/A		M	
SCSMs supported						
B21	**SCSM**: IEC 61850-8-1 used	No	Yes			
B22	**SCSM:** IEC 61850-9-1 used	N/A	N/A	Deprecated Ed2		
B23	**SCSM**: IEC 61850-9-2 used	No	No			
B24	**SCSM**: other					
Generic substation event model (GSE)						
B31	**Publisher** side	N/A	Yes			O
B32	**Subscriber** side	Yes	N/A		O	
Transmission of sampled value model (SVC)						
B41	**Publisher** side	N/A	No			O
B42	**Subscriber** side	No	N/A		O	
N/A = not applicable Yes = supported No or empty = not supported					M-Mandatory O-Optional	

3. ACSI models conformance statement

The ACSI models conformance statement is defined in Table A.2.

Table A.2 – ACSI models conformance statement

		Client/ Subscriber	Server/ Publisher	Value/ Comments	Client	Server
If **Server** side (B11) and/or **Client** side (B12) supported						
M1	**Logical device**	No	Yes		c2	c2
M2	**Logical node**	No	Yes		c3	c3
M3	**Data**	No	Yes		c4	c4
M4	**Data set**	No	Yes		c5	c5
M5	**Substitution**	No	Yes		O	O
M6	**Setting group control**	No	Yes		O	O
	Reporting					
M7	**Buffered report control**	No	Yes		O	O
M7-1	sequence-number	No	Yes			
M7-2	report-time-stamp	No	Yes			
M7-3	reason-for-inclusion	No	Yes			
M7-4	data-set-name	No	Yes			
M7-5	data-reference	No	Yes			
M7-6	buffer-overflow	No	Yes			
M7-7	entryID	No	Yes			
M7-8	BufTm	No	Yes			
M7-9	IntgPd	No	Yes			
M7-10	GI	No	Yes			
M7-11	conf-revision	No	Yes			
M8	**Unbuffered report control**	No	Yes		O	O
M8-1	sequence-number	No	Yes			
M8-2	report-time-stamp	No	Yes			
M8-3	reason-for-inclusion	No	Yes			
M8-4	data-set-name	No	Yes			
M8-5	data-reference	No	Yes			
M8-6	BufTm	No	Yes			
M8-7	IntgPd	No	Yes			
M8-8	GI	No	Yes			
M8-9	conf-revision	No	Yes			
	Logging	No	N		O	O
M9	**Log control**	No	N		O	O
M9-1	IntgPd	No	N			
M10	**Log**	No	N		O	O
M11	**Control**	No	Yes		O	O
M17	**File Transfer**	No	Yes		O	O
M18	**Application association**	No	Yes		c3	c3
M19	**GOOSE Control Block**	No	Yes		O	O
M20	**Sampled Value Control Block**	No	N		O	O

		Client/ Subscriber	Server/ Publisher	Value/ Comments	Client	Server
If **GSE** (B31/32) is supported						
M12	**GOOSE**	No	Yes		O	O
M13	**GSSE**			Deprecated Ed2	O	O
If **SVC** (B41/42) is supported						
M14	Multicast SVC	No	No		O	O
M15	Unicast SVC	No	No		O	O
For all IEDs						
M16	**Time**	No	Yes	Time source with required accuracy shall be available. Only Time Master are SNTP (Mode 4 response) time server. All other Client / Server devices require SNTP (Mode 3 request) clients	O	M
Yes = service is supported No or empty = service is not supported					c2 – shall be 'M' if support for logical-node model has been declared. c3 – shall be 'M' if support for data model has been declared. c4 – shall be 'M' if support for data-set, Substitution, Report, Log Control, or Time model has been declared. c5 – shall be 'M' if support for Report, GSE, or SV models has been declared. M – Mandatory O – Optional	

4. ACSI service conformance statement

The ACSI service conformance statement is defined in Table A.4 (depending on the statements in Table A.1 and in Table A.2).

Table A.3 – ACSI service Conformance statement

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments	Client	Server
Server								
S1	1,2	GetServerDirectory (LOGICAL-DEVICE)	TP	No	Y		O	c12
							c12 - Mandatory if B11=Yes	
Application association								
S2-1	1,2	Associate_Request		No	Yes		M	O
S2-2		Associate_Response		No	Yes		O	M
S3-1	1,2	Abort_Request		No	Yes		c11	M
S3-2		Abort_Processing		No	Yes		M	M
S4-1		Release_Request		No	Yes		c11	O
S4-2	1,2	Release_Responde		No	Yes		M	M
		c11 – Either the Abort or the Release request shall be supported by the client. Additionaly, the client must understand the abort request delivered by the server.						
Logical device								
S5	1,2	GetLogicalDeviceDirectory	TP	No	Yes		O	c12
							c12 - Mandatory if B11=Yes	
Logical node								
S6	1,2	GetLogicalNodeDirectory	TP	No	Yes		O	c12
S7	1,2	GetAllDataValues	TP	No	Yes		O	M
							c12 - Mandatory if B11=Yes	
Data								
S8	1,2	GetDataValues	TP	No	Yes		O	M
S9	1,2	SetDataValues	TP	No	Yes		O	O
S10	1,2	GetDataDirectory	TP	No	Yes		O	M
S11	1,2	GetDataDefinition	TP	No	Yes		O	M
Data set								
S12	1,2	GetDataSetValues	TP	No	Yes		O	M
S13	1,2	SetDataSetValues	TP	No	No		O	O
S14	1,2	CreateDataSet	TP	No	No		O	O
S15	1,2	DeleteDataSet	TP	No	No		O	O
S16	1,2	GetDataSetDirectory	TP	No	Yes		O	M
Substitution								
S17	1	SetDataValues	TP	No	Yes		M	M
Setting group control								
S18	1,2	SelectActiveSG	TP	No	Yes		M	M
S19	1,2	SelectEditSG	TP	No	Yes		O	O
S20	1,2	SetEditSGValues	TP	No	Yes		O	O
S21	1,2	ConfirmEditSGValues	TP	No	Yes		O	O
S22	1,2	GetEditSGValues	TP	No	Yes		O	O
S23	1,2	GetSGCBValues	TP	No	Yes		O	M

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments	Client	Server
Reporting								
Buffered report control block (BRCB)								
S24	1,2	Report	TP	No	Yes		c6	c6
S24-1	1,2	data-change (dchg)		No	Yes		-	M
S24-2	1,2	quality-change (qchg)		No	Yes		-	M
S24-3	1,2	data-update (dupd)		No	No		-	M
S25	1,2	GetBRCBValues	TP	No	Yes		c6	c6
S26	1,2	SetBRCBValues	TP	No	Yes		c6	c6
Unbuffered report control block (URCB)								
S27	1,2	Report	TP	No	Yes		c6	c6
S27-1	1,2	data-change (dchg)		No	Yes		-	M
S27-2	1,2	quality-change (qchg)		No	Yes		-	M
S27-3	1,2	data-update (dupd)		No	No		-	M
S28	1,2	GetURCBValues	TP	No	Yes		c6	c6
S29	1,2	SetURCBValues	TP	No	Yes		c6	c6

c6 – shall declare support for at least one (BRCB or URCB)

Logging								
Log control block								
S30	1,2	GetLCBValues	TP	No	No		M	M
S31	1,2	SetLCBValues	TP	No	No		O	M
Log								
S32	1,2	QueryLogByTime	TP	No	No		c7	M
S33	1,2	QueryLogAfter	TP	No	No		c7	M
S34	1,2	GetLogStatusValues	TP	No	No		M	M

c7 – shall declare support for at least one (QueryLogByTime or QueryLogAfter).

Generic substation event model (GSE)								
GOOSE								
S35	1,2	SendGOOSEMessage	MC	No	Yes		c8	c8
GOOSE-CONTROL-BLOCK								
S36	1,2	GetGoReference	TP	No	No		O	O
S37	1,2	GetGOOSEElementNumber	TP	No	No		O	O
S38	1,2	GetGoCBValues	TP	No	Yes		O	O
S39	1,2	SetGoCBValues	TP	No	Yes		O	O
GSSE								
S40	1	SendGSSEMessage	MC			Deprecated in Edition 2	c8	c8
GSSE-CONTROL-BLOCK								
S41	1	GetReference	TP			Deprecated in Edition 2	O	O
S42	1	GetGSSEElementNumber	TP			Deprecated in Edition 2	O	O
S43	1	GetGsCBValues	TP			Deprecated in Edition 2	O	O
S44	1	SetGsCBValues	TP			Deprecated in Edition 2	O	O

c8 – shall declare support for at least one (SendGOOSEMessage or SendGSSEMessage

	Ed.	Services	AA: TP/MC	Client (C)	Server (S)	Comments	Client	Server
Transmission of sampled value model (SVC)								
Multicast SV								
S45	1,2	SendMSVMessage	MC	No	No		c10	c10
Multicast Sampled Value Control Block								
S46	1,2	GetMSVCBValues	TP	No	No		O	O
S47	1,2	SetMSVCBValues	TP	No	No		O	O
Unicast SV								
S48	1,2	SendUSVMessage	TP	No	No		c10	c10
Unicast Sampled Value Control Block								
S49	1,2	GetUSVCBValues	TP	No	No		O	O
S50	1,2	SetUSVCBValues	TP	No	No		O	O

c10 – shall declare support for at least one (SendMSVMessage or SendUSVMessage).

Control								
S51	1,2	Select		No	Yes		M	O
S52	1,2	SelectWithValue	TP	No	Yes		M	O
S53	1,2	Cancel	TP	No	Yes		O	c13
S54	1,2	Operate	TP	No	Yes		M	M
S55	1,2	CommandTermination	TP	No	Yes		M	O
S56	1,2	TimeActivatedOperate	TP	No	No		O	O

c13 – shall declare support if either S51 (Select) or S52 (SelectWithValue) is Y.

File Transfer								
S57	1,2	GetFile	TP	No	Yes		M	M
S58	1,2	SetFile	TP	No	Yes		O	O
S59	1,2	DeleteFile	TP	No	No		O	O
S60	1,2	GetFileAttributeValues	TP	No	Yes		O	M
S61	1,2	GetServerDirectory (FILE-SYSTEM)	TP	No	Yes		M	M

Time								
T1	1,2	Time resolution of internal clock		xx	10 (1ms)	Nearest negative power of 2^{-n} in seconds (number 0 .. 24)		
T2	1,2	Time accuracy of internal clock		Tx	T1	TL (ms) (low accuracy), T3 < 7) T0 (ms) (<= 10 ms), 7 <= T3 < 10 T1 (µs) (<= 1 ms), 10 <= T3 < 13 T2 (µs) (<= 100 µS), 13 <= T3 < 15 T3 (µs) (<= 25 µS), 15 <= T3 < 18 T4 (µs) (<= 25 µS), 15 <= T3 < 18 T5 (µs) (<= 1 µS), T3 >= 20		
T3	1,2	Supported TimeStamp resolution	-	xx	10	Nearest value of 2^{-n} in seconds (number 0 .. 24)		
N/A = not applicable Yes = supported No or empty = not supported								

5. 61869-9 Communication Profile conformance statement

The A-Profile conformance statement shall be as defined in Table 912.

Table 912 – PICS for A-Profile support: 61869-9

	Ed.	Services	Client (C)	Server (S)	Comments	Conformance Classes			
						a	b	c	d
A0	2	Conformance class supported	No	No		a=only SV, b=+GOOSE, c=+MMS, d=+reports			
A1	2	Client/Server A-Profile	No	No		-	-	M	M
A2	2	GOOSE mgmt A-Profile	No	No		-	M	M	M
A3	2	GOOSE A-Profile	No	No		-	M	M	M
A4	2	TimeSync A-Profile	No	No		N1	N1	N1	N1
A5	2	Security for client/server A-Profile	No	No		-	-	-	-
A6	2	Security for GOOSE/GSE mgmt A-Profile	No	No		-	-	-	-
A7	2	SV A-Profile per IEC 61850-9-2:2011	No	No		M	M	M	M

The T-Profile conformance statement shall be as defined in Table 913.

Table 913 – PICS for T-Profile support: 61869-9

	Ed.	Services	Client (C)	Server (S)	Comments	Conformance Classes			
						a	b	c	d
T1	2	TCP/IP T-Profile per IEC 61850-8-1	No	No		-	-	M	M
T2	2	SV T-Profile per IEC 61850-9-2	No	No		M	M	M	M
T3	2	GOOSE T-Profile per IEC 61850-8-1	No	No		-	M	M	M
T4	2	GSSE T-Profile	No	No		-	-	-	-
T5	2	TimeSync T-Profile per IEC 61850-8-1	No	No		-	-	O	O

6. 61850-9-3 Clock Profile conformance statement

The capabilities and options supported by the PTP clock is shown in Table 22.

Table 22 – PICS for Clocks ~~A-Profile support~~: 61850-9-3

PICS proforma reference	Ed.	Capability	Client (C)	Server (S)	Comments	Value Range	Base	Condition	Example
CLOCK_TYPE_OC	2	clock is OC according to this base	Y	N		Y/N	M	c.1	Y
CLOCK_TYPE_TC	2	clock is TC according to this base	Y	N		Y/N	M	c.1	
CLOCK_TYPE_BC	2	clock is BC according to this base	N	N		Y/N	M	c.1	
NR_PORTS	2	number of clock ports (total)	2/4	N		Int>0	M	-	2
PORTS_STEP	2	1: all ports support 1-step on egress 2: all ports support 2-step on egress 3: all ports support both 1-step and 2	2	N		1.3	M	-	{1}
SLAVE_ONLY	2	all ports of the clock are slave-only	N	N		Y/N	M	c.2	
TIME_TRACEABLE	2	connectable to a time reference outside of PTP (e.g. GPS)	Y	N		Y/N	M	c.3	Y
FREQ_TRACEABLE	2	connectable to a frequency reference outside of PTP (e.g. GPS)	Y	N		Y/N	M	c.3	Y
DAC	2	doubly attached OC	Y	N		Y/N	O		Y
PORTS_PAIRED	2	paired clock ports for redundancy (e.g. {3-4})	{1-2},{3-4}	N		Port pair	O	c.4	Y
REDBOX_DATC	2	Redbox as Transparent Clock	N	N		Y/N	O	c.5	{0,1}
REDBOX_SLTC	2	Redbox as Stateless Transparent Clock	N	N		Y/N	O	c.5	
REDBOX_TWBC	2	Redbox as three-way Boundary Clock	N	N		Y/N	O	c.6	
REDBOX_DABC	2	Redbox as DAC BC	N	N		Y/N	O	c.6	
MIB_SNMP	2	supports MIB of IEC 62439-3 Annex E	N	N		Y/N	M	c.7	
MIB_61850	2	supports IEC 61859-90-4 Clock Objects	Y	N		Y/N	M	c.7	
MIB_OTHER	2	clock supports fixed values or a mechanism defined by the manufacturer. (If True, this list is appended to this PICS)	N	N		Y/N	M	c.7	Y, void list
ATOI	2	A master clock attaches the ALTERNATE_TIME_OFFSET_INDICATOR TLV as defined in IEC 61588 as set by its application. A slave clock makes this TLV information available to the application if it receives it. A BC forwards the ATOI TLV from the slave port to the master ports	N	N		Y/N	O	-	N
						c.1: at least one shall be supported (CLOCK_TYPE_OC and CLOCK_TYPE_TC may be both True) c.2: only if CLOCK_TYPE_OC = True c.3: only if SLAVE_ONLY = False c.4: shall be "m" (>1) if DAC = True c.5: support shall only be declared if CLOCK_TYPE_TC = True and DAC=True c.6: support shall only be declared if CLOCK_TYPE_BC = True and DAC=True c.7: at least one shall be supported			

Protocol Implementation eXtra Information for Testing (PIXIT) for the IEC 61850 Edition 2 server interface in IRF/IDF/ZLF/DLF/RTF from ZIV Aplicaciones y Tecnología

Version 0.0, Date: 15/05/2021

Based Upon UCAIug Server PIXIT Template version 20

UCA International Users Group
Testing Sub Committee

PIXIT template for Server Test Procedures
for Edition 1 and Edition 2
Revision 20

Date: July 02, 2020

PIXIT for server

Introduction

This document specifies the protocol implementation extra information for testing (PIXIT) of the IEC 61850 interface in IRF/IDF/ZLF/DLF/RTF with firmware version 0.10.0.

Together with the PICS and the MICS the PIXIT forms the basis for a conformance test according to IEC 61850-10. The PIXIT entries contain information, which is not available in the PICS, MICS, TICS documents or SCL file.

Each table specifies the PIXIT for applicable ACSI service model as structured in IEC 61850-10. The “Ed” column indicates if the entry is applicable for IEC 61850 Edition 1 and/or Edition 2. A hyphen (“-“) in the Ed column indicates the PIXIT entry is not applicable for any version.

PIXIT for Documentation

ID	Ed	Description	Value / Clarification
Do1	2	How to expose required firmware versions not present in the datamodel	

PIXIT for Association model

ID	Ed	Description	Value / Clarification
As1	1	Maximum number of clients that can set-up an association simultaneously	10
As2	1,2	TCP_KEEPALIVE value. The recommended range is 1..20s	Configurable 20 seconds by default
As3	1,2	Lost connection detection time	Configurable: number of retries and time between retries 40 seconds by default
As4	-	Authentication is not supported yet	
As5	1,2	What association parameters are necessary for successful association Called values: Calling values:	Transport selector N Session selector N Presentation selector N AP Title N AE Qualifier N other Transport selector N Session selector N Presentation selector N AP Title N AE Qualifier N other
As6	1,2	If association parameters are necessary for association, describe the correct values e.g.	Association parameters are not necessary for association

ID	Ed	Description	Value / Clarification
As7	1,2	What is the maximum and minimum MMS PDU size	Max MMS PDU size 65000 Min MMS PDU size Is determined by the size of the request.
As8	1,2	What is the maximum start up time after a power supply interrupt	50 seconds in normal situation (when no control configuration needs to be loaded)
As9	1,2	Does this device function only as test equipment? (test equipment need not have a non-volatile configuration; but it cannot be part of the substation automation system)	No. It has non-volatile configuration.

PIXIT for Server model

ID	Ed	Description	Value / Clarification
Sr1	1,2	Which analogue value (MX) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, N Reserved, Y Questionable Detail Quality: Y Overflow Y OutofRange Y BadReference Y Oscillatory Y Failure Y OldData Y Inconsistent Y Inaccurate Miscellaneous: Y Source Y Test N OperatorBlocked If no user configuration is done, by default the measurements support: OutOfRange and OldData.

ID	Ed	Description	Value / Clarification
Sr2	1,2	Which status value (ST) quality bits are supported (can be set by server)	Validity: Y Good, Y Invalid, N Reserved, Y Questionable Detail Quality Y BadReference Y Oscillatory Y Failure Y OldData Y Inconsistent Y Inaccurate Miscellaneous: Y Source Y Test N OperatorBlocked If no user configuration is done, by default the signals support: Oscillatory, Failure and OldData.
Sr3	-	What is the maximum number of data object references in one GetDataValues request	Deprecated
Sr4	-	What is the maximum number of data object references in one SetDataValues request	Deprecated
Sr5	1	Which Mode values are supported [1]	On Y [On-]Blocked Y Test Y Test/Blocked Y Off Y The supported Mode values are indicated by using different enumeration types for each case. Control LNs (CSWI, GAPC…) just support On and Test.

[1] IEC 61850-6:2009 clause 9.5.6 states that if only a subrange of the enumeration value set is supported, this shall be indicated within an ICD file by an enumeration type, where the unsupported values are missing

PIXIT for Data set model

ID	Ed	Description	Value / Clarification
Ds1	1	What is the maximum number of data elements in one data set (compare ICD setting)	Fixed in ICD to 500
Ds2	1	How many persistent data sets can be created by one or more clients (this number includes predefined datasets)	0
Ds3	1	How many non-persistent data sets can be created by one or more clients	0

PIXIT for Substitution model

ID	Ed	Description	Value / Clarification
Sb1	1	Are substituted values stored in volatile memory	Yes

PIXIT for Setting group control model

ID	Ed	Description	Value / Clarification
Sg1	1	What is the number of supported setting groups for each logical device	8
Sg2	1,2	What is the effect of when and how the non-volatile storage is updated (compare IEC 61850-8-1 $16.2.4)	If values are updated in a CID, these changes take effect after starting up. If values are updated by MMS services, these changes take effect immediately
Sg3	1	Can multiple clients edit the same setting group	N
Sg4	1	What happens if the association is lost while editing a setting group	The EditSG is reset to 0
Sg5	1	Is EditSG value 0 allowed	Y
Sg6	2	When ResvTms is not present how long is an edit setting group locked	ResvTms is present. Its default value is 3600 seconds

PIXIT for Reporting model

ID	Ed	Description	Value / Clarification
Rp1	1	The supported trigger conditions are (compare PICS)	integrity Y data change Y quality change Y data update N general interrogation Y
Rp2	1	The supported optional fields are	sequence-number Y report-time-stamp Y reason-for-inclusion Y data-set-name Y data-reference Y buffer-overflow Y entryID Y conf-rev Y segmentation Y
Rp3	1,2	Can the server send segmented reports (when not supported, it is allowed to refuse an association with a PDU smaller than the supported minimum PDU size)	Y
Rp4	1,2	Mechanism on second internal data change notification of the same analogue data value within buffer period (Compare IEC 61850-7-2 Ed2 $17.2.2.9)	The DUT behaves as if BufTm has expired and sends the report immediately, restarts the timer with BufTm value and processes the second change
Rp5	1	Multi client URCB approach (compare IEC 61850-7-2:2003 $14.2.1)	Each URCB is visible to all clients
Rp6	-	What is the format of EntryID	Deprecated
Rp7	1,2	What is the buffer size for each BRCB or how many reports can be buffered	30 Kbytes
Rp8	-	Pre-configured RCB attributes that are dynamic, compare SCL report settings	Deprecated
Rp9	1	May the reported data set contain: - structured data objects - data attributes	 Y Y
Rp10	1,2	What is the scan cycle for binary events Is this fixed, configurable	2 ms Fixed
Rp11	1	Does the device support to pre-assign a RCB to a specific client in the SCL	Y

ID	Ed	Description	Value / Clarification
Rp12	2	After restart of the server is the value of ConfRev restored from the original configuration or retained prior to restart	Restored from original CID configuration
Rp13	1,2	Does the server accept any client to configure/enable a BRCB with ResvTms=-1? What fields are used to do the identification?	N Client's IP Address
Rp14	2	When BRCB.ResvTms is exposed, what is default value for BRCB.ResvTms if client does not write (must be > 0) or When BRCB.ResvTms is not exposed, what is the internal reservation time (must be >= 0)	10 seconds N/A
Rp15	2	Is data model db=0 supported	Yes
Rp16	1,2	Each RCB should be configured with a different Data Set. In case of configuring the same Data Set in different RCBs those RCBs must be configured with the same trigger options and integrity period.	

PIXIT for Logging model

ID	Ed	Description	Value / Clarification
Lg1	1,2	What is the default value of LogEna (Compare IEC 61850-8-1 $17.3.3.2.1, the default value should be FALSE)	FALSE
Lg2	-	What is the format of EntryID	Deprecated
Lg3	1,2	Are there are multiple Log Control Blocks that specify the Journaling of the same MMS NamedVariable and TrgOps and the Event Condition (Compare IEC 61850-8-1 $17.3.3.3.2)	Single Journal Entry
Lg4	1	Pre-configured LCB attributes that cannot be changed online	Deprecated, the information is already available in SCL
Lg5		Which TrgOps are supported for logging (note Ed2 and up requires support for all TrgOps)	data change Y quality change Y data update N integrity Y

PIXIT for GOOSE publish model

ID	Ed	Description	Value / Clarification
Gp1	1,2	Can the test (Ed1) / simulation (Ed2) flag in the published GOOSE be set	Y
Gp2	1	What is the behaviour when the GOOSE publish configuration is incorrect	If goose pdu is too large NdsCom=True and DUT keeps GoEna=False If no DatSet is configured NdsCom=True and DUT keeps GoEna=False CIDs with incorrect goose publish configuration are rejected
Gp3	1,2	Published FCD supported common data classes are	Any FCD with FC=ST/MX/SP Arrays are not supported
Gp4	1,2	What is the slow retransmission time Is it fixed or configurable	Max value: 2.147.483.647 ms Configured by GoCB MaxTime Default value: 2000 ms
Gp5	1,2	What is the fastest retransmission time Is it fixed or configurable	Min value: 2ms Configured by GoCB MinTime Default value: 2ms
Gp6	-	Can the GOOSE publish be turned on / off by using SetGoCBValues(GoEna)	Deprecated See PICS - SetGoCBValues
Gp7	1,2	What is the initial GOOSE sqNum after restart	1
Gp8	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y Y
Gp9	1,2	Does Server or ICT refuse GOOSE payload dataset length greater than SCSM supports?	No

PIXIT for GOOSE subscribe model

ID	Ed	Description	Value / Clarification
Gs1	1,2	What elements of a subscribed GOOSE message are checked to decide the message is valid and the allData values are accepted? If yes, describe the conditions. Notes: • the VLAN tag may be removed by a ethernet switch and shall not be checked • the simulation flag shall always be checked (Ed2)	Y destination MAC address Y APPID Y gocbRef Y timeAllowedtoLive Y datSet Y goID N t Y stNum Y sqNum Y simulation / test Y confRev Y ndsCom Y numDatSetEntries sqNum greater than expected: Not detected (check Gs4) sqNum less than expected: Detected Data-type mismatch in data set elements: Detected N out-of-order dataset members When Y (except datSet, confRev, simulation, ndsCom and numDatSetEntries): the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the GOOSE message indicating it by changing the quality (questionable-old data). When receiving a subscribed GOOSE with the simulate bit or the ndsCom flag activated or an incorrect dataset or confRev, the DUT will discard the GOOSE message without indicating it by changing the quality. In these cases, as soon as received a subscribed GOOSE with a data value change, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the message indicating it by changing the quality (questionable-old data).

ID	Ed	Description	Value / Clarification
			When receiving a subscribed GOOSE with numDatSetEntries less than expected or data-type mismatch, the DUT will discard the GOOSE message without indicating it by changing the quality. In these cases, as soon as received a subscribed GOOSE with a data value change, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and the DUT will discard the GOOSE message indicating it by changing the quality (invalid). When receiving a subscribed GOOSE with an incorrect confRev, the DUT will use the latest value received when the goose was correct before identifying that the new subscription data is invalid and immediatly the DUT will discard the GOOSE message indicating it by changing the quality (invalid).
Gs2	1,2	When is a subscribed GOOSE marked as lost (TAL = time allowed to live value from the last received GOOSE message)	Message does not arrive prior to TAL
Gs3	1,2	What is the behaviour when one or more subscribed GOOSE messages isn't received or syntactically incorrect (missing GOOSE)	If the TAL is expired the quality of the attribute in the database will be set to Questionable and Old Data and it will keep the last received value

ID	Ed	Description	Value / Clarification
Gs4	1,2	What is the behaviour when a subscribed GOOSE message is out-of-order	To protect the system against out-of-order GOOSE messages the IED uses a combination of TAL and a time association setting (LPHD1.GoAsLosTms). The time used to invalidate one association will be the biggest one between them. By default, LPHD1.GoAsLosTms=10 seconds. While one association is in active status, the IED will only accept GOOSE messages where stNum+sqNum are incrementing (integer of 32 bits). If the increment is bigger than 2^31, the GOOSE is discarded and the IED will wait to receive a correct GOOSE message inside the TAL. If no GOOSE message arrives, then the IED sets the quality to questionable-old data. Once the IED has marked one GOOSE as lost, it will wait for the association time to reactivate the subscription accepting the first GOOSE (stNum+sqNum) that arrives and using those values as the new reference.
Gs5	1,2	What is the behaviour when a subscribed GOOSE message is duplicated	The DUT ignores the duplicated message.
Gs6	1	Does the device subscribe to GOOSE messages with/without the VLAN tag	Y, with the VLAN tag Y, without the VLAN tag
Gs7	1	May the GOOSE data set contain: - structured data objects (FCD) - timestamp data attributes	 Y N
Gs8	1,2	Subscribed FCD supported common data classes are	SPS, DPS, INS, ENS, ACT, ACD, SEC, MV, CMV, WYE, DEL, SPC, DPC, INC, ENC, BSC, ISC, APC, BAC, SPG, ING, ENG, ASG, CURVE, CSG. Arrays are not supported

ID	Ed	Description	Value / Clarification
Gs9	1,2	Are subscribed GOOSE with test=T (Ed1) / simulation=T (Ed2) accepted in test/simulation mode	Y
Gs10	1,2	Max number of dataset members	Unlimited
Gs11	1	Is Fixed-length encoded GOOSE supported	No
Gs12	1	Is IEC 62351-6 security supported	No

PIXIT for GOOSE performance

ID	Ed	Description	Value / Clarification	
Gf1	1,2	Performance class	P1 = 3ms	
Gf2	1,2	GOOSE ping-pong processing method	¿? Event driven based OR SCAN CYCLE BASED	
Gf3	1,2	Application logic scan cycle (ms)	Max	20ms
			Min	2ms
Gf4	1	Maximum number of data attributes in GOOSE dataset (value and quality has to be counted as separate attributes)	Maximum number of 1265 bytes. (Around 421 DAs if they are stVal)	

PIXIT for Control model

ID	Ed	Description	Value / Clarification
Ct1	1	What control models are supported (compare ICD file enums for Ed2)	DOns: Y SBOns: Y DOes: Y SBOes: Y
Ct2	1,2	Is the control model fixed, configurable and/or dynamic	Dynamic
Ct3	-	Is TimeActivatedOperate supported (compare PICS or SCL)	Deprecated
Ct4	-	Is “operate-many” supported (compare sboClass)	Deprecated, see sboClass in datamodel (ICD)
Ct5	1	Will the DUT activate the control output when the test attribute is set in the SelectWithValue and/or Operate request (when N test procedure Ctl2 is applicable)	N
Ct6	-	What are the conditions for the time (T) attribute in the SelectWithValue and/or Operate request	Deprecated
Ct7	-	Is pulse configuration supported (compare pulseConfig)	Deprecated

ID	Ed	Description	Value / Clarification
Ct8	1	What is the behaviour of the DUT when the check conditions are set Is this behaviour fixed, configurable, online changeable	N synchrocheck Y interlock-check DUT ignores synchrocheck value. DUT uses interlock-check to perform or not the check. Fixed
Ct9	1,2	Which additional cause diagnosis are supported	Y Unknown Y Not-supported Y Blocked-by-switching-hierarchy Y Select-failed Y Invalid-position Y Position-reached Y Step-limit (just in RTF model) Y Blocked-by-Mode Y Blocked-by-process Y Blocked-by-interlocking N Blocked-by-synchrocheck Y Command-already-in-execution N Blocked-by-health Y 1-of-n-control N Abortion-by-cancel N Time-limit-over N Abortion-by-trip Y Object-not-selected **Edition 1 specific values:** N Parameter-change-in-execution (PCIE Ed1 semantics) **Edition 2 specific values:** Y Object-already-selected N No-access-authority N Ended-with-overshoot N Abortion-due-to-deviation N Abortion-by-communication-loss N Blocked-by-command N None Y Inconsistent-parameters Y Locked-by-other-client N Parameter-change-in-execution (PCIE Ed2 semantics)

ID	Ed	Description	Value / Clarification
Ct10	1,2	How to force a “test-not-ok” respond with SelectWithValue request	Invalid orCat value, orCat >= 9
Ct11	1,2	How to force a “test-not-ok” respond with Select request	The control is selected
Ct12	1,2	How to force a “test-not-ok” respond with Operate request	Invalid orCat value, orCat >= 9 DOns, SBOns, DOes: Operate value and actual position are the same SBOes: Operate values are different than selected
Ct13	1,2	Which origin categories are supported / accepted	Y bay-control Y station-control Y remote-control N automatic-bay Y automatic-station Y automatic-remote Y maintenance Y process
Ct14	1,2	What happens if the orCat value is not supported or invalid	DOns: command rejected SBOns: command rejected DOes: command rejected SBOes: command rejected The DUT sends reponse– with AccessResult=Object_access_denied and it sends, for enhanced security, CommandTermination with AddCause= Not-supported
Ct15	1,2	Does the IED accept a SelectWithValue / Operate with the same control value as the current status value Is this behaviour configurable	DOns: N SBOns: N DOes: N SBOes: Y/N Configurable N The DUT sends reponse– with AccessResult=Object_access_denied and it sends, for enhanced security, CommandTermination with AddCause= Position-reached

ID	Ed	Description	Value / Clarification
Ct16	1,2	Does the IED accept a select/operate on the same control object from 2 different clients at the same time	DOns: N SBOns: N DOes: N SBOes: N The DUT sends reponse– with AccessResult=temporarily-unavailable and it sends, for enhanced security, CommandTermination with AddCause= Object-already-selected / Command-already-in-execution
Ct17	1	Does the IED accept a Select/SelectWithValue from the same client when the control object is already selected (Tissue #334)	SBOns: N SBOes: N
Ct18	1,2	Is for SBOes the internal validation performed during the SelectWithValue and/or Operate step	The validation is performed during the Operate step
Ct19	-	Can a control operation be blocked by Mod=Off or [On-]Blocked (Compare PIXIT-Sr5)	Deprecated
Ct20	1,2	Does the IED support local / remote operation	Y
Ct21	1,2	Does the IED send an InformationReport with LastApplError as part of the Operate response-for control with normal security	SBOns: N DOns: N
Ct22	2	How to force a “parameter-change-in-execution”	N/A
Ct23	1,2	How many SBOns/SBOes control objects can be selected at the same time?	SBOns: multiple SBOes: multiple
Ct24	1,2	Can a controllable object be forced to keep its old state e.g. Internal Controllable Objects may not be accessible to force this, whereas a switch like Circuit Breaker outside the DUT can?	Y
Ct25	1,2	When CDC=DPC is supported, is it possible to have DPC (Controllable Double Point) go to the intermediate state? (00)	Y
Ct26	1,2	Name a DOes point (if any) with a finite operate timeout and specify the timeout (in milliseconds)	CTRL/CSWI1.Pos Timeout is configurable
Ct27	2	Does the IED support control objects with external signals?	DOns: Y SBOns: Y DOes: Y SBOes: Y

PIXIT for Time synchronisation model

ID	Ed	Description	Value / Clarification
Tm1	1	What time quality bits are supported (may be set by the IED)	Y LeapSecondsKnown N ClockFailure Y ClockNotSynchronized
Tm2	1,2	Describe the behaviour when the time server(s) ceases to respond What is the time server lost detection time	Wait for a configurable number of connection retries (unicast mode) or wait a configurable period of time (multicast mode). After that "Clock-not-synchronized" will be set. Configurable. Tested value: 10 seconds after the first request send to the time server without response.
Tm3	1,2	How long does it take to take over the new time from time server	Configurable Tested value: as soon as the new time from the time server is received.
Tm4	1,2	When is the time quality bit "ClockFailure" set	N/A
Tm5	1,2	When is the time quality bit "Clock not Synchronized" set	When connection to all time servers are lost (see PIXIT-Tm2)
Tm6	-	Is the timestamp of a binary event adjusted to the configured scan cycle	Deprecated
Tm7	1	Does the device support time zone and daylight saving	Y
Tm8	1,2	Which attributes of the SNTP response packet are validated	Y Leap indicator not equal to 3 N Mode is equal to SERVER N OriginateTimestamp is equal to value sent by the SNTP client as Transmit Timestamp N RX/TX timestamp fields are checked for reasonableness Y SNTP version 3 and/or 4 N other (describe)
Tm9	1,2	Do the COMTRADE files have local time or UTC time and is this configurable	Local Time Not configurable

PIXIT for File transfer model

ID	Ed	Description	Value / Clarification
Ft1	1	What is structure of files and directories Where are the COMTRADE files stored Are comtrade files zipped and what files are included in each zip file	/COMTRADE/ /SCL/active/ /SCL/notvalidated /SYSTEMLOG/ /COMTRADE/ Not zipped
Ft2	1,2	Directory names are separated from the file name by	"/"
Ft3	1	The maximum file name size including path (recommended 64 chars)	255 chars
Ft4	1,2	Are directory/file name case sensitive	Case sensitive
Ft5	1,2	Maximum file size for SetFile	N/A
Ft6	1	Is the requested file path included in the MMS fileDirectory respond file name	(Ed2: always complete path)
Ft7	1	Is the wild char supported MMS fileDirectory request	No
Ft8	1,2	Is it allowed that 2 clients get a file at the same time	Y same file Y different files
Ft9	1,2	Which files can be deleted	N/A

TISSUES Implementation Conformance Statement for the IEC 61850 Ed2 interface in IRF/IDF/ZLF/DLF/RTF

Version 0.0, Date: 15/05/2021

UCA International Users Group
Testing Sub Committee

TICS Template Ed2 for TPCL 1.2.6

Introduction

This document provides a template for the Tissues conformance statement. According to the UCA IUG QAP the Tissue conformance statement is required to perform a conformance test and is referenced on the certificate.

This document is applicable for IRF/IDF/ZLF/DLF/RTF with firmware version 0.10.0.

Mandatory Edition 2 Tissues

Below tables give an overview of the applicable mandatory Tissues.
Items in *italic* are brief interpretations provided by the UCA International Users Group to aid in interpretation and is not normative.
The original TISSUE should be consulted for details of changes.

Part 6 Tissue	Description	Implemented Y/na
658	Tracking related features *EntryID and CST missing, these are checked by schema*	Y
1324	FCDA element cannot be a "functionally constrained logical node" *doName now mandatory in FCDA element, SCT: refuse to make empty doName? ICT: Refuse SCD*	Y
668	Autotransformer modeling *Autotransformer model in substation section has changed*	Y
687	SGCB ResvTms *SettingControl has added attribute resvTms see also TISSUE 845*	Y
719	ConfDataSet - maxAttributes definition is confusing *maxAttributes now means max count of FCDA in dataset*	Y
721	Log element name *LN0/Log now has optional attribute "name"*	Y
768	bType VisString65 is missing *VisString65 added as SCL BasicType*	na
779	object references *"@" as first character in object references now allowed*	Y
788	SICS S56 from optional to mandatory *SICS S56="Interpret IED capabilities and prohibit unsupported usage"*	na
789	ConfLdName as services applies to both server and client *Many changes made to Services section*	Y
804	valKind and IED versus System configuration *valImport missing/false DAI means ICT shall ignore value in SCD and SCT shall not change from ICD/IID value. Instance section inherits from DA/BDA element.*	Y
806	Max length of log name inconsistent between -6 and -7-2 *LogControl.logName and Log.name restricted to 32 chars*	Y
807	Need a way to indicate if "Owner" present in RCB *Services/ReportSettings@owner added*	Y
823	ValKind for structured data attributes *valKind is prohibited on structured attributes*	Y

Part 6 Tissue	Description	Implemented Y/na
824	Short addresses on structured data attributes *sAddr is now allowed for structured attributes*	Y
825	Floating point value *Server shall support <Val> with exponential notation*	Y
845	SGCB ResvTms *Services/SettingGroups/SGEdit added attribute resvTms Services/SettingGroups/ConfSG added attribute resvTms See also TISSUE 687*	Y
853	SBO and ProtNs *DA[@name=SBO] element shall have ProtNS element*	Y
855	Recursive SubFunction *Substation section extension must be tolerated*	na
856	VoltageLevel frequency and phases *Substation section extension must be tolerated*	na
857	Function/SubFunction for ConductingEquipment *Substation section extension must be tolerated*	na
886	Missing 8-1 P-types *"tP_IP_UDP_PORT" and "tP_IP_TCP_PORT" added*	na
901	tServices as AP or as IED element *Rules for contents of AP/Server/Services are now defined*	Y
936	SupSubscription parameter usage is difficult *SupSubscription "max" replaced by "maxGo" and "maxSv"*	Y
1147	tServices - FileHandling not consistent with -7-2 *Services/FileHandling now means only support for GetFile and GetFileAttributeValues and NOT SetFile/DeleteFile*	Y
1185	Valkind value Conf for EX FC data *valKind=Conf is allowed for dataNs*	N
1284	SCSM mapping may require a communication section in an ICD file *Server IEDs supporting client/server associations to 61850-8-1 shall include a <Communication> section*	Y
1328	Limitation on the size of data type templates identifiers *Identifer now limited to 255 characters*	N
1395	Client LN attributes *ReportControl/RptEnabled/ClientLN@ldInst shall be "LD0" for pure clients (without any Logical Devices)*	Na
1402	ExtRef during engineering *an ExtRef.intAddr attribute value unequal to empty string (prescribed or filled by the IED tool) is the flag indicating that the ExtRef shall not be deleted by the system tool. The system tool can however remove the link to the source IED* <<applicable for SCL tool test>>	Y
1415	SICS-S110 IID import mandatory for Edition2 *only the import of data model modifications and CF value changes is mandatory for system tool* <<applicable for SCL tool test>>	na
1419	Support of ldName on other IEDs *SICS I212 is now mandatory*	Y
1444	Need to support fixed and SCT controlled Datasets *Services/xxxSetttings@datSet=fix now means "data set pointed by Control Block cannot be altered from ICD/IID* value <<applicable for SCL tool test>>	na
1445	ConfReportControl and a fixed ReportSettings *Control block capabilities must be consistent <<applicable for SCL tool test>>*	Y

Part 6 Tissue	Description	Implemented Y/na
1450	originalSclXxx computation rules *Ed2 ICD/IID files specifying SCL@version=2007 SHALL include originalSCLVersion=2007 and originalSCLRevision as attributes of the <IED>element*	Y
1485	Need to supercede Tissue 1398 to clarify SCT behavior *Same as TISSUE 1450 <<applicable for SCL tool test>>*	na

Part 7-1 Tissue	Description	Implemented Y/na
828	Data model namespace revision IEC 61850-7-4:2007[A]	Y
948	Enumeration (string) values format *Enums are limited to 127 characters from Basic-Latin and Latin-1 character sets*	Y
1151	simulated GOOSE disappears after 1st appearance when LPHD.Sim = TRUE *New LGOS state machine defined, but TISSUE is not IntOp2, therefore TISSUE is optional if LGOS is used*	Y
1396	The use and configuration flow of LGOS and LSVS is unclear *If Services/SupSubscription@maxGo > 1 then at least 1 LGOS must exist. Same for maxSv/LSVS. If maxGo > count(LGOS) then SCT can create additional LGOS. Same for maxSv/LSVS*	Y
1447	Restriction on ENUMtypes in SCL *If a ENUM DA limits write or configuration to a subset, then that subset must be declared.*	Y
1457	Multiple DOI nodes with the same name. *LN can have no more than one DOI with same name.*	Y
1468	Re-use DO from other LN *allow standard or private dataNs*	Y
1491	CmdBlk blocks itself? *The data CmdBlk shall have no effect on the controllable data Mod or CmdBlk.*	na

Part 7-2 Tissue	Description	Implemented Y/na
728	BRCB: could PurgeBuf be set when RptEna=TRUE? *PurgeBuf while RptEna=true is prohibited.*	Y
778	AddCause values – add value not-supported *Align 7-2 with 8-1 (nothing new to 8-1)*	Y
780	What are unsupported trigger option at a control block? *All control blocks must support all trigger options.*	Y
783	TimOper Resp- ; add Authorization check *Clarifies Time-Operated Controls.*	Y
786	AddCause values 26 and 27 are switched *Annex B.2 has wrong AddCause values.*	Y
820	Mandatory ACSI services (use for PICS template) *Model entries M18 (Application Association), M19 (GCB), M20 (SVCB) are new. Services S17 (Substitution) and S61 (GetServerDirectory) are new. Services S1, S3, S4, S5, S6, S8, S16, S18, S23, S36, S37, S41, S42 are changed.*	Y
858	typo in enumeration ServiceType *Tracking serviceType now has GetLogicalNodeDirectory*	Y

Part 7-2 Tissue	Description	Implemented Y/na
861	dchg of ConfRev attribute *Clarifies (tracking) BTS.confRev is AFTER BRCB change.*	na
1050	GTS Phycomaddr definition in SCL *(Tracking) GTS needs a special structure for SCL.*	na
1071	Length of DO name *Private DO name length shall be <=12 including instance.*	Y
1127	Missing owner attribute in BTS and UTS *NSD files for 61850-7-3 show owner in (tracking) BTS/UTS.*	na
1202	GI not optional *GI support is mandatory for both URCB and BRCB*	Y
1232	EntryID needs clarification *Segments of a report shall have same identifiers*	Y
1242	NTS definition *NTS.resv have been added*	na
1307	Segmented report with Buffer overflow *Segments of a report shall have identical buf-overflow value*	Y
1428	MTS and NTS should use svOptFlds *MTS.optFlds and NTS.optFlds now have bType=SvOptFlds*	na
1630	Attributes in CDC=LTS do not match 8-1 definition *Order of attributes in LTS changed to: logEna, logRef, datSet, oldEntrTm, newEntrTm, oldEnt, newEnt, trgOps, intgPd*	Y

Part 7-3 Tissue	Description	Implemented Y/na
697	persistent command / PulseConfig *PulseConfig adds enum "persistent-feedback"* *DPC.cmdQual==”persistent” is conditionally allowed*	na
698	Wrong case is BAC.dB attribute *attribute renamed from "dB" to "db"*	Y
711	blkEna freeze data update while setting its quality to operaterBlocked *Mode=Blocked shall not cause q.operatorBlocked*	na
722	Units for 'h' and 'min' not in UnitKind enumeration. *New unit enums 84=hours, 85=minutes*	Y
919	Presence Condition for sVC *svC may be valKind=Conf in ICD file*	na
925	Presence of i or f attribute - Problem with writing *New constructed attribute class "AnalogueValueCtl"*	Y
926	Presence Conditions within RangeConfig *All or none of hhLim+hLim+lLim+llLim shall be present*	Y
954	Data attributes with FC=CF should have trgOp=dchg *Some INS and HST and CSG attributes missing dchg*	y
1078	CMV.t update if rangeAng changed *Add rangeAng to"reasons-to-update-timestamp-of-CMV"*	na
1565	db = 0 behaviour *db=0 not longer suppresses reporting*	Y
1578	dataAttribute NameSpace content *Attributes with FC=EX must be initialized in ICD/IID file*	Y

Part 7-4 Tissue	Description	Implemented Y/na
671	mistake in definition of Mod & Beh *Beh=on, q=test should be "Processed as valid"*	Y
674	CDC of ZRRC.LocSta is wrong *ZRRC LocSta should be CDC=SPC*	na
676	Same data object name used with different CDC *LCCH.Fer renamed to FerCh, LCCH.RedFer to RedFerCh*	Y
677	MotStr is used with different CDC in PMMS and SOPM LN classes *Rename SOPM.MotStr to MotStrNum*	na
679	Remove CycTrMod Enum *Enum is no longer used, use TrMod instead*	na
680	SI unit for MHYD.Cndct *Change unit from S/cm2 to S/m*	na
681	Enum PIDAlg *Typographical error, invalid XML syntax*	na
682	ANCR.ParColMod *ParColMod enum values text have changed*	na
683	Enum QVVR.IntrDetMth *IntrDetMth enum values text have changed*	na
685	Enum ParTraMod *ParTraMod enum values text have changed*	na
686	New annex H - enums types in XML *Many changes have been made to enumeration names*	Y
694	Data object CmdBlk *CmdBlk semantics have changed*	na
696	LSVS.St (Status of subscription) *LSVS.St is now mandatory*	na
712	interpretation of quality operatorBlocked *Mode and Behavior semantics have changed*	na
713	DO Naming of time constants in FFIL *Many DO names in FFIL have changed*	na
714	Enums for ShOpCap and SwOpCap *Type for YPSH.ShOpCap and XSWI.SwOpCap have changed*	Y
715	RBDR.ChNum1 *RBDR.ChNum1 changes from optional to conditional*	na
716	TAXD text for condition *TAXD.SmRte condition for inclusion has changed*	na
724	ANCR.Auto *ANCR.Auto changes from mandatory to optional*	Y
725	Loc in LN A-group *Loc changes to optional, LocKey/LocSta conditions change*	na
734	LLN0.OpTmh vs. LPHD.OpTmh *LLN0.OpTmh deleted, LPHD.OpTmH added as conditional*	na
736	PFSign *MMXU.PFSign enum's 1 = IEC and 2 = EEI*	na
742	GAPC.Str, GAPC.Op and GAPC.StrVal *Objects have instance indicator removed (ex, Str1 to Str)*	Y
743	CCGR.PmpCtl and CCGR.FanCtl *Object have instance indicator added (ex:PmpCtl to PmpCtl1)*	na
744	LN STMP, EEHealth and EEName *Removed STMP.EEHealth and STMP.EEName*	na
772	LPHD.PwrUp/PwrDn should be transient *These objects are now transient*	N

Part 7-4 Tissue	Description	Implemented Y/na
773	Loc, LocKey and LocSta YPSH and YLTC *Add Loc, LocKey and LocSta in YLTC and YPSH (optional)*	na
774	ITCI.LocKey *Add ITCI.LocKey as optional*	na
776	LPHD.OutOv/InOv and LCCH.OutOv/InOv *Clarified: stays true until buffer space again available*	na
800	Misspelling in CSYN *CSYN.VInvTmms renamed to CSYN.VIntvTmms*	na
802	CCGR and Harmonized control authority *Add Loc, LocKSta to every controllable LN (e.g. FSPT)*	na
808	Presence condition of ZMoT.DExt and new DOs *Change ZMOT.DExt to optional; add TotThmSt and MotSt*	na
831	Setting of ConfRevNum in LGOS *Add RxConfRevNum to LGOS and LSVS*	na
838	Testing in Beh=Blocked *Change sematic of Beh=Blocked to allow controls to be acknowledged even when LN is blocked*	na
844	MFLK.PhPiMax, MFLK.PhPiLoFil, MFLK.PhPiRoot DEL->WYE *Change these NFLK objects from cdc=DEL to cdc=WYE*	na
877	QVUB -settings should be optional	na
908	ARIS.StrSeq – transient *Change ARIS.StrSeq to transient*	na
909	Remove ANCR.ColOpR and ColOpL	na
912	Clarification of PwrRtg/VARtg *Change many DOs in YPTR, and ZGEN, see name space 2007A nsd for final result*	Y
920	Resetable Counter is NOT resetable	na
932	Rename AVCO.SptVol to AVCO.VolSpt	na
933	Presence of LCCH.RedFerCh and RedRxCnt *Change the presence condition of LCCH.RedChLiv*	na
939	Change CDC for ANCR.FixCol *Change ANCR.FixCol from APC to ASG*	na
991	LGOS: GoCBRef (as well as LSVS.SvCBRef) should be mandatory *LGOS.GoCBRef and LSVS.SvCBRef are now both mandatory*	na
1007	PTRC as fault indicator - Update of description required *PTRC.Tr and Op and Str conditional (at least 1 of group)*	na
1044	TapChg in AVCO *AVCO.TapChg is now optional*	na
1077	Rename DOnames within LTIM *LTIM.TmChgDayTm, changed to TmChgDay;* *LTIM.TmChgStdTm changed to TmChgStd*	Y
1256	New DO for LTIM to set time "manually" *Add LTIM.TmSet*	N
1331	Mod, Beh and Health with q=TEST, client can't receive their states *Mod while in Blocked will always be processed*	Y
1426	Add two DO for leap seconds in LTIM *LTIM.Leap added*	na
1456	Annex A and Mod/Beh/Health *Mod.stVal writes always igore test bits in controls*	N

Part 7-4 Tissue	Description	Implemented Y/na
1568	ISAF.AlmReset ->transient *Change ISAF.AmlReset to transient*	na

Note: Tissues 675, 735, 772, 775, 776, 878 are not relevant for conformance testing

Part 8-1 Tissue	Description	Implemented Y/na
770	GoID type mitmatch 18.1.1 and 18.1.2.5.2 *GoID string length is now 129*	Y
784	Tracking of control (CTS) *Tracking CTS has been added*	na
817	Fixed-length GOOSE float encoding *GOOSE float is encoded Tag-0x87, length=5, first octet=8*	na
827	Mandatory ACSI services (Part of 7-2 TISSUE resolution) *Change Table 111 (ServicesSupported): Add initiate, abort, and release. Change conditions for defineNamedVariables.*	Y
834	File dir name length 64 *Filename length changed from 32 to 64*	Y
951	Encoding of Owner attribute *xRCB.owner is encoded as 4 octets(IPv4) or 16 octets(IPv6)*	Y
1040	More associate error codes *3 additional associate error codes added*	Y
1178	Select Response+ is non-null value *Response to SBO read should be <CO_CtrlObjectRef>*	Y
1324	The response- for DeleteNamedVariableList is not defined *numDeleted=0; error=service/object-constraint-conflict*	na
1345	Fixed-length GOOSE ASN.1 length encoding *GOOSE publisher shall always encode minimum size legth field*	na
1441	Optonal fields in buffered reports *Writing BRCB.optFld shall not cause a purgeBuf operation*	Y
1442	Journal variableTag for ReasonCode *Example in the standard is incorrect*	Y
1453	Purge buffer on write to BRCB *PurgeBuf only occurs if different value is written*	Y
1454	Reports can be transmitted before write(RptEna=true) is confirmed	Y
1495	GetVariableAccessAttributes error code *Return MMS error access/object-non-existent if the object does not exist*	Y
1500	the response for DeleteNamedVariableList with a non-existent LN is not specified *CreateDataSet/DefineNamedVariableList specifying a non-existing LD/LN shall fail with access/object-non-existent*	na
1626	PICS for Information Report is incorrect *MMS ServicesSupported "informationReport" should be optional for servers because they never receive InformationReport requests. It is only required for clients which process reports or control command-termination*	Y

Compare the TISSUE database for more details: www.tissues.iec61850.com

F. Cybersecurity

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F.1 Introduction

In the past, substation networks were traditionally isolated, and the protocols and data formats used to transmit information between devices were often proprietary.

Because of this, the substation environment was very safe from cyberattacks. The terms used for this type of inherent security are:

- Security by isolation (if the substation network is not connected to the outside world, it cannot be accessed from the outside world).
- Security by obscurity (if data formats and protocols are proprietary, they are difficult for a third party to interpret).

The increasing sophistication of protection devices, together with the advancement of technology and the requirement for interoperability between manufacturers, have resulted in a standardization of networks and data exchange in substations. Today, devices within substations use standardized protocols for communications. In addition, substations can connect to open networks, such as the Internet and vast corporate networks, which employ standardized protocols for communications. This introduces a greater security risk, making the network vulnerable to cyberattacks, which could result in a higher electrical failure rate. Clearly there is now a need to secure communications and devices in substations.

Cybersecurity provides protection against unauthorized disclosure, transfer, modification or destruction of information or information systems, whether accidental or intentional. To achieve this, there are several security requirements:

- Confidentiality (avoid unauthorized access to information).
- Integrity (avoid modification of unauthorized information).
- Availability (avoid denial of service).
- Non-repudiation (avoid denying that an action was taken or asserting that it was done when it was not done).
- Traceability / Detection (monitoring and logging of activity to detect intrusions and analyze incidents).

Cybersecurity threats can be unintentional (natural disasters, human error) or intentional (cyber-attacks by hackers).

Some examples of vulnerabilities are:

- Indiscretions on the part of the staff (users keep the keys on their computers).
- Bad practices (users do not change passwords by default, or everyone uses the same password to access all substation devices).
- Circumvention of control (users deactivate security measures).
- Inadequate technology (no firewalls are installed in the substation).

Some examples of availability problems are:

- Device overload resulting in poor or even no performance.
- Expiration of the certificate preventing access to the device.

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To help solve these problems, standardization organizations have developed several standards/norms. Compliance with these standards significantly reduces the threats associated with a lack of cybersecurity.

The cybersecurity measures implemented in the device include the following:

- Disabling of ports and communications services.
- Role-based access control (RBAC).
- Remote user authentication (LDAP and RADIUS).
- Use of secure sockets.
- Digital firmware securization.
- Cybersecurity audit log.

F.2 Ports and Communications Services

It is important to be able to guarantee that a device has active only those physical ports and logical ports (services) strictly necessary to comply with the required functionality. Therefore, it is essential to be able to enable or disable physical ports and services. These physical ports and services are managed through the configuration tool and the HMI of the device.

Depending on the model, the device may have the following physical ports:

- Local port.
- Remote port 1.
- Remote port 2.
- LAN 1.
- LAN 2.
- LAN 3.
- LAN 4.
- USB (pendrive).

By default, all ports on the device are disabled except the local port and the LAN ports. This means that remote ports 1 and 2 and USB (pendrive) will not be operational until they are enabled.

The user must initially enable the ports and services to be used, either by connecting to the configuration tool or by accessing the corresponding HMI menus.

When a port is disabled, it means that both transmission and reception are blocked.

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The device has the following settings for enabling and disabling physical ports:

Port Enabling				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
Local Port	Local Port	Inactive / Active		Active
Remote Port 1	Remote Port 1	Inactive / Active		Inactive
Remote Port 2	Remote Port 2	Inactive / Active		Inactive
LAN 1 Port	LAN 1 Port	Inactive / Active		Active
LAN 2 Port	LAN 2 Port	Inactive / Active		Active
LAN 3 Port	LAN 3 Port	Inactive / Active		Active
LAN 4 Port	LAN 4 Port	Inactive / Active		Active
USB Port	USB Port	Inactive / Active		Inactive

If network redundancy (PRP, HSR, RSTP) is configured on a pair of ports (LAN1-2 or LAN3-4), enabling/disabling the second port (LAN2 or LAN4) has no effect on the device. Enabling/disabling the first port (LAN1 or LAN3) enables/disables both ports (LAN1-2 or LAN3-4).

The communication services supported by the device are the following:

- HTTP.
- HTTPS.
- Telnet.
- SSH.
- FTP.
- SFTP.
- MMS (IEC 61850).
- PROCOME Protocol.
- TCP/IP 1 Protocol (PROCOME, DNP3 or MODBUS).
- TCP/IP 2 Protocol (PROCOME, DNP3 or MODBUS).
- TCP/IP 3 Protocol (PROCOME, DNP3 or MODBUS).
- TCP/IP 4 Protocol (PROCOME, DNP3 or MODBUS).
- Syslog Client.

By default, all services are disabled except those which use secure sockets (HTTPS, SSH, SFTP and PROCOME). When a service is disabled, the socket associated with the service may appear as open (in listen state), but does not support connections, filtering is done by software.

The device has the following settings for enabling and disabling logical ports (services):

Service Enabling				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
HTTP	HTTP	Inactive / Active		Inactive
HTTPS	HTTPS	Inactive / Active		Active
SSH	SSH	Inactive / Active		Active
SFTP	SFTP	Inactive / Active		Active
Telnet	Telnet	Inactive / Active		Inactive
FTP	FTP	Inactive / Active		Inactive
MMS (IEC 61850)	MMS (IEC 61850)	Inactive / Active		Inactive
PROCOME	PROCOME	Inactive / Active		Active
TCP/IP Protocol 1	TCP/IP Protocol 1	Inactive / Active		Inactive
TCP/IP Protocol 2	TCP/IP Protocol 2	Inactive / Active		Inactive
TCP/IP Protocol 3	TCP/IP Protocol 3	Inactive / Active		Inactive
TCP/IP Protocol 4	TCP/IP Protocol 4	Inactive / Active		Inactive
Syslog Client	Syslog Client	Inactive / Active		Inactive

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To disable other services such as synchronization by SNTP or by PTP (IEEE 1588), see Chapter 1, **Description and Start-Up**, **Synchronization Settings** section.

As an additional security measure, the device offers the possibility of changing the logical ports assigned to the services. The device has the following settings for changing service ports:

Service Ports				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
HTTP	HTTP	1 - 65535	1	80
HTTPS	HTTPS	1 - 65535	1	443
Telnet	Telnet	1 - 65535	1	23
FTP	FTP	1 - 65535	1	21
SSH/SFTP	SSH/SFTP	1 - 65535	1	22

The logical ports corresponding to the PROCOME, DNP3 and MODBUS protocols can be modified as described in Chapter 1, **Description and Start-Up**, **Communications Settings** section.

The logical port of the MMS protocol corresponding to IEC 61850 communications is 102 and cannot be modified.

All the services must have different port numbers assigned to them.

F.3 Role Based Access Control (RBAC)

The concept of **R**ole **B**ased **A**ccess **C**ontrol (RBAC) is used.

RBAC is not a new concept, many operating systems use it to control access to system resources.

RBAC is an alternative to the total access (superuser) or read-only model.

RBAC complies with the principle of minimum privilege security, which states that no user should be granted more rights than are necessary to perform that user's work.

RBAC allows an organization to separate the different capabilities and group them into special user accounts called roles for assignment to specific individuals according to the needs of their work.

RBAC carries implicitly the concepts of *users*, *roles* and *permissions* that will be developed next.

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F.3.1 Users, Roles and Permissions

RBAC intrinsically carries the concepts of *users*, *roles* and *permissions*. A *user* has an associated *role*. Each *role* has one or more associated *permissions*.

Some examples that can help to understand the concept of roles and permissions would be the following:

Role	Permissions
VIEWER	Visualization
OPERATOR	Visualization, Command execution
ENGINEER	Visualization, Setting change, Configuration change
INSTALLER	Visualization, Setting change, Configuration change, Firmware change
RBACMNT	Visualization, User management
SECAUD	Visualization, Audit log
ADMINISTRATOR	All

The device allows the creation of up to **20 users**. Each user has associated a username, a password and a role.

The device allows the creation of up to **10 roles**. At the same time, each role can be associated with a series of permissions, in addition to a name and an identifier (used to univocally relate the user with a role).

Each access to the device by a user or application by remote access to console (Telnet / SSH), web (HTTP / HTTPS), file transfer (FTP / SFTP) and configuration tool (PROCOME), must be authenticated (login) through the introduction of user and password.

Access through other protocols, such as DNP3, MODBUS and MMS (IEC 61850), is still free of username and password.

The following permissions have been defined in the device:

- *Visualization* permission. With this permission it is possible to visualize states, measurements, settings, etc., as well as to collect oscillographs, events and fault reports, configuration files and log files (except for the cybersecurity event file).
- *Command execution* permission. With this permission it is possible to execute commands (e.g., date/time change).
- *Setting change* permission. With this permission it is possible to change the value of the settings, as well as to change the active table of settings and load the settings file.
- *Configuration change* permission. With this permission it is possible to load configuration files.
- *Firmware change* permission. With this permission it is possible to load the firmware to the device.
- *User management* permission. With this permission it is possible to manage users (add, delete or modify a user or a role), configure authentication methods and manage credentials.
- *Audit log* permission. With this permission it is possible to view/collect the cybersecurity event file.

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By default, there is a single *admin* user with password *Passwd@02* associated with a role with identifier *-1*. This role is configured by default with all the permissions.

As a minimum, the visualization permission must be active. A user who does not have visualization permission will not have permission to do anything and therefore the device will reject his/her authentication attempts.

There must always be a user with user management permission.

To configure users and roles a user with *user management* permission must be used and next procedures can be used:

- From a website, via HTTP (not recommended because the data is not encrypted) or HTTPS, by accessing the ***Configuration→Access*** menu.
- From command line interface (CLI), via Telnet (not recommended because the data is not encrypted) or SSH.
- From the ***ZIV e-NET Tool***® configuration tool, using *LocalRBAC* and *DevicePreferences* files.

The following parameters are configured for each user:

Users					
Website	**CLI**	**LocalRBAC**	**Range**	**Step**	**Default**
Login	*main/access/user[x]/login*	name	char[32]		admin
Password	*main/access/user[x]/pwd*	pwd	char[32]		Passwd@02
Role Id	*main/access/user[x]/roleid*	role	-32768… 32767	1	-1

where *x* goes from 1 to 20, depending on the number of users that have been created.

Name. It supports up to 32 characters and its default value is *admin*. If it is empty, it means that the user does not exist. The username is unique (no two users with the same name can exist) and is case sensitive (i.e., "Admin" and "admin" are two different users).

Password. Users' passwords are strong. They allow a minimum length of 8 characters and a maximum of 32, are case sensitive and contain:

- At least one uppercase letter.
- At least one lowercase letter.
- At least one number.
- At least one non-alphanumeric character from ASCII 33 to ASCII 126 (both included). Blank space (ASCII character 32) is not a valid character to be used as part of passwords.

Passwords are never shown in clear and are stored encrypted on the device. Its default value is *Passwd@02*.

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Role. An existing role identifier is configured.

The following parameters are configured for each role:

Roles					
Website	**CLI**	**DevicePreferences**	**Range**	**Step**	**Default**
Name	*main/access/role[y]/name*	name	char[32]		admin
Id	*main/access/role[y]/id*	id	-32768… 32767	1	-1
View	*main/access/role[y]/rview*	rightMsk (bit 0x01)	NO / YES		YES
Control	*main/access/role[y]/rctrl*	rightMsk (bit 0x02)	NO / YES		YES
Settings	*main/access/role[y]/rchset*	rightMsk (bit 0x04)	NO / YES		YES
Config	*main/access/role[y]/rchcfg*	rightMsk (bit 0x08)	NO / YES		YES
Firmware	*main/access/role[y]/rchfw*	rightMsk (bit 0x10)	NO / YES		YES
Users	*main/access/role[y]/rusrmgmt*	rightMsk (bit 0x20)	NO / YES		YES
Audit	*main/access/role[y]/raudit*	rightMsk (bit 0x40)	NO / YES		YES
Global role concurrency	*main/access/global_conc*	global_conc	NO / YES		YES
Priority	*main/access/role[y]/priority*	priority	1…10		5
Concurrency	*main/access/role[y]/concurrency*	concurrency	NO / YES		NO

where *y* goes from 1 to 10, depending on the number of roles that have been created.

Name. It supports up to 32 characters and its default value is *admin*. It cannot be empty. The role name is unique (there cannot be two roles with the same name) and is case sensitive (i.e., "Admin" and "admin" are two different roles).

This is the text used to check the role returned by remote authentication services (AAA) when they return a text.

Identifier. It uniquely identifies the role and is used on the user to indicate its associated role.

This is the number used to check the role returned by remote authentication services (AAA) when they return a number.

According to the IEC 62351-8 standard, negative numbers will be used for private roles, since this standard reserves positive numbers. The user can assign the desired value within the range -32768...32767, but by default the identifier -1 is assigned to comply with IEC 62351-8 standard.

Permissions. These are the different permissions that a role can have.

A role without associated permissions is not allowed to do anything and the device will reject authentication attempts from users who have that role associated with them.

The characters supported for usernames and roles are those indicated in the POSIX standard (Portable Operating System Interface for Unix) (IEEE Standard 1003.1 2008), with the exception that the hyphen character '-' cannot be used as the first character of the username or role:

```
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
0 1 2 3 4 5 6 7 8 9 . _ -
```


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The last three parameters are related to **Role Concurrency**:

Access Priority. This is a numeric setting indicating the access priority of that role. There will be as many priorities as roles (10). The lowest number (1) indicates the lowest priority and the highest number (10) indicates the highest priority. The default value is 5.

When the session limit has been reached (see **Session Concurrency** section), the access of a user with a higher priority role will cause the session of a user with a lower priority role to be automatically closed without any warning. The criterion will be to close the session of the user with a lower priority role and who has been connected for the longest time.

This priority will become clearer later when the different configuration possibilities are explained.

Concurrent Access. This is a Boolean setting that indicates whether concurrency is allowed for that role. Concurrency is when a role is authenticated more than once. The value **YES** indicates concurrency, **NO** indicates non-concurrency (a role can only be authenticated once). The default value will be **NO**.

Once there is an authenticated user with a certain non-concurrent role, authentication of another user with that role is prevented. The exceptions to this general rule are explained in detail below.

Apply non-concurrent roles together. If selected (value **YES**) it means that non-concurrency is additionally checked among all roles marked as non-concurrent, i.e., only one non-concurrent role can be authenticated at any given time. For example, if the roles ENGINEER, INSTALLER and SECADM are configured as non-concurrent and this setting is set to YES, only a user with role ENGINEER, INSTALLER or SECADM can be active (if a user with role ENGINEER is authenticated, a second user with role INSTALLER or SECADM will not be able to access). The default value is YES.

Always taking the criterion of facilitating access to users with priority roles (non-concurrent):

- In case there are authenticated users with non-priority (concurrent) roles, the user with the lowest priority role and who has been logged in the longest is logged out automatically and without warning.
- In case there is another authenticated user with priority (non-concurrent) role, the new user is asked if he/she wants to log out the user with priority role who is currently authenticated. This option is only available via website and HMI.

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The following shows how the device behaves in the different cases of role concurrency configuration:

Case in which the *Apply Non-Concurrent Roles Together* parameter is set to YES

- If the accessing user has a concurrent role:
  - If there are available sessions in that service, the access is granted.
  - If there are no available sessions in that service, a check is made to see if there is an authenticated user with less priority role:
    - If there is, the session of the longest authenticated user is automatically closed, access is granted to the new user and the **Logout - session closed by other user** event is generated with the user that has just been expelled.
    - If not, access is denied and the event **Login failed - too many user sessions** is generated.

- If the accessing user has a non-concurrent role:
  - A check is made to see if there is any other authenticated user with non-concurrent role:
    - If there is and it is higher priority than the user trying to access, access is denied and the event **Login failed - user rejected due to role concurrency** is generated.
    - If there is and it is equal or lower priority than the user trying to access and the service is not a website or HMI, access is denied and the event **Login failed - user rejected due to role concurrency** is generated.
    - If there is and it is equal or lower priority than the user trying to access and the service is a website or HMI, a warning is displayed that there is another authenticated privileged user and is offered to the user the possibility of expelling it:
      - If the user accepts, the other user with non-concurrent role is logged out, access is granted to the new user and the **Logout - session closed by other user** event is generated with the user that was just expelled.
      - If the user cancels, access is denied and the event **Login failed - user rejected due to role concurrency** is generated.
    - If there is not, a check is made to see if there are available sessions in that service:
      - If there are available sessions, access is granted.
      - If there are no available sessions, a check is made to see if any user with a lower priority role is authenticated:
        - If there is, the session of the user who has been logged in the longest is automatically closed, access is granted to the new user and the **Logout - session closed by other user** event is generated with the user who has just been expelled.
        - If not, access is denied and the event **Login failed - too many user sessions** is generated.

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Case where the *Apply Non-Concurrent Roles Together* parameter is set to NO

- If the accessing user has a concurrent role:
  - If there are available sessions in that service, the access is granted.
  - If there are no available sessions in that service, a check is made to see if there is an authenticated user with less priority role:
    - If there is, the session of the user with the lowest priority role who has been logged in the longest is automatically closed, access is granted the new user and the **Logout - session closed by other user** event is generated with the user who has just been expelled.
    - If not, access is denied and the event **Login failed - too many user sessions** is generated.

- If the accessing user has a non-concurrent role:
  - A check is made to see if there is any other authenticated user with the same role:
    - If there is, and the service is not a website or HMI, access is denied and the event **Login failed - user rejected due to role concurrency** is generated.
    - If there is and the service is a website or HMI, a warning is displayed that there is another authenticated privileged user and is offered to the user the possibility of expelling it:
      - If the user accepts, the other user with the same role is logged out, access is granted to the new user and the **Logout - session closed by other user** event is generated with the user that was just expelled.
      - If the user cancels, access is denied and the event **Login failed - user rejected due to role concurrency** is generated.
    - If there is not, a check is made to see if there are available sessions in that service:
      - If there are available sessions, access is granted.
      - If there are no available sessions, a check is made to see if any user with a lower priority role is authenticated:
        - If there is, the user with the lowest priority role who has been logged in the longest is automatically logged out, access is granted to the new user and the **Logout - session closed by other user** event is generated with the user who has just been logged out.
        - If not, access is denied and the event **Login failed - too many user sessions** is generated.

F.3.2 User and Role Management

User and role management must be performed by a user with *user management* permission. It is managed from several interfaces:

- Web interface (HTTP / HTTPS).
- CLI Command Line Interface (Telnet / SSH).
- ***ZIV e-NET Tool***® Configuration Tool, using *LocalRBAC* and *DevicePreferences* files.

F.3.2.a User and Role Management from the Web

In order to manage users from the web interface, some LAN ports and HTTP or HTTPS services need to be enabled. It is recommended to use the HTTPS connection instead of HTTP because the data is encrypted.

- The website of the device is accessed through a browser, entering the IP address configured in the LAN adapter of the device. Initially, a login web page appears where the user's name and password must be entered (*admin* is the default user).

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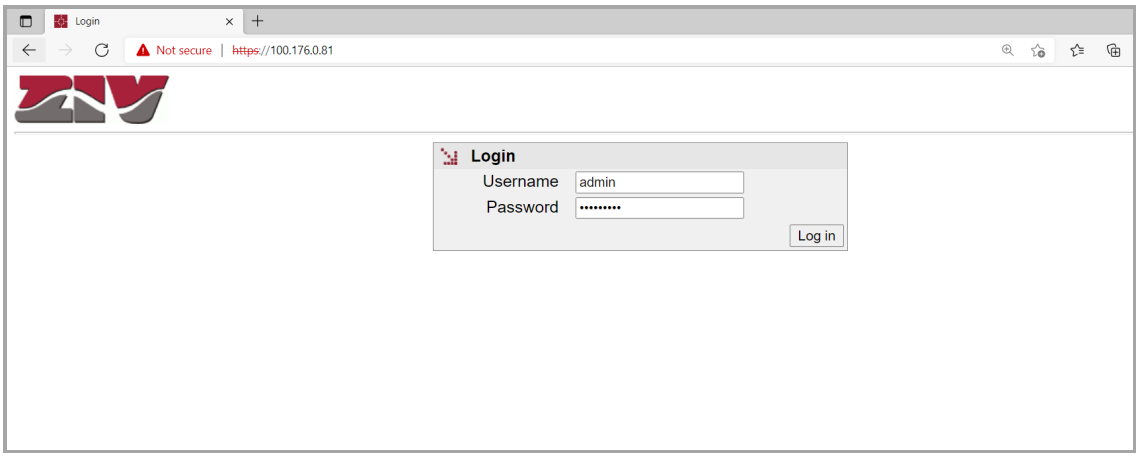


Figure F.1 User Authentication on Website.

- The ***Configuration→Access*** menu is accessed to manage user configuration.

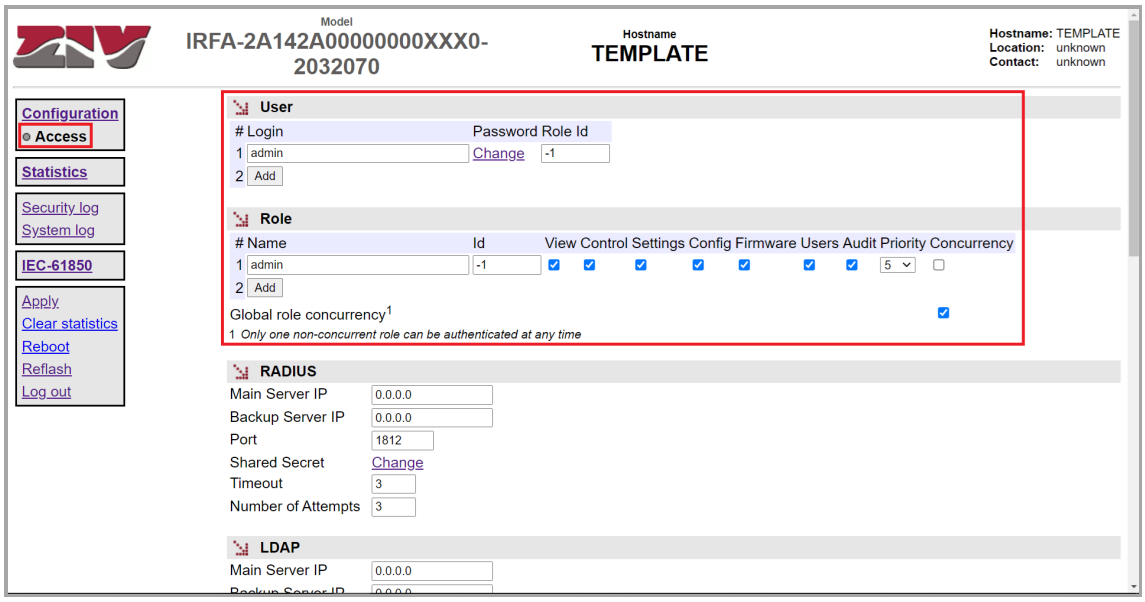


Figure F.2 Users and Roles Configuration in Website.

To add a new role, click on the ***Add*** button in the ***Role*** section and enter a name (cannot be repeated), a role identifier (cannot be repeated), select the permissions assigned to the role, adjust the priority if desired and configure its concurrency. In the following example, the *guest* role is created with identifier '-2' and only *visualization* permission, priority 5 and concurrent.

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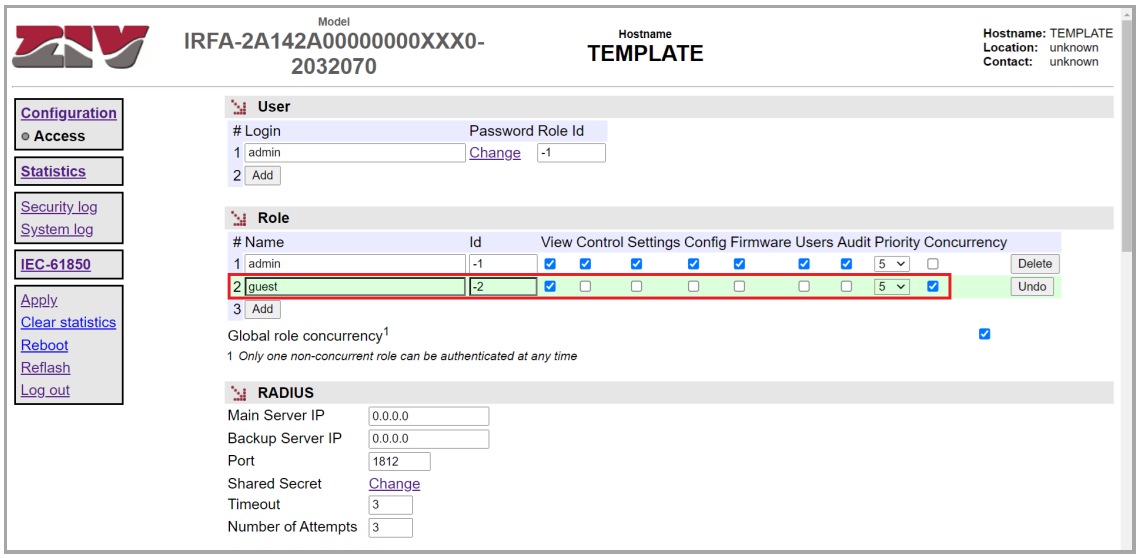


Figure F.3 Adding a Role on a Website.

To add a new user, press the ***Add*** button in the ***User*** section and enter the username (cannot be repeated) and the associated role identifier. In the example, a *guest* user is created and assigned the role with identifier -2.

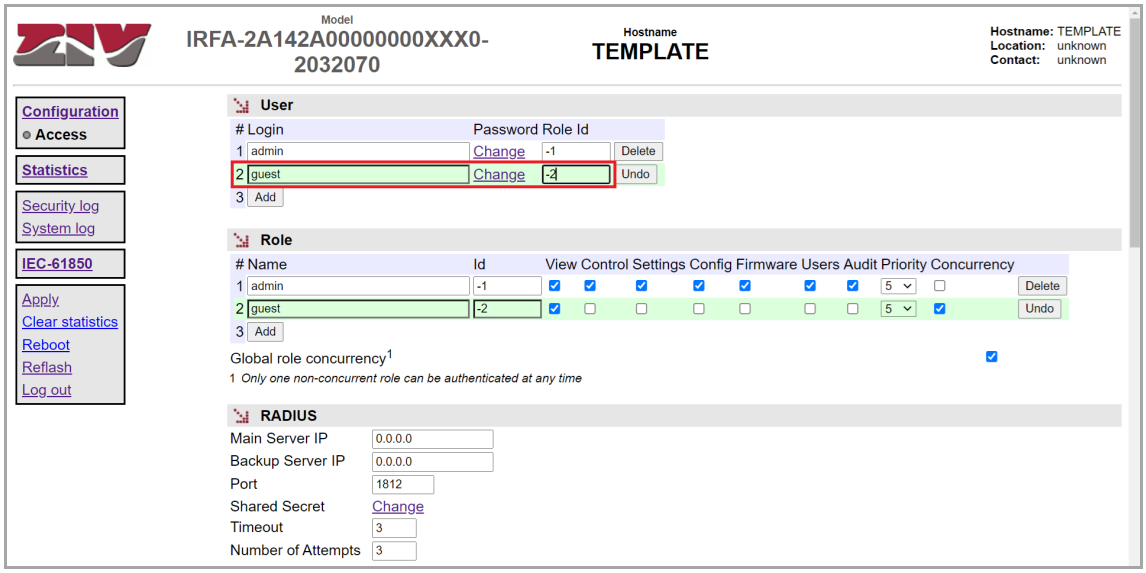


Figure F.4 Adding a User on a Website.

You can then change the password of the new user by clicking on the ***Change*** link.

*Before changing your password, validate the above data by clicking on the **Send** button located at the bottom of the web page (scroll down to the bottom of the web page). Otherwise, the data entered will be lost.*

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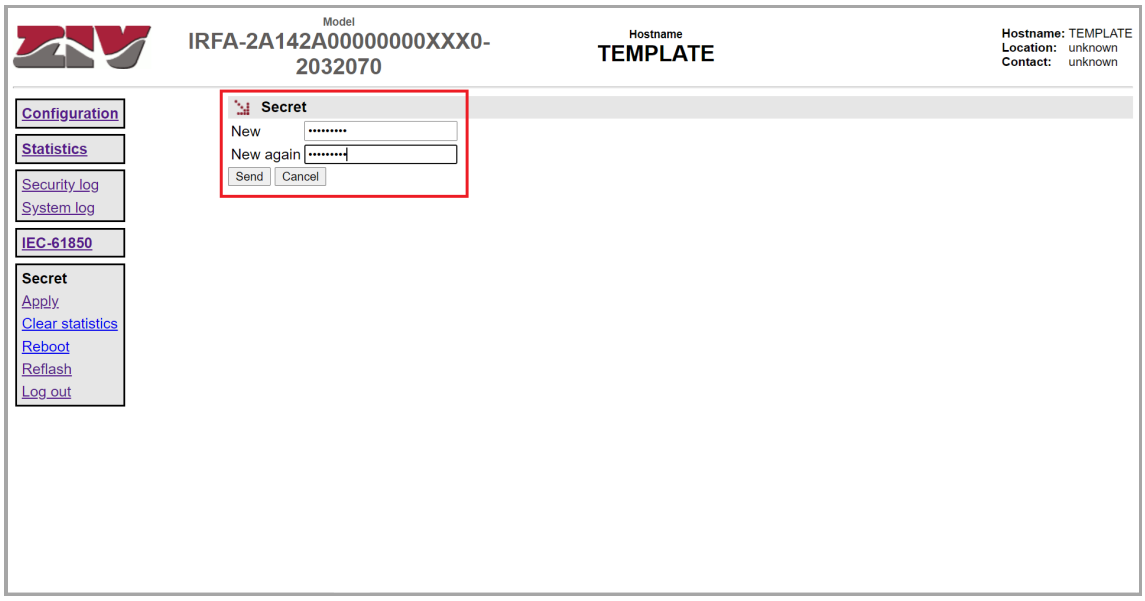


Figure F.5 Changing User Password on Website.

On the password change web page, enter the new password twice and click ***Send***.

For new users to take effect, click on the ***Apply*** menu, click ***OK*** and wait for the message *'Configuration applied successfully'* to appear.

If you wish to temporarily disable a role, and therefore the users that include it, you can deactivate the *visualization* permission of a role.

To delete a user or role, press the corresponding ***Delete*** button and then press ***Send*** and ***Apply***. In the following example the user 'Dummy' and the role '-1234' will be deleted.

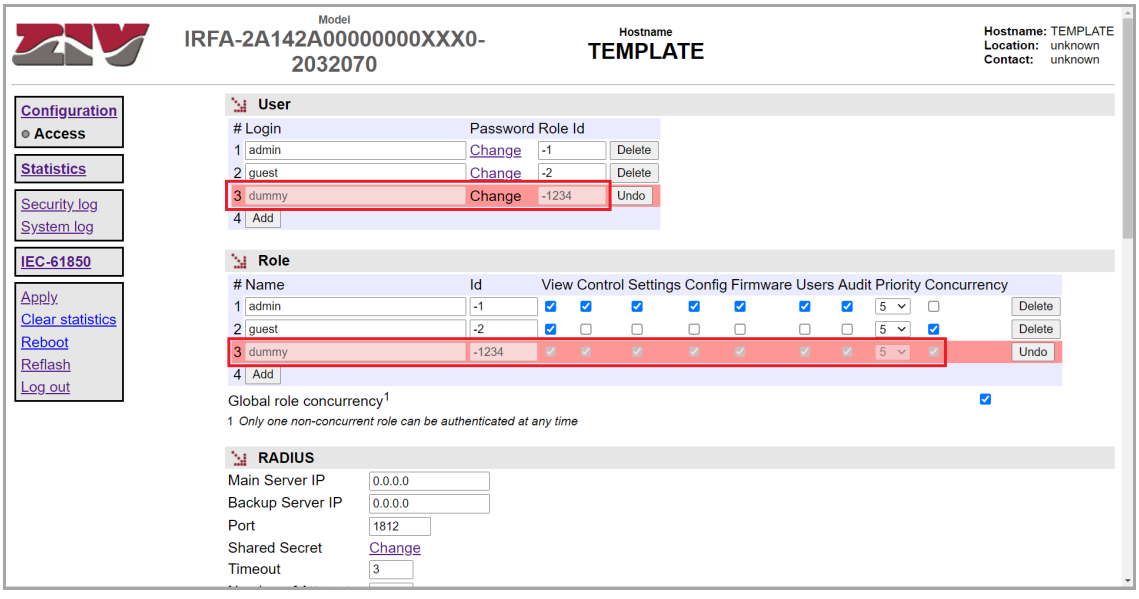


Figure F.6 Delete User and Role on Website.

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*Before changing your password, validate the above data by clicking on the **Send** button located at the bottom of the web page (scroll down to the bottom of the web page). Otherwise, the data entered will be lost.*

F.3.2.b User and Role Management from CLI

To manage users and roles from the CLI command line interface, some LAN ports and Telnet or SSH services need to be enabled. It is recommended to use the SSH connection instead of Telnet because the data is encrypted.

The CLI of the device is accessed by launching the Telnet or SSH application from a host and entering the login of the user who has *user management* permission.

The CLI of the device is automatically accessed. You can see the parameters tree with the ***get*** command. The corresponding user settings are in the ***main/access*** node.

```
TEMPLATE /> get
/
   main/
      hostname       = TEMPLATE
      location       = unknown
      contact        = unknown
      product        = any
      model          = IRFA-2A142A00000000XXX0-2032070
      iedInfo        = ZIV   IRFA-2A142A00000000XXX0-2032070   0.10.0-0C03-00
      fw_version     = 0.10.0-0C03-00
      fw_reference   = unknown
      serialnumber   = 160538
      config_version = 00.00
      time           = 2021/06/29,10:25:11
      localtime      = 2021/06/29,10:25:11
      access/
         global_conc = on
         user[]/
            [user] login pwd      roleid
            ---------------------------
            1      admin ******** -1
         role[]/
            [role] name  id rview rctrl rchset rchcfg rchfw rusrmgmt raudit priority concurrency
            ------------------------------------------------------------------------------------
            1      admin -1 on    on    on     on     on    on       on     5        off
         radius/
            server1_ip = 0.0.0.0
            server2_ip = 0.0.0.0
            port       = 1812
            secret     = ********
            timeout    = 3
            attempts   = 3
```

Figure F.7 User and Role Settings in CLI.

To add a new role, first add a new element in the ***role[]*** table with the command ***add/main/access/role***. A new role is created with index 2 in the table and with the default values.

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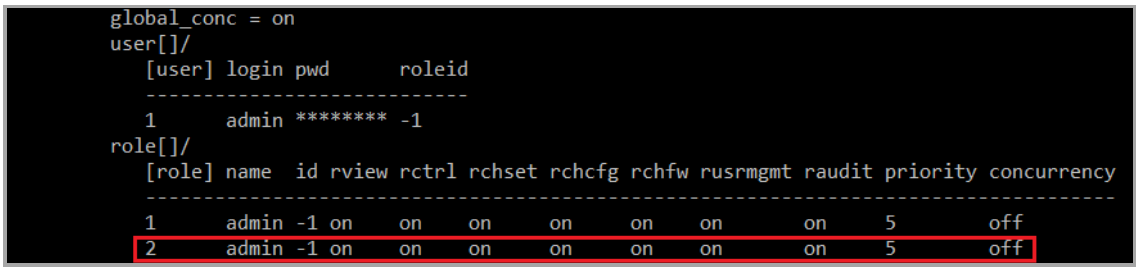


Figure F.8 Adding a Role in CLI.

The new role is now modified with the desired name, identifier, permissions, priority and concurrency. It can be done interactively executing the command ***set main/access/role[2]*** where each one of the fields will be asked to complete the role, or directly executing the set of the field to modify, for example:

- ***set /main/access/role[2]/name guest***
- ***set /main/access/role[2]/id -2***
- ***set /main/access/role[2]/rview on***
- ***set /main/access/role[2]/rctrl off***
- ***set /main/access/role[2]/rchset off***
- ***set /main/access/role[2]/rchcfg off***
- ***set /main/access/role[2]/rchfw off***
- ***set /main/access/role[2]/rusrmgmt off***
- ***set /main/access/role[2]/raudit off***
- ***set /main/access/role[2]/priority 5***
- ***set /main/access/role[2]/concurrency on***

To add a new user, you must perform a similar process to the previous one but in the ***user[]*** table.

- ***add main/access/user***

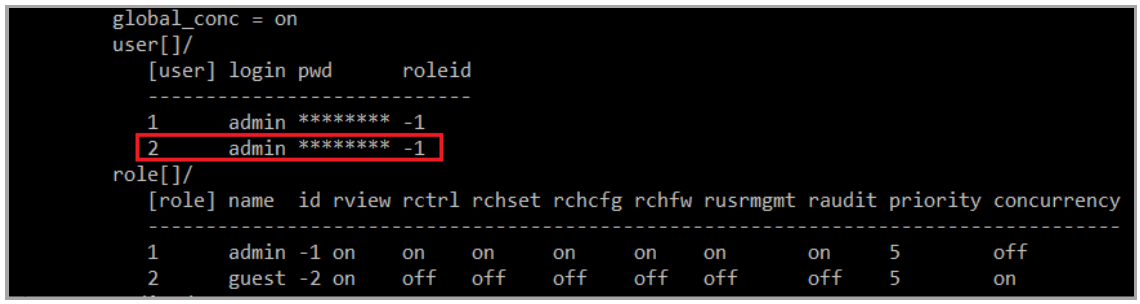


Figure F.9 Adding a User in CLI.

- ***set main/access/user[2]/login guest***
- ***set main/access/user[2]/roleid -2***
- ***set main/access/user[2]/pwd*** (by entering the key value twice).

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```
global_conc = on
user[]/
   [user] login pwd      roleid
   ---------------------------
   1      admin ******** -1
   2      guest ******** -2
role[]/
   [role] name  id rview rctrl rchset rchcfg rchfw rusrmgmt raudit priority concurrency
   ------------------------------------------------------------------------------------
   1      admin -1 on    on    on     on     on    on      on     5        off
   2      guest -2 on    off   off    off    off   off     off    5        on
```

Figure F.10 Modified User and Role in CLI.

Once the new user and/or role has been created, the data is saved with the ***save*** command and the changes in the device are made effective with the ***apply*** command.

F.3.2.c User and Role Management from *ZIV e-NET Tool*®

To manage users and roles from ***ZIV e-NET Tool***® it is necessary that some of the LAN ports and the SSH and SFTP services are enabled.

A distinction is made between users and roles, as they are configured in different configuration files. The operation is as follows: first the roles are created (they are stored as part of the *DevicePreferences* file), then the local users are created (they are stored in the *LocalRBAC* file) and finally both files are transferred to the device. When collecting information from the device, only the complete *DevicePreferences* file can be collected (this includes the roles). Local users cannot be retrieved from the device, as the *LocalRBAC* file contains the device passwords, it is considered a file only for input to the device.

To configure local users, in the ***Navigation View*** go to the ***Preferences→Security→Local Users*** option.

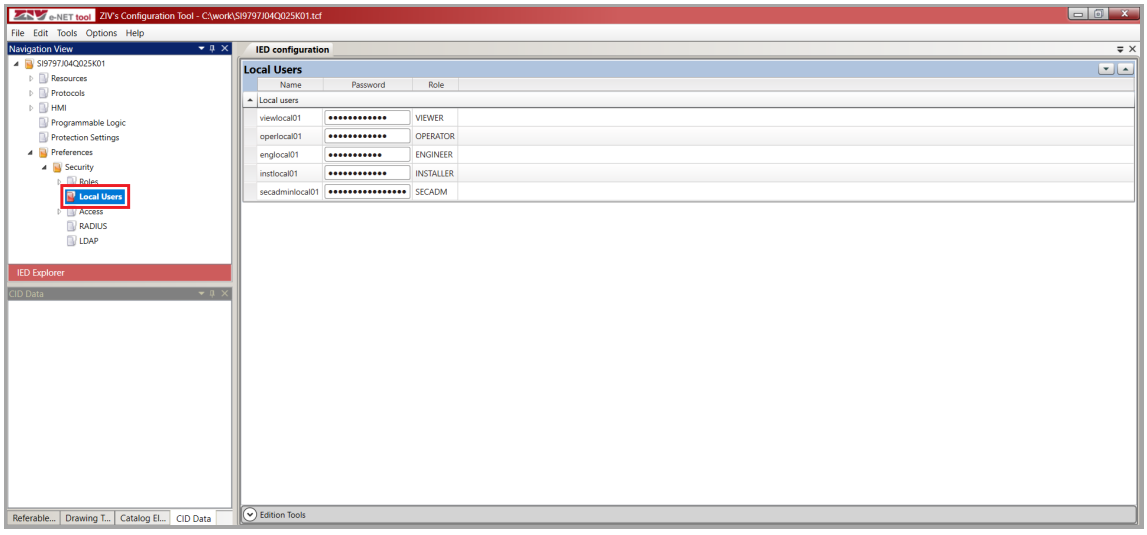


Figure F.11 Configuration of Local Users with Configuration Tool.

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Following the usual philosophy of the tool, local users can be added or deleted (using the ***Edition Tools*** tab), as well as modifying the current local users. For each user, its name, password and associated role must be configured (therefore the roles must be created previously).

By right-clicking on this option ***Preferences→Security→Local Users***, you can export the users to a *LocalRBAC* file or import them from a previously configured *LocalRBAC* file.

The *LocalRBAC* file is an XML file with the following format:

Node	Description	Child nodes	Attributes
RBACtemplate	Root node.	**device**	-
device	Main node.	**LOCALUSRDB**	**name**: name of the device. **IP**: IP address of the device.
LOCALUSRDB	Local users.	**LocalUsr**	-
LocalUsr	Definition of a local user: name, password and assigned role.	-	**name**: name of the user. **pwd**: user password. **role**: numeric identifier of the role assigned to the user.

Example of a *LocalRBAC* file:

```
<?xml version="1.0" encoding="utf-8"?>
<RBACtemplate>
 <device name="TEMPLATE" IP="192.168.1.81">
  <LOCALUSRDB>
   <LocalUsr name="viewlocal" pwd="PwdView@01" role="7"/>
   <LocalUsr name="operlocal" pwd="PwdOper@01" role="8"/>
   <LocalUsr name="englocal" pwd="PwdEng@01" role="9"/>
   <LocalUsr name="instlocal" pwd="PwdInst@01" role="10"/>
   <LocalUsr name="secadmlocal" pwd="PwdSecadm@01" role="15"/>
  </LOCALUSRDB>
 </device>
</RBACtemplate>
```

To transfer local users to the device, go to the menu ***Tools→Device access***. In this window, check that SFTP + SSH is selected in ***Protocol***, configure the IP address of the device and port (it must match the SSH/SFTP port of the device) and enter the user's credentials (user and password). In the ***Transfer Files*** tab, check the ***LRBAC*** option and click ***Transfer*** to upload the *LocalRBAC* file to the device. The upload progress is indicated in the ***Information*** window. If the *LocalRBAC* file is successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if any error occurs in the validation of the *LocalRBAC* file by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

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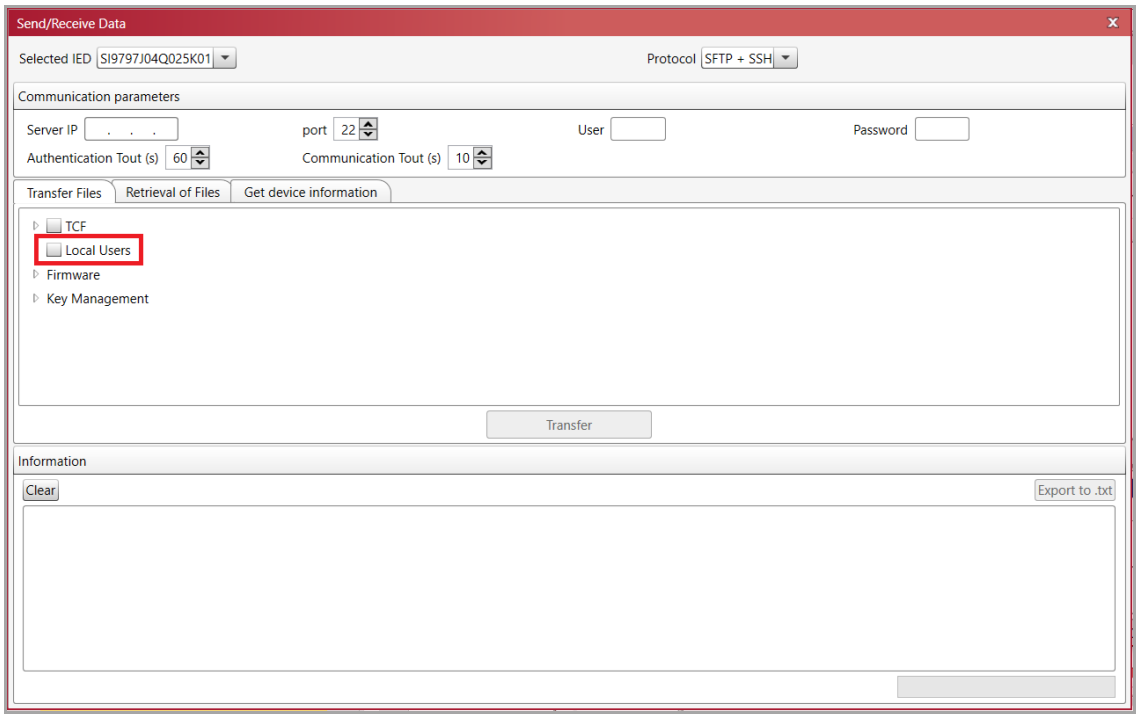


Figure F.12 Sending Local Users with Configuration Tool.

To configure the roles, in the Navigation View go to the ***Preferences→Security→Roles*** option.

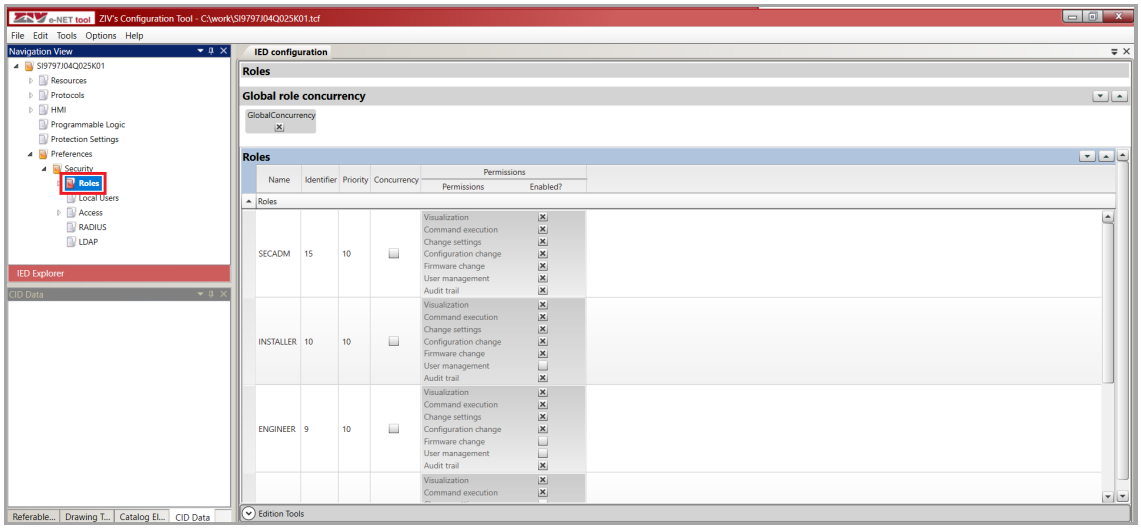


Figure F.13 Role Configuration with Configuration Tool.

Following the usual philosophy of the tool, roles can be added or deleted (using the ***Edition Tools*** tab), as well as modifying the current roles. For each role, its name, identifier, priority, concurrency and associated permissions must be configured.

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By right-clicking on this option ***Preferences→Security→Roles***, you can export the roles to a *DevicePreferences* file or import them from a previously configured *DevicePreferences* file.

The roles are part of the *DevicePreferences* file. This is an XML file whose roles section has the following format:

Node	Description	Child nodes	Attributes
device	Root node.	**ROLES**, RADIUS, LDAP, ACCESS	**tversion**: file version. **filetype**: file type ("DevicePreferences").
ROLES	Roles.	**Role**	**global_conc**: indicates whether only one or more non-concurrent roles can be authenticated at the same time.
Role	Role definition: name, identifier, permission mask, priority and concurrency.	-	**name**: name of the role. **id**: numerical identifier of the role. **rightMsk**: permissions mask, where: - 0x01: *Visualization* permission. - 0x02: *Command execution* permission. - 0x04: *Setting change* permission. - 0x08: *Configuration change* permission. - 0x10: *Firmware change* permission. - 0x20: *User management* permission. - 0x40: *Audit log* permission. **priority**: role priority. **concurrency**: indicates whether the role is concurrent or not.

Example of *DevicePreferences* file (only with roles section):

```
<?xml version="1.0" encoding="utf-8"?>
<device tversion="0.1" fileType="DevicePreferences">
  <ROLES global_conc="Yes">
    <Role name="SECADM" id="15" rightMsk="127" priority="10" concurrency="No" />
    <Role name="INSTALLER" id="10" rightMsk="95" priority="10" concurrency="No" />
    <Role name="ENGINEER" id="9" rightMsk="79" priority="10" concurrency="No" />
    <Role name="OPERATOR" id="8" rightMsk="3" priority="1" concurrency="Yes" />
    <Role name="VIEWER" id="7" rightMsk="1" priority="1" concurrency="Yes" />
  </ROLES>
</device>
```


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To transfer the roles to the device, go to the menu ***Tools→Device access***. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the IP address and port data of the device (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Transfer Files*** tab, check the option ***TCF→Preferences*** (if you want to transfer the complete *DevicePreferences* file) or the option ***TCF→Preferences→Roles*** (if you want to transfer only the roles) and click ***Transfer*** to upload the complete *DevicePreferences* file or only the roles to the device. The upload progress is indicated in the ***Information*** window. If it has been successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if there is any error in the validation by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

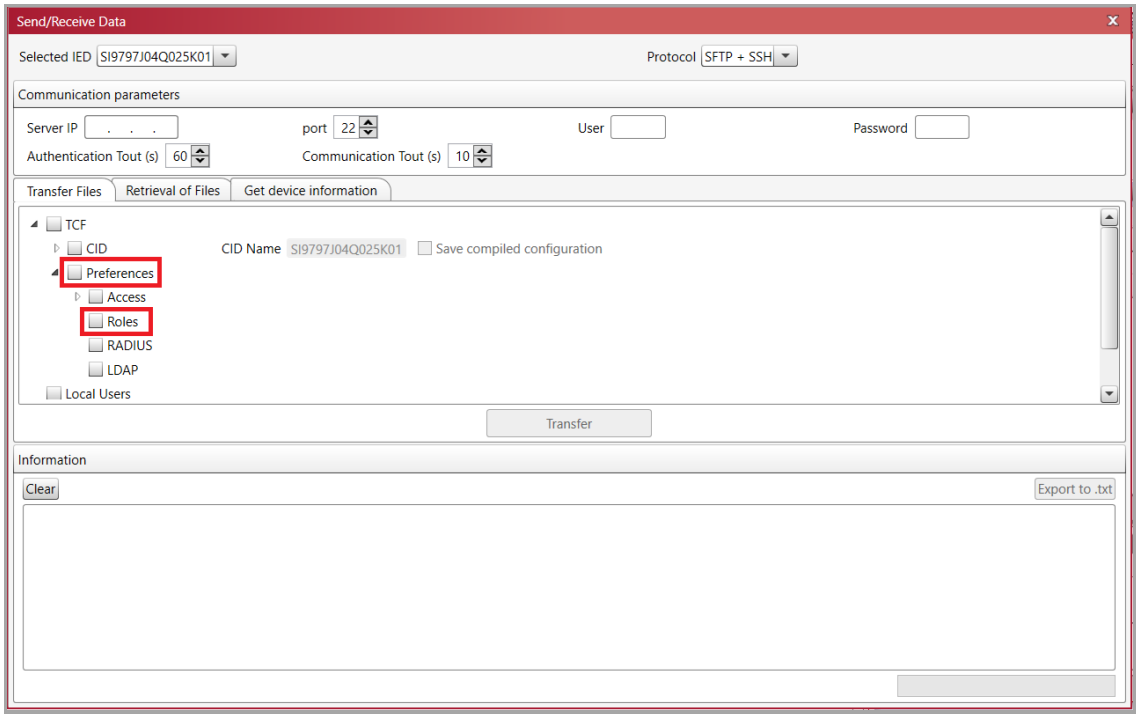


Figure F.14 Sending Roles with Configuration Tool.

To collect the roles from the device, access the menu ***Tools→Device access***. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the IP address of the device and port (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Retrieval of Files*** tab, check the ***Preferences*** option (only the complete *DevicePreferences* file can be downloaded) and click ***Retrieval*** to download the *DevicePreferences* file. The download progress is displayed in the ***Information*** window. Once the file has been downloaded, the **Configuration downloaded** cybersecurity event is generated.

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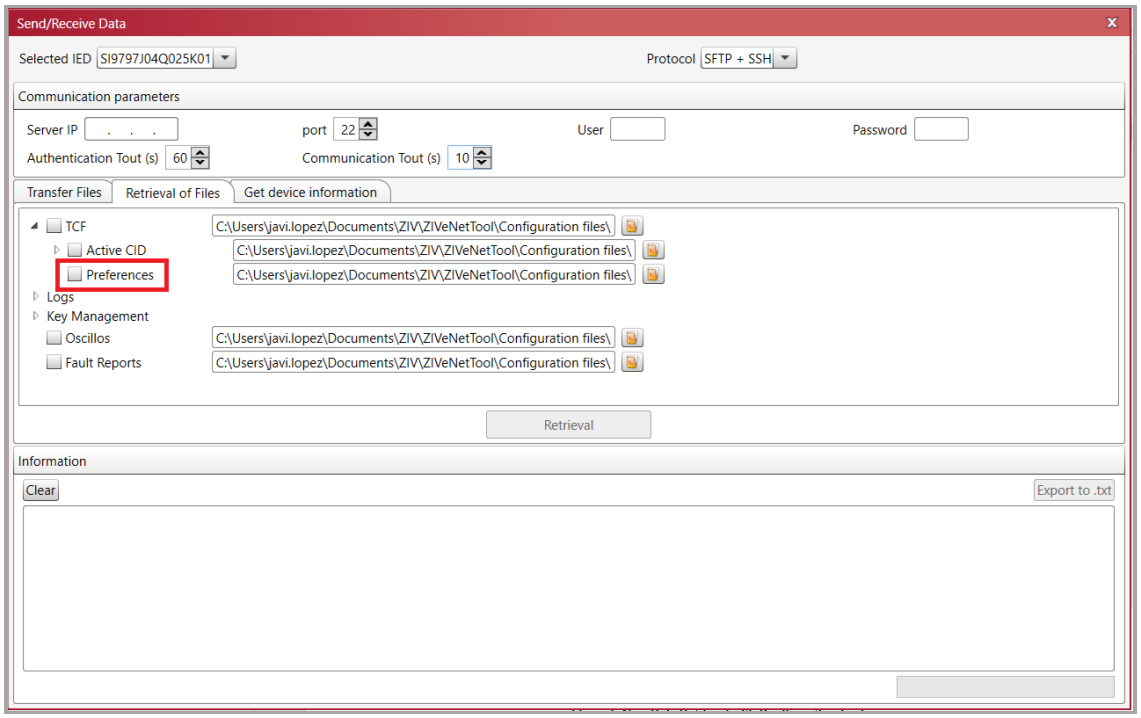


Figure F.15 Role Retrieval with Configuration Tool.

F.3.3 Session Concurrency

In order to control the resources used by the device, it was decided to limit the number of authenticated concurrent sessions per type of service available in the device.

The device has the following settings, which can be modified from the configuration tool and from the HMI:

Concurrent sessions				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
The same user can occupy all available sessions	`Same usr all sess`	YES / NO		YES
Telnet	`Telnet`	1 – 5	1	2
FTP	`FTP`	1 – 5	1	2
HTTP	`HTTP`	1 – 5	1	2
SSH/SFTP	`SSH/SFTP`	1 – 10	1	4
HTTPS	`HTTPS`	1 – 5	1	2

Some clients wish to prevent the same user from being able to occupy all available sessions of a service, preventing others from authenticating. For this purpose, the setting ***The same user can occupy all available sessions*** is used as follows:

- If the setting takes the value **YES**, all sessions of a service can be occupied by the same user and an attempt to open a new session when all of them are occupied will mean that the session is not accepted, generating the **Login failed - too many user sessions** cybersecurity event.

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- If the setting is set to **NO**, all sessions of a service may be occupied by the same user and an attempt to open a new session when all of them are occupied will mean that:
  - If the session is of another user, this is accepted and the oldest (longest running) session of the other user who had all sessions occupied is closed without any warning. The **Logout - session closed by other user** cybersecurity event is generated.
  - If the session is of the same user who has all other sessions occupied, this new connection is rejected and the **Login failed - too many user sessions** cybersecurity event is generated.

F.3.4 Local Access

Local accesses correspond to accesses via HMI and USB (pendrive). As these are face-to-face accesses, which take place within the physical security perimeter of the electrical installations (considered secure), it is generally enough for them to be protected by a numerical password. Even under these conditions, there are customers who require all accesses to be protected with a username and password, and the HMI is no exception.

The device is able to operate in both ways depending on the following setting, which can be modified from the website, command line (CLI) or ***ZIV e-NET Tool***® configuration tool (using the *DevicePreferences* file).

User required for HMI authentication					
Website	**CLI**	**DevicePreferences**	**Range**	**Step**	**Default**
User required for HMI authentication	*main/access/hmi/ usrauthhmi*	usrauthhmi	NO / YES		NO

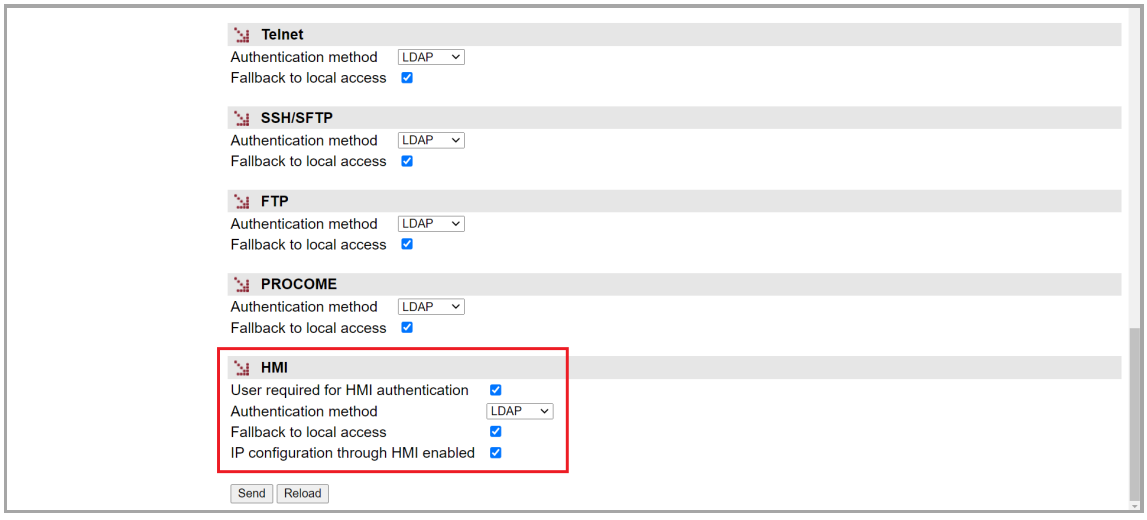


Figure F.16 Setting to Require User for HMI Authentication on Website.

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```
main/
   access/
      hmi/
         usrauthhmi  = off
         pwdconfig   = ********
         pwdcontrol  = ********
         pwdsettings = ********
         method      = LDAP
         local       = on
         confiphmi   = on
```

Figure F.17 Setting to Require User for HMI Authentication on CLI.

To change this setting via website or CLI, it is necessary that, after modifying the setting, the ***Send*** and ***Apply*** buttons/commands are pressed/executed in website/CLI.

To change this setting by ***ZIV e-NET Tool***® it is necessary that some of the LAN ports and the SSH and SFTP services are enabled. In the ***Navigation View***, go to the ***Preferences→Security→Access→HMI*** option.

By right-clicking on this option ***Preferences→Security→Access→HMI***, you can export the HMI settings (the present one plus others explained in other sections) to a *DevicePreferences* file or import them from a previously configured *DevicePreferences* file.

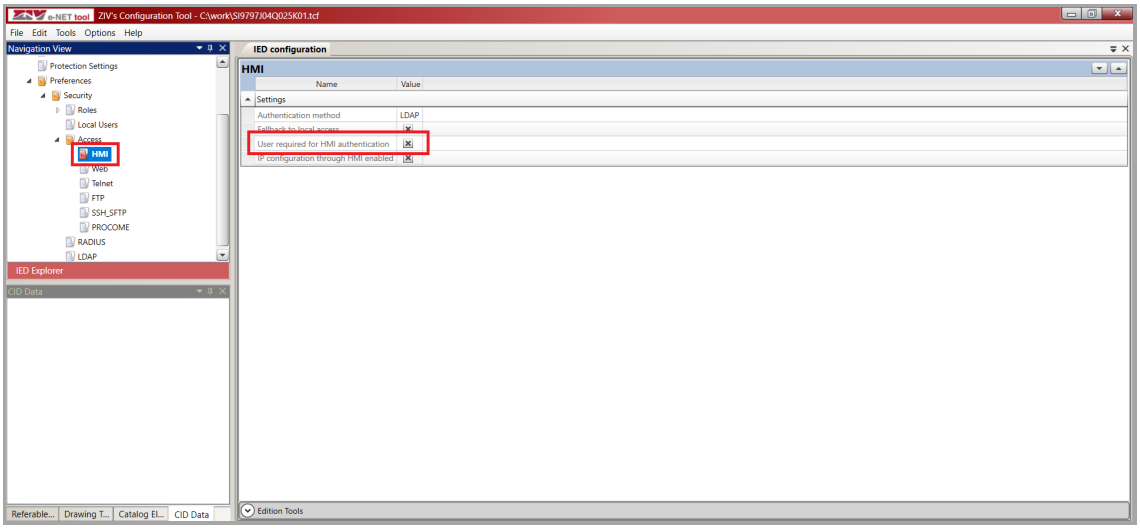


Figure F.18 Setting to Require User for HMI Authentication on Configuration Tool.

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This setting is part of the *DevicePreferences* file. It is an XML file and this setting is located inside the HMI section (highlighted):

Node	Description	Child nodes	Attributes
Device	Root node.	ROLES, RADIUS, LDAP, **ACCESS**	**tversion**: file version. **filetype**: type of file ("DevicePreferences").
ACCESS	Parameters to control access	**HMI**, WEB, TELNET, FTP, SSH_SFTP, PROCOME	-
HMI	HMI access parameters.	**Setting**	-
Setting	One **Setting** node for each HMI access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for HMI access (local, LDAP or RADIUS). - **local**: alternative use of local users for HMI access. - **userauthhmi**: name of the role. - **confiphmi**: it is allowed to change the IP via HMI. **value**: setting value.

Example of *DevicePreferences* file (with complete HMI section, the setting of require user for HMI authentication is highlighted):

```
<?xml version="1.0" encoding="utf-8"?>
<device tversion="0.1" fileType="DevicePreferences">
  <ACCESS>
    <HMI>
      <Setting name="method" value="LDAP" />
      <Setting name="local" value="Yes" />
      <Setting name="usrauthhmi" value="Yes" />
      <Setting name="confiphmi" value="Yes" />
    <HMI>
  </ACCESS>
</device>
```

To transfer the setting to the device, access the ***Tools→Device access*** menu. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the IP address data of the device and port (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Transfer Files*** tab, check the option ***TCF→Preferences*** (if you want to transfer the complete *DevicePreferences* file), the option ***TCF→Preferences→Access*** (if you want to transfer the complete access section) or the option ***TCF→Preferences→Access→HMI*** (if you want to transfer the complete HMI access section, this is the minimum section that can be sent) and press ***Transfer*** to upload the information to the device. The upload progress is indicated in the ***Information*** window. If it has been successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if there is any error in the validation by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

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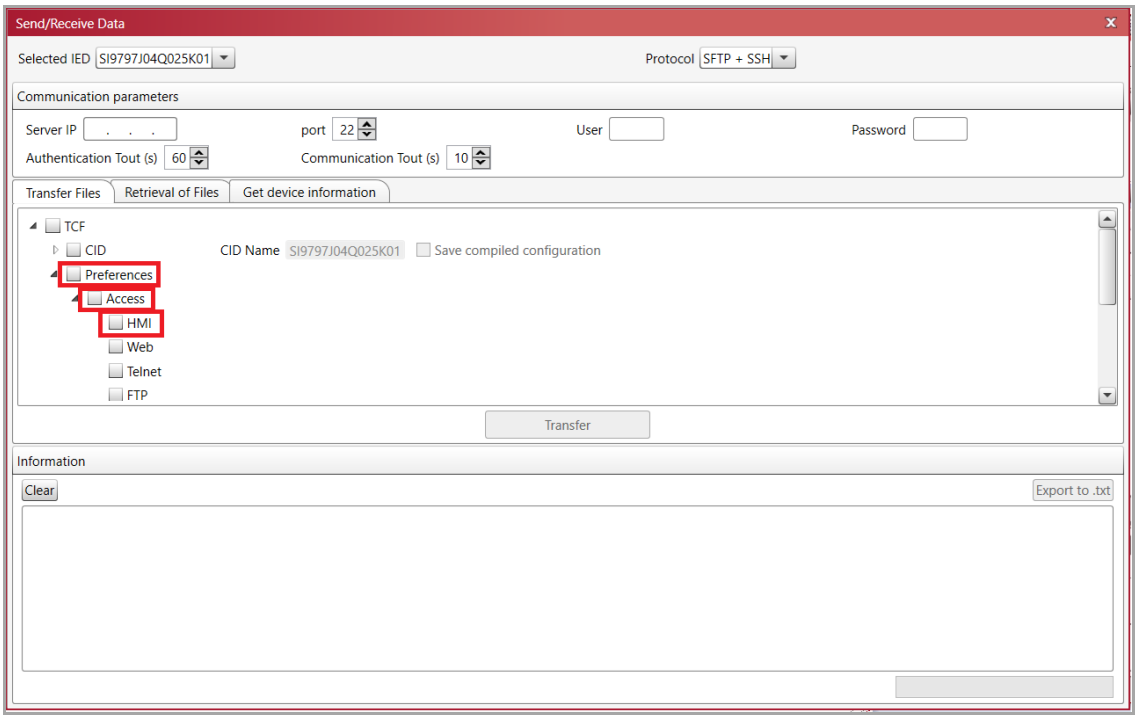


Figure F.19 Sending Setting to Require User for HMI Authentication with Configuration Tool.

To collect this setting from the device, proceed as indicated in the **User and Role Management from ZIV e-NET Tool®** section for the roles, as it is only possible to collect the complete *DevicePreferences* file.

Depending on this setting, the device behaves as follows:

- The value **NO** will indicate that the HMI authentication is performed using only a 4-number password.
- The value **YES** indicates that the HMI authentication is performed using user and password.

Both authentication modes are explained below.

F.3.4.a Password Authentication

The device has three passwords to access different levels of HMI management:

- *Configuration*: used to change parameters in the HMI configuration menu, as well as to download information to the USB pendrive.
- *Operations*: used to perform operations (commands) from HMI.
- *Settings*: used to change settings, including changing the active settings table.

The default value of the three passwords is 2140.

Two procedures can be used to change the value of these passwords:

- From HMI, by accessing the ***Configuration→Passwords*** menu.
- From the command line interface (CLI), through Telnet (not recommended because the data is not encrypted) or SSH.

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The settings corresponding to the three local passwords are as follows:

Local Passwords				
CLI	**HMI**	**Range**	**Step**	**Default**
main/access/hmi/pwdconfig	Configuration	0 - 9999	1	2140
main/access/hmi/pwdcontrol	Operations	0 - 9999	1	2140
main/access/hmi/pwdsettings	Settings	0 - 9999	1	2140

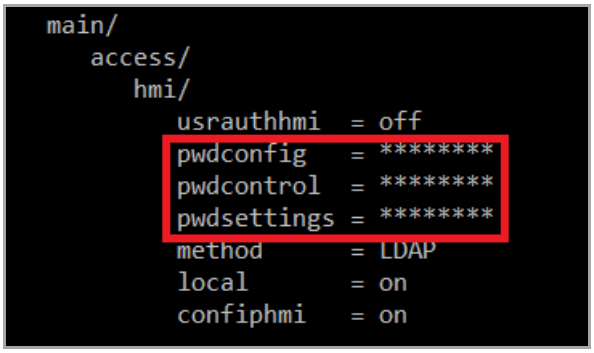


Figure F.20 HMI Passwords in CLI.

The remote change of local passwords via CLI facilitates the integration of device into centralized cybersecurity systems, allowing them to meet one of their main requirements: to periodically update device passwords.

When entering the password value, leading zeros are not entered. If, for example, the password is '0012', the digits to be entered will be '12'.

The menu options that are available with each of the passwords are listed below:

Password	HMI Menu Option
No password	*Information* menu. *USB* menu (if USB port activated and pendrive inserted): *Eject USB*. Access to *CLR* key to reset LEDs, trips, etc. Access to the *commandable objects* of the graphic display (accessible with SEL and executable with the O and | buttons). Access to *push buttons P1 to P12*.
Configuration	*Configuration* menu. *USB* menu (if USB port activated and pendrive inserted): *Storage dump*.
Operations	*Operations* menu.
Settings	*Activate Group* menu. *Change Settings* menu.

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F.3.4.b User and Password Authentication

When username/password use is required, the entered users are validated against the users available on the device, i.e., remote users (when using remote authentication methods such as LDAPS or RADIUS) and/or local users (when not using remote authentication methods or, if using remote authentication methods, they are not available and you have configured to use local users alternatively).

This user and password authentication option is only available on devices with enhanced cybersecurity.

Only access to the following menus will be possible without authentication:

- *Information*:
  - *Relay information*.
  - *Status*.
  - *Measurements*.
  - *Records*.

To access the rest of the menus it will be necessary to authenticate with username and password.

To log in or log out a user by HMI, one of the following two ways must be used:

- When in the default screen, pressing ENTER will take you to the first menu option:
  - When there is no user authenticated by HMI, the first menu option is **Login** and when you enter that option the login screen explained below is displayed.
  - When there is a user authenticated by HMI, the first menu option is **Logout** and when that option is entered, the logout screen explained below is displayed.
- If there is no HMI authenticated user and an attempt is made to access an area that requires a user, the login screen is automatically displayed.

The **login** screen initially has the focus on the user line.

Initially the character 'a' is displayed, with ↑ the next character option ('b') is displayed, with ↓ the previous character option is displayed, with → you advance to the next character, with ← you go back to the previous character (the current character is deleted). Pressing and holding down the ↑ or ↓ arrow speeds up the search for the desired character.

The possible character options are as follows (shown in order of appearance):

```
a b c d e f g h i j k l m n o p q r s t u v w x y z
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
0 1 2 3 4 5 6 7 8 9 . _ -
```


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Press ENTER to enter the password; the focus moves to the password field.

The way of entering the characters of the password is equivalent to that of the user. The order of displaying characters is: lowercase, uppercase, numbers and special characters in the order of the ASCII table:

```
a b c d e f g h i j k l m n o p q r s t u v w x y z
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
0 1 2 3 4 5 6 7 8 9 ! " # $ % & ' ( ) * + , - . / @
: ; < = > ? [ \ ] ^ _ ` { | } ~
```

Each character of the confirmed password (when ➔ is pressed) is graphically replaced by the '*' character to prevent the password from being seen.

Pressing ENTER completes the user and password entry and the device proceeds to authenticate the user. While the user is being authenticated, the message LOGIN IN PROGRESS is displayed.

If the user authentication is accepted by the device, an "L" character (login) is displayed on the HMI in the upper right corner. This allows to clearly identify when there is a user authenticated by HMI ("L" character present) or not ("L" character absent).

If the user authentication is rejected by the device, the message LOGIN FAILED / PRESS ANY KEY appears. When any key is pressed, the login screen is displayed again.

The **logout** screen requires confirmation: YES (➔) confirms the logout and NO (➔) or ESC cancels it and the user remains authenticated by HMI. While the user is being logged out, the message LOGOUT IN PROGRESS is displayed.

If ESC is pressed at any time within the login or logout screen, the login/logout window closes (in the case of logout the user would still be authenticated).

To log out (close user session) there are two options:

- A timeout after inactivity (no key presses, see **Automatic Logout** section): in this case the user returns to the main screen automatically.
- The user selects the option from the menu and confirms the logout.

A user authenticated by HMI counts as any other access for role concurrency (see **Users, Roles and Permissions** section). Therefore, a user by HMI can:

- Be expelled by another user (e.g., by web). In this case, the user is returned to the main screen, the HMI authenticated user indication is removed ("L" character in the display) and the **Logout - session closed by other user** cybersecurity event is generated with the user that has just been expelled.
- Expel another user. If the HMI user can expel a user and confirmation is required to do so (because it is about expelling another privileged user), after the login screen and confirmation that the user exists and is valid, a screen is presented to be able to expel the other user. This screen requires confirmation. If YES (➔) is chosen, the other user will be expelled and this HMI user will be authenticated. If NO (➔) is chosen or ESC is pressed, the HMI user authentication process is aborted and the **Login failed - user rejected due to role concurrency** cybersecurity event is generated.

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The menu options that are available with each of the permissions are listed below:

Permission	HMI menu option
Visualization	*Information* menu. *USB* menu (if USB port activated and pendrive inserted): *Eject USB*.
Command execution	*USB* menu (if USB port activated and pendrive inserted): *Storage Dump*. *Operations* menu. Access to *CLR* key to reset LEDs, trips, etc. Access to the *commandable objects* of the graphic display (accessible with SEL and executable with the O and | buttons). Access to *push buttons P1 to P12*.
Setting change	*Configuration* menu. *Activate Group* menu. *Change Settings* menu.
Configuration change	-
Firmware change	-
User management	-
Audit log	-

When a NOT allowed operation/option is selected, a PERMISSION DENIED message is displayed for a few seconds.

Examples where the PERMISSION DENIED message is displayed:

- A user without *command execution* permission presses P1.
- A user without *command execution* permission presses CLR.
- A user without *configuration change* permission tries to access *the Activate Group* menu.

F.3.5 Automatic Logout

A user's session is automatically logged out by the device after a period of inactivity. The concept of inactivity varies depending on the access:

- Communications: absence of communications messages (keep-alive in case of sockets are not taken into account). It affects HTTP, HTTPS, Telnet, SSH, FTP, SFTP and PROCOME services.
- HMI: no user interaction (keystrokes).
- USB (pendrive): no user interaction (key presses causing file download operations).

The device has the following setting, which can be modified from the configuration tool and from the HMI:

Configuration Tool	HMI	Range	Step	Default
Inactivity Timeout	`Inactivity Timeout`	1 – 60 min	1	5

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F.4 Remote User Authentication

As described above, there is the possibility of local user authentication in the device. A series of local users and a series of roles with permissions are defined and a role is associated to each user. When a user authenticates, the device validates it against these local users.

Clients do not usually use local authentication on the device. They usually use centralized repositories where they configure their users with their associated roles. The device must authenticate users against these remote repositories using different standards. These repositories will return to the device, in case of positive user/password authentication, the user's role. In this way, the device will check internally if such role is defined in the device, the permissions assigned to such role in the device and will allow such user to perform the actions associated to such permissions.

The definition of users, roles and permissions using remote authentication is deployed as follows:

- Outside the device, in the remote repository, users are defined and their roles are associated with them.
- On the device, the roles and their associated permissions are defined (and additionally the local users with their roles).

This remote authentication option is only available on devices with enhanced cybersecurity.

As a general rule, the device can be configured to use remote or local authentication (local users of the device) and, in case of remote authentication, which remote authentication method to use (RADIUS or LDAP).

In addition, in case of using remote authentication, you can configure whether you want to use local users (local authentication) as an alternative source of authentication in case of impossibility to access the configured remote authentication repositories. If this option is chosen, the user/password authentication will be done locally (taking into account the local users defined in the device) when the requests to the remote repositories fail.

The following settings are defined for these two functionalities:

Authentication					
Website	**CLI**	**DevicePreferences**	**Range**	**Step**	**Default**
Authentication method	*main/access/xxxx/method*	method	local RADIUS LDAP		Local
Fallback to local access	*main/access/xxxx/local*	local	on (Yes) / off (No)		on (Yes)

where *xxxx* is the service name: web, telnet, ssh_sftp, ftp, procome and hmi.

These settings can be adjusted individually for each of the services requiring authentication: web access, telnet access, SSH/SFTP access, PROCOME access and HMI access.

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*If all **Fallback to local access** settings are set to **No** and the authentication methods for all services are set to a value other than **local**, the device will not be able to authenticate if the device is taken to the factory for repair or diagnostics, as it will not be possible to connect to the remote authentication servers and there will be no possibility of alternative use of local users.*

*It is therefore recommended that at least the HMI access be configured with **Fallback to local access** set to **Yes**.*

The device uses two remote authentication methods which are explained in detail below: RADIUS and LDAP.

F.4.1 RADIUS (Remote Authentication Dial In User Service)

The device acts as a RADIUS client to authenticate the user/password against up to two RADIUS servers (primary and secondary).

The device uses the RADIUS UDP client version specified by RFC 2865. The password is encrypted, but not the user. If more security is desired for RADIUS, alternative bump-in-the-wire methods, such as the use of VPN, should be employed.

For role notification by the server, the device processes the *Management-Privilege-Level* attribute (Type=136), explained in RFC 5607. This attribute contains the following fields:

- Type (1 byte): takes the value 136.
- Length (1 byte): takes the value 6.
- Value (4 bytes): this is an integer indicating the user's role. As private roles not predefined in IEC 62351-8 must take a negative value, this value is interpreted by the device as a signed integer (INT32).

When the device receives an Access-Accept message, it takes the role of this *Management-Privilege-Level* attribute and checks it against the list of roles it has defined:

- If it does not match any role or matches any role, but this one does not have *Visualization* permission, it shall refuse to authenticate the user.
- Otherwise, it must accept the user's authentication, take note of the permissions associated with that role and allow the user to execute only the operations associated with the permissions available to that role.

The RADIUS client settings are as follows:

RADIUS					
Website	**CLI**	**DevicePreferences**	**Range**	**Step**	**Default**
Main Server IP	*main/access/radius/server1_ip*	server1_ip	XXX.XXX.XXX.XXX		0.0.0.0
Backup Server IP	*main/access/radius/server2_ip*	server2_ip	XXX.XXX.XXX.XXX		0.0.0.0
Port	*main/access/radius/port*	port	1 – 65535	1	1812
Shared Secret	*main/access/radius/secret*	secret	8 – 128 chars		ziv12345
Timeout	*main/access/radius/timeout*	timeout	1 – 30 s	1	3
Number of Attempts	*main/access/radius/attempts*	attempts	1 – 10	1	3

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The meaning of the settings is as follows:

- *Main Server IP*: IP address of the primary RADIUS server. If **0.0.0.0** (default value) is set, it means that this server will not be used.
- *Backup Server IP*: IP address of the secondary RADIUS server. If **0.0.0.0** (default value) is configured, it means that this server will not be used.
- *Port*: Port on which the RADIUS servers operate. The default value is **1812** (UDP), which is the one reserved by RFC 2865.
- *Shared Secret*: Shared secret key between client and RADIUS server for password encryption. The default value is **ziv12345**. The length will range from 8 to 128 characters.
- *Timeout*: Maximum waiting time (in seconds) for obtaining the response from the RADIUS server. The default value is **3 seconds**.
- *Number of Attempts*: Number of attempts (not retries) to authenticate against a server before deciding that the server could not be accessed. The default value is **3 attempts**.

If both IPs are set to 0.0.0.0, it means that the RADIUS is disabled and therefore tries to validate the incoming user against local users, even if the *Authentication Method* setting is set to **RADIUS** and the *Fallback to Local Access* setting is set to **Off**.

For all other cases, upon receiving a login from a user, the device executes the following process if the *Authentication Method* setting is set to **RADIUS**:

1) Send an *Access-Request* to the primary server (or go to step 2 if the primary's IP is 0.0.0.0.0):

   1.1) If it replies, it no longer tries the secondary:
   - If the response is *Access-Reject*, the user is rejected and the process is terminated.
   - If the answer is *Access-Accept*:
     - And the role does not exist on the device, the user is rejected and the process is terminated.
     - And the role does not have *visualization* permission assigned, the user is rejected and the process is terminated.
     - Otherwise, the user is accepted and the permissions associated to the role received from the server are granted and the process ends.

   1.2) If the user does not answer in the *Timeout* setting:
   - If it has tried less than *Number of Attempts* times, go to step 1.
   - If it has tried *Number of Attempts* times, go to step 2 and the **RADIUS server not accessible** cybersecurity event is generated.

2) Repeat step 1, but now with the secondary server.
   If the IP of the secondary is 0.0.0.0, continue to step 3.

3) If the *Fallback to Local Access* setting is set to:
   - **On**, it attempts to validate the user and password against the local users of the device and terminates the process.
   - **Off**, the user is rejected and the process is terminated.

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F.4.2 LDAP (Lightweight Directory Access Protocol)

The device acts as an LDAP client to authenticate the user/password against up to two LDAP servers (primary and secondary).

Authentication is performed by validating the user's credentials on the LDAP server. The LDAP client used is OpenLDAP 2.4.50. Simple synchronous authentication is supported according to the following summary procedure:

- Anonymous bind to LDAP server using anonymous authentication ("*Anonymous Authentication Mechanism of Simple Bind*" according to RFC 4513).
- Verification by the LDAP server of the username and password entered when opening a session via web, file transfer (FTP/SFTP), console access (Telnet/SSH), configuration tool (ICT) or other means, verifying that the username/password pair is correct.
- Reading the attribute defining the user's role (defined below), to apply the appropriate permissions to the user before granting access to the device by limiting, according to the role, the actions that the user can perform on the device.

The LDAP client settings are as follows:

LDAP					
Website	**CLI**	**DevicePreferences**	**Range**	**Step**	**Default**
Main Server IP	*main/access/ldap/ server1_ip*	IpAuth	XXX.XXX.XXX.XXX		0.0.0.0
Backup Server IP	*main/access/ldap/ server2_ip*	IpAuth2	XXX.XXX.XXX.XXX		0.0.0.0
Port	*main/access/ldap/ port*	port	1 – 65535	1	389
Timeout	*main/access/ldap/ timeout*	tRetryAuth	1 – 600 s	1 s	3 s
Number of Attempts	*main/access/ldap/ attempts*	NRetryAuth	1 – 10	1	3
Base DN	*main/access/ldap/ base_dn*	base_dn		0-100 chars	ou=users,dc=ziv,dc=es
Search Filter	*main/access/ldap/ search_filter*	search_filter		0-100 chars	objectClass=equiposSAS
Role Attribute	*main/access/ldap/ role_attribute*	role_attribute		0-60 chars	perfil-usu
Version	*main/access/ldap/ version*	version	2 – 3	1	3
Secure Connection	*main/access/ldap/ secure_cx*	secure_cx	Yes / No		Yes
Secure Protocol	*main/access/ldap/ secure_protocol*	secure_protocol	LDAPS / StartTLS		StartTLS

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The meaning of the settings is as follows:

- *Main Server IP*: IP address of the primary LDAP server. If **0.0.0.0** (default value) is set, it means that this server will not be used.
- *Backup Server IP*: IP address of the secondary LDAP server. If **0.0.0.0** (default value) is configured, it means that this server will not be used.
- *Port*: Port on which the LDAP servers operate. The default value is **389** (TCP), which is the one reserved according to RFC 4511.
- *Timeout*: Maximum waiting time (in seconds) for obtaining the response from the LDAP server. The default value is **3 seconds**.
- *Number of Attempts*: Number of attempts (not retries) to authenticate against a server before deciding that the server could not be accessed. The default value is **3 attempts**.
- *Base DN*: organizational unit (OU) in which users are stored in the LDAP server. The default value is **ou=users,dc=ziv,dc=en**. The length will range from 0 to 100 characters.
- *Search Filter*: additional search filter for the user, obviously together with the username (this will be done by the firmware by default). The default value is **objectClass=equiposSAS**. If no such filter is found, the user will not be validated. If an empty value is set, it means that the device will not perform this filter check to validate the user. The length will be between 0 and 100 characters.
- *Role Attribute*: name of the attribute that will contain the role of the user belonging to *Base DN* and that complies with the *Search Filter*. The default value is **perfil-usu**. If this attribute is not found on the server, the user will not be validated. If an empty value is set, the user will never be validated. The length will range from 0 to 60 characters.
- *Version*: version of LDAP to be used. The default value is **3** (LDAPv3).
- *Secure Connection*: indicates whether the connection to the LDAP server is secure or not. By default, a secure connection is used (**Yes**).
- *Secure Protocol*: secure protocol used if *Secure Connection* = **Yes**. The options are **LDAPS** or **StartTLS**. As the use of StartTLS is reserved for LDAPv3, if *Secure Connection* = **Yes** and *Version* = **2** are chosen, the LDAPS secure protocol (LDAP over SSL/TLS) will always be used regardless of the *Secure Protocol* parameter. The default value is **StartTLS**.

If both IPs are set to 0.0.0.0, it means that LDAP is disabled and therefore tries to validate the incoming user against local users, even if the *Authentication Method* setting is set to **LDAP** and the *Fallback to Local Access* setting is set to **Off**.

For all other cases, upon receiving a login from a user, the device, if the *Authentication Method* setting is set to **LDAP**, executes the following process:

1) If the device is able to connect to the primary server, continue to step 1.1.
   If it is not able to connect to the primary server, continue to step 1.2.
   If the IP of the primary is 0.0.0.0, continue to step 2.

   1.1) Send a *bindRequest* to the primary server indicating simple authentication, but without username and password (both zero length). This is known as *Anonymous authentication*.
   - If the response is *bindResponse* success, continue to step 1.1.1.
   - Otherwise, the user's authentication is rejected and the process is terminated.

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1.1.1) Send a *searchRequest* to search for the user's role, consisting of:
- *baseObject* field equal to the *Base DN* setting.
- *Filter* field that is an AND of:
  - *Search Filter* setting (e.g., **objectClass=equiposSAS**).
  - *uid* equal to the name of the user to be authenticated (e.g., *uid=admin*).
- *attributes* field containing a single attribute whose *AttributeDescription* is the value of the *Role Attribute* setting (e.g., *perfil-usu*).

It must receive from the LDAP server as many *searchResEntry* as entries in the *Base DN* directory and match the indicated search criteria (theoretically one, if it hypothetically responds with more, the device will keep the first one), ending in a *searchResDone*. This means that if only *searchResDone* is returned, there are no entries in the directory.

- If the response is at least one *searchResEntry*, continue to step 1.1.1.1.
- Otherwise, the user's authentication is rejected and the process is terminated.

1.1.1.1) It sends a *bindRequest* to the primary server indicating simple authentication, with username and password (in clear). This is known as the *Name/Password Authentication Mechanism of Simple Bind*.
- If the response is *bindResponse* success, continue to step 1.1.1.1.1.
- Otherwise, the user authentication is rejected and the process is terminated.

1.1.1.1.1) The device takes the first *SearchResEntry* received in step 1.1.1.
The device checks the value of the role received from the server against the list of roles it has defined. The role attribute can contain a text string or an integer. Therefore, to be versatile, the device compares the value of that variable with (in this order):
- The role *name* field. It must match exactly (case sensitive).
- The role *identifier* field.

First the names are checked and then the role identifiers. The first role of the device that matches this search will be the chosen role. For better understanding, the following example of device roles is included:

# (role)	*Name*	*identifier*
1	VIEWER	-7
2	OPERATOR	-5
3	-7	3

If the role attribute received by LDAP is "-7", the chosen role will be #3, because the *name* field is checked first.
- If it does not match any role or it matches one, but it does not have *visualization* permission, the user authentication is rejected and the process is terminated.

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- If the check has been successful, the user authentication is accepted, takes note of the permissions associated with said role and allows the user to execute only the operations associated with the permissions available to said role and the process is finished.

1.2) If it does not answer or refuses the socket connection in the *Timeout* setting:
- If it has tried less than *Number of Attempts* times, skip to step 1.
- If it has tried *Number of Attempts* times, go to step 2 and generate the **LDAP repository not accessible** cybersecurity event.

2) Repeat step 1, but now with the secondary server.
If the secondary's IP is 0.0.0.0, continue to step 3.

3) If the *Fallback to Local Access* setting is a:
- **On**, it attempts to validate the user and password against the local users of the device and terminates the process.
- **Off**, the user authentication is rejected and the process is terminated.

At the end of the process, if it has been able to connect to the server, the device sends an *unbindRequest* before closing the connection to the LDAP server.

In the case of using a secure method (LDAPS or StartTLS), when connecting to the LDAP server, the device performs a TLS mutual authentication based on certificates. On the one hand, the device sends its device certificate so that it can be validated by the LDAP server. On the other hand, the device asks the LDAP server for its certificate and checks that the certificate sent by the LDAP server is valid based on the following checks:

- The remote certificate must be signed by one of the certificate authorities (CA) present in the list of CAs of the device. If it is not, the connection to the LDAP server is rejected and the **Certificate validation failed - certificate signature check failed** cybersecurity event is generated.
- The remote certificate must not be revoked, which is checked using certificate revocation lists (CRL) of the device. If the certificate is revoked, the connection to the LDAP server is rejected and the **Certificate validation failed - certificate revoked** cybersecurity event is generated.
- The remote certificate must not be expired (checking that the current date of the device is between the *Valid from* and *Valid to* dates of the server certificate). If the certificate is expired, the connection to the LDAP server is rejected and the **Certificate validation failed - certificate expired** cybersecurity event is generated.
- The remote certificate must contain the IP of the LDAP server in one of the following certificate fields: CN (Common Name) or SAN (Subject Alternative Name). If the IP does not appear in either of these two fields or appears but does not match the IP of the LDAP server, the connection to the LDAP server is rejected and the **Certificate validation failed - certificate does not comply with authorization policies** cybersecurity event is generated.

For details on how the certificate and lists of CAs and CRLs of the device are managed, see **Credential Management** section.

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F.4.3 Remote User Authentication Configuration

The configuration of remote user authentication must be performed by a user with *user management* permission. Remote user authentication is managed from several interfaces:

- Web interface (HTTP / HTTPS).
- CLI command line interface (Telnet / SSH).
- ***ZIV e-NET Tool***® configuration tool, using the *DevicePreferences* file.

F.4.3.a Remote User Authentication Configuration from the Web

To manage remote user authentication from the web interface, some of the LAN ports and the HTTP or HTTPS services must be enabled. It is recommended to use HTTPS connection instead of HTTP because the data is encrypted.

The website of the device is accessed through a browser by entering the IP address configured in the LAN adapter of the device. Initially, a login web page appears where the user's name and password must be entered (*admin* is the default user).

The ***Configuration→Access*** menu is accessed to manage the following information related to remote authentication:

- Configuration of the authentication method for each access:

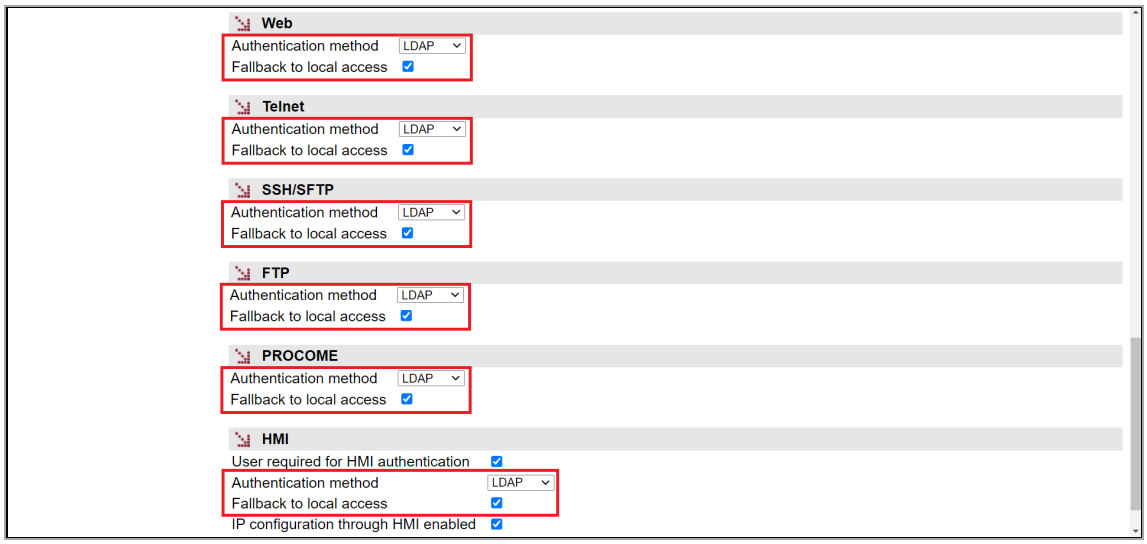


Figure F.21 Authentication Method Settings in Website.

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- RADIUS Configuration:

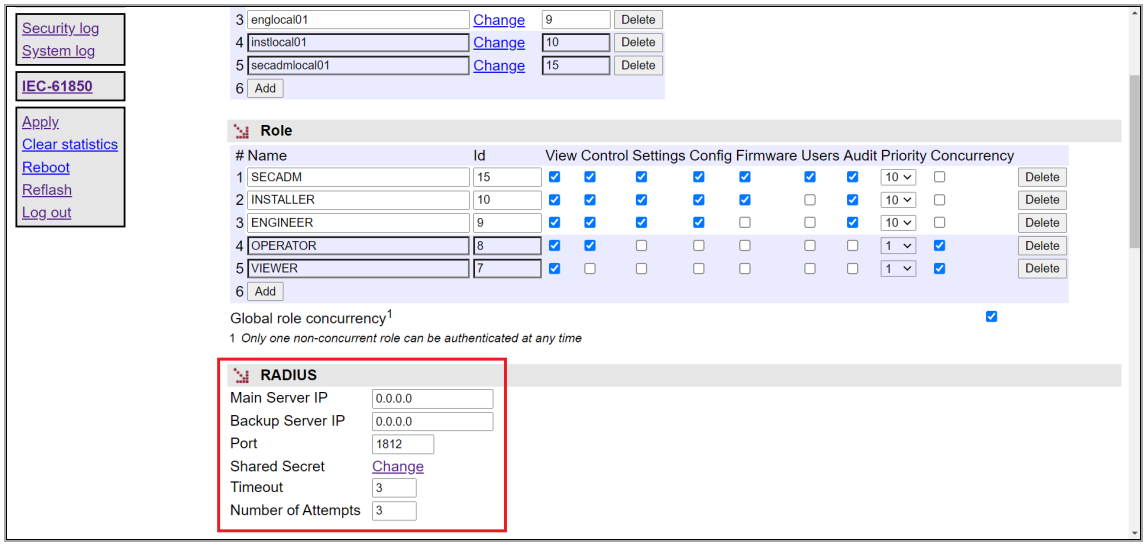


Figure F.22 RADIUS Settings in Website.

To change the secret key, proceed in the same way as for changing a user's password (Figure F.5).

- LDAP Configuration:

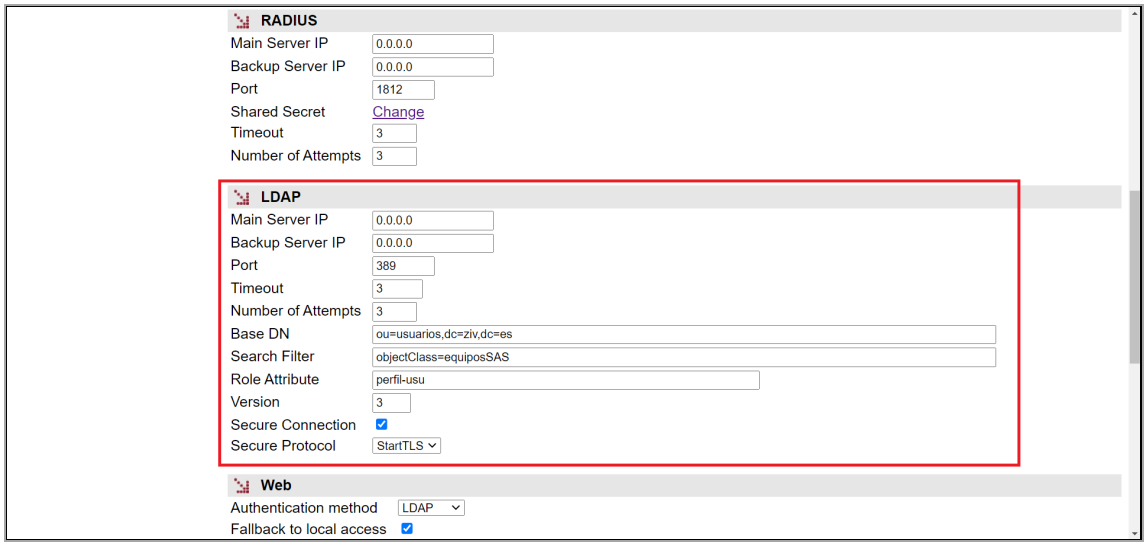


Figure F.23 LDAP Settings in Website.

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F.4.3.b Remote User Authentication Configuration from CLI

To manage remote user authentication from the CLI command line interface, one of the LAN ports and the Telnet or SSH services must be enabled. It is recommended to use the SSH connection instead of Telnet because the data is encrypted.

The CLI of the device is accessed by launching the Telnet or SSH application from a host and entering the login of the user who has user management permissions.

The CLI of the device is automatically accessed. The parameter tree can be viewed with the ***get*** command. The settings for remote user authentication are in the ***main/access*** node:

- Configuration of the authentication method for each of the accesses:

```
web/
   method = local
   local  = on
telnet/
   method = local
   local  = on
ssh_sftp/
   method = local
   local  = on
ftp/
   method = local
   local  = on
procome/
   method = local
   local  = on
hmi/
   usrauthhmi  = off
   pwdconfig   = ********
   pwdcontrol  = ********
   pwdsettings = ********
   method      = local
   local       = on
   confiphmi   = on
```

Figure F.24 Authentication Method Settings in CLI.

- RADIUS Configuration:

```
radius/
   server1_ip = 0.0.0.0
   server2_ip = 0.0.0.0
   port       = 1812
   secret     = ********
   timeout    = 3
   attempts   = 3
```

Figure F.25 RADIUS Settings in CLI.

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- LDAP Configuration:

```
ldap/
   server1_ip      = 0.0.0.0
   server2_ip      = 0.0.0.0
   port            = 389
   timeout         = 3
   attempts        = 3
   base_dn         = ou=usuarios,dc=ziv,dc=es
   search_filter   = objectClass=equiposSAS
   role_attribute  = perfil-usu
   version         = 3
   secure_cx       = on
   secure_protocol = StartTLS
```

Figure F.26 LDAP Settings in CLI.

To change a setting, proceed by executing the ***set*** command with the name of the setting and the device will ask for the value, or by directly executing the ***set*** command of the field to be modified, for example:

- ***set main/access/web/method local***
- ***set main/access/radius/timeout 5***
- ***set main/access/radius/secret*** (entering the key value twice).
- ***set main/access/ldap/port 636***

Once the desired settings have been configured, the data are saved with the ***save*** command and the changes are made effective on the device with the ***apply*** command.

F.4.3.c Remote User Authentication Configuration from *ZIV e-NET Tool®*

To manage remote user authentication from the ***ZIV e-NET Tool®*** it is necessary that some of the LAN ports and the SSH and SFTP services are enabled.

Remote user authentication is configured with the *DevicePreferences* file.

- Configuration of the authentication method for each of the accesses:

  To configure the authentication methods for the different accesses, in the ***Navigation View*** go to the ***Preferences→Security→Access*** option.

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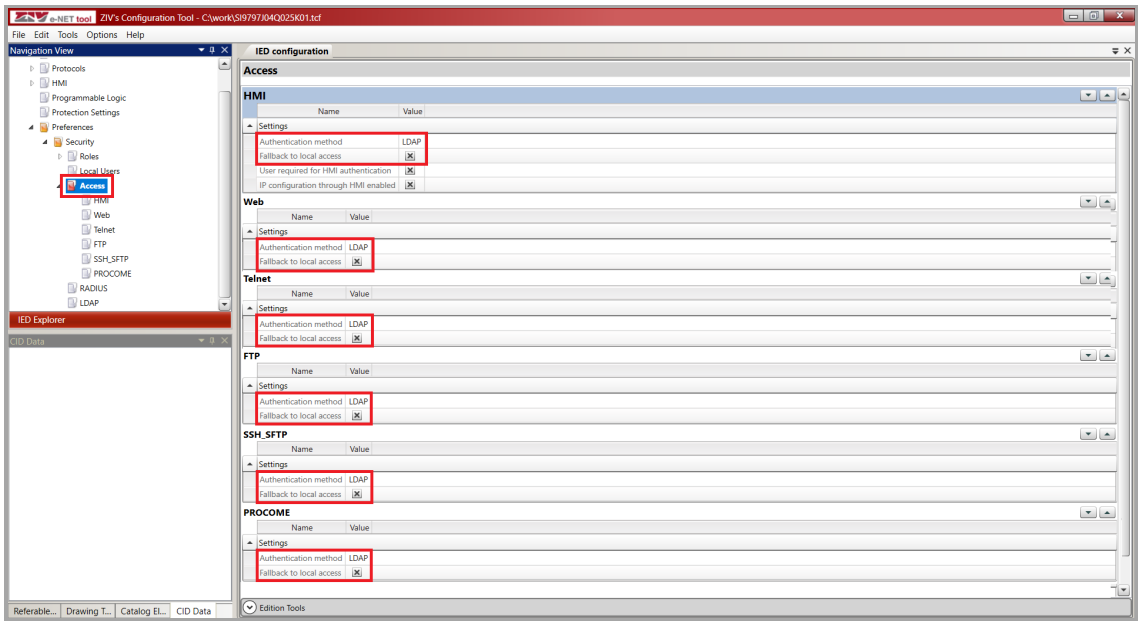


Figure F.27 Configuring the Authentication Method for each Access with the Configuration Tool.

By right-clicking on this option ***Preferences→Security→Access***, you can export the authentication methods to a *DevicePreferences* file or import them from a previously configured *DevicePreferences* file.

The authentication methods for each access are part of the *DevicePreferences* file. This is an XML file whose authentication methods section has the following format (settings are highlighted):

Node	Description	Child nodes	Attributes
device	Root node.	ROLES, RADIUS, LDAP, **ACCESS**	**tversion**: file version. **filetype**: type of file ("DevicePreferences").
ACCESS	Access parameters.	**HMI**, **WEB**, **TELNET**, **FTP**, **SSH_SFTP**, **PROCOME**	-
HMI	Definition of authentication method for HMI access: method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each HMI access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for HMI access (local, LDAP or RADIUS). - **local**: alternative use of local users for HMI access. - **userauthhmi**: role name. - **confiphmi**: it is allowed to change the IP by HMI. **value**: setting value.

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Node	Description	Child nodes	Attributes
WEB	Definition of authentication method for web access (HTTP/HTTPS): method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each web access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for web access (local, LDAP or RADIUS). - **local**: alternative use of local users for web access. **value**: setting value.
TELNET	Definition of authentication method for Telnet access: method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each Telnet access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for Telnet access (local, LDAP or RADIUS). - **local**: alternative use of local users for Telnet access. **value**: setting value.
FTP	Definition of authentication method for FTP access: method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each FTP access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for FTP access (local, LDAP or RADIUS). - **local**: alternative use of local users for FTP access. **value**: setting value.
SSH_SFTP	Definition of authentication method for SSH/SFTP access: method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each SSH/SFTP access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for SSH/SFTP access (local, LDAP or RADIUS). - **local**: alternative use of local users for SSH/SFTP access. **value**: setting value.

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Node	Description	Child nodes	Attributes
PROCOME	Definition of authentication method for PROCOME access: method and alternative use of local users.	**Setting**	-
Setting	One **Setting** node for each PROCOME access setting.	-	**name**: setting name. The following settings are available: - **method**: authentication method for PROCOME access (local, LDAP or RADIUS). - **local**: alternative use of local users for PROCOME access. **value**: setting value.

Example of *DevicePreferences* file (only with access section, authentication method settings are highlighted):

```
<?xml version="1.0" encoding="utf-8"?>
<device tversion="0.1" fileType="DevicePreferences">
 <ACCESS>
  <HMI>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
   <Setting name="usrauthhmi" value="Yes" />
   <Setting name="confiphmi" value="Yes" />
  </HMI>
  <WEB>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
  </WEB>
  <TELNET>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
  </TELNET>
  <FTP>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
  </FTP>
  <SSH_SFTP>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
  </SSH_SFTP>
  <PROCOME>
   <Setting name="method" value="LDAP" />
   <Setting name="local" value="Yes" />
  </PROCOME>
 </ACCESS>
</device>
```


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To transfer the authentication methods for the different accesses to the device, access the ***Tools→Device access*** menu. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Transfer Files*** tab, check the ***TCF→Preferences*** option (if you want to transfer the complete *DevicePreferences* file), the ***TCF→Preferences→Access*** option (if you want to transfer the complete access section) or the ***TCF→Preferences→Access→XXX*** option (where XXX=HMI, Web, Telnet, FTP, SSH_SFTP or PROCOME if you want to transfer a particular access section, this is the minimum section that can be sent) and click ***Transfer*** to upload the information to the device. The upload progress is indicated in the ***Information*** window. If it has been successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if there is any error in the validation by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

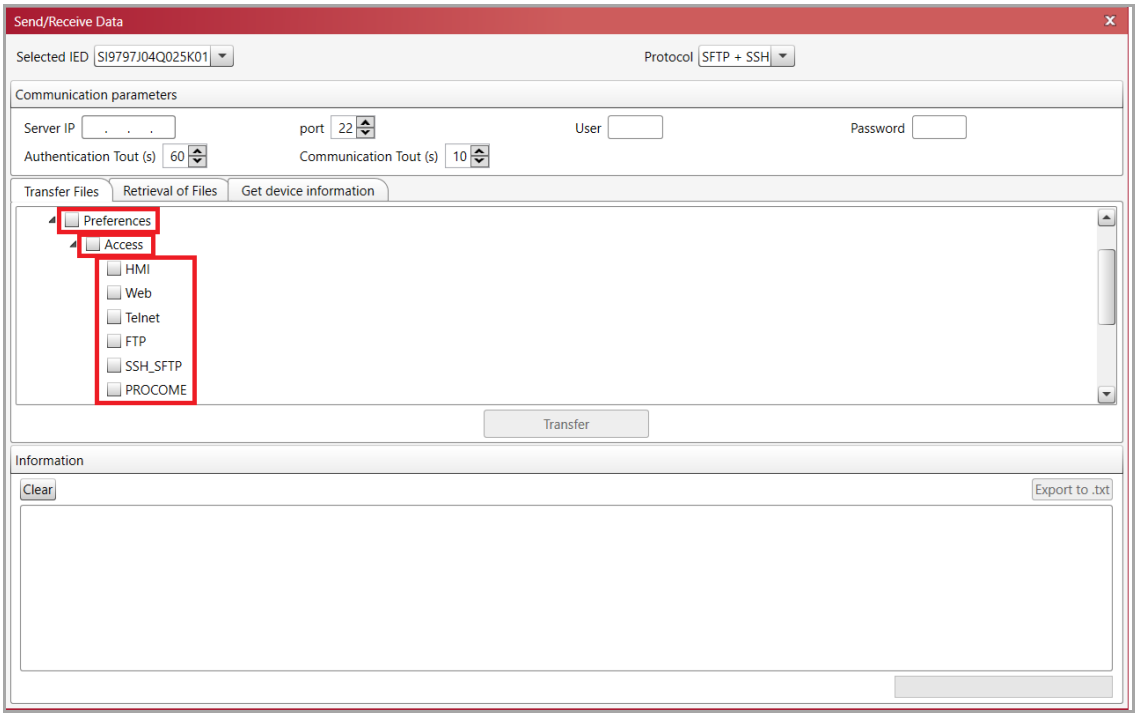


Figure F.28 Sending Authentication Methods with Configuration Tool.

To retrieve the authentication methods for the different accesses of the device, proceed as indicated in the **User and Role Management from ZIV e-NET Tool®** section for the roles, as it is only possible to retrieve the complete *DevicePreferences* file.

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- RADIUS Configuration:

  To configure RADIUS, in the ***Navigation View*** go to the ***Preferences→Security→RADIUS*** option.

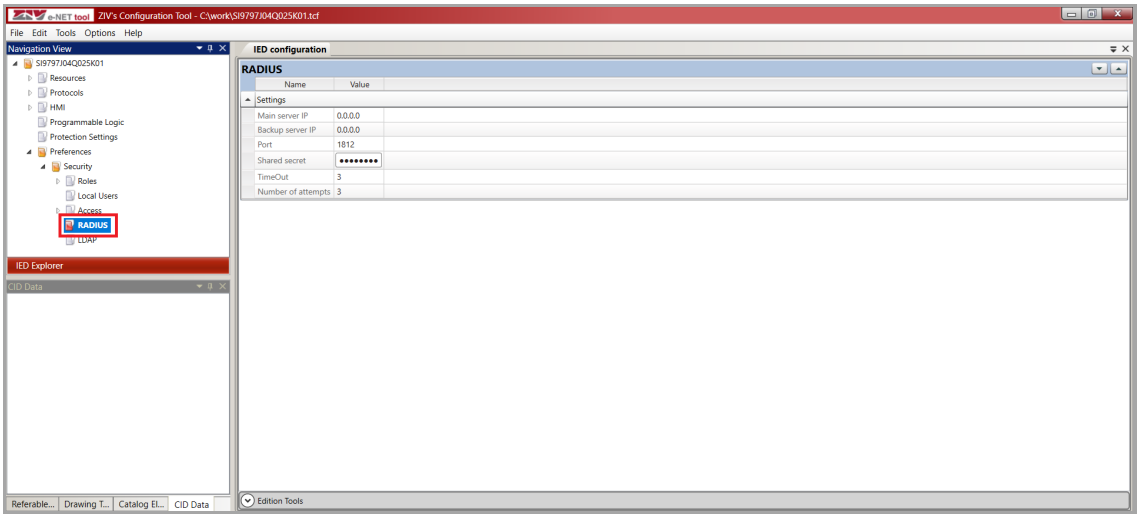


Figure F.29 RADIUS Configuration with Configuration Tool.

By right-clicking on this option ***Preferences→Security→RADIUS***, you can export the RADIUS settings to a *DevicePreferences* file or import them from a previously configured *DevicePreferences* file.

The RADIUS settings are part of the *DevicePreferences* file. This is an XML file whose RADIUS section has the following format:

Node	Description	Child nodes	Attributes
device	Root node.	ROLES, **RADIUS**, LDAP, ACCESS	**tversion**: file version. **filetype**: type of file ("DevicePreferences").
RADIUS	Parameters for RADIUS remote authentication	**Setting**	-
Setting	One **Setting** node for each RADIUS setting.	-	**name**: setting name. The following settings are available: - **server1_ip**: IP address of the primary RADIUS server. - **server2_ip**: IP address of the secondary RADIUS server. - **port**: RADIUS server port. - **secret**: password encryption key. - **timeout**: RADIUS server response waiting time. - **attempts**: authentication attempts against the RADIUS server. **value**: setting value.

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Example of *DevicePreferences* file (only with RADIUS section):

```
<?xml version="1.0" encoding="utf-8"?>
<device tversion="0.1" fileType="DevicePreferences">
   <RADIUS>
   <Setting name="server1_ip" value="0.0.0.0" />
   <Setting name="server2_ip" value="0.0.0.0" />
   <Setting name="port" value="1812" />
   <Setting name="secret" value="ziv12345" />
   <Setting name="timeout" value="3" />
   <Setting name="attempts" value="3" />
  </RADIUS>
</device>
```

To transfer RADIUS settings to the device, access the ***Tools→Device access*** menu. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Transfer Files*** tab, check the ***TCF→Preferences*** option (if you want to transfer the entire *DevicePreferences* file) or the ***TCF→Preferences→RADIUS*** option (if you want to transfer only the RADIUS section) and click ***Transfer*** to upload the information to the device. The upload progress is indicated in the ***Information*** window. If it has been successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if there is any error in the validation by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

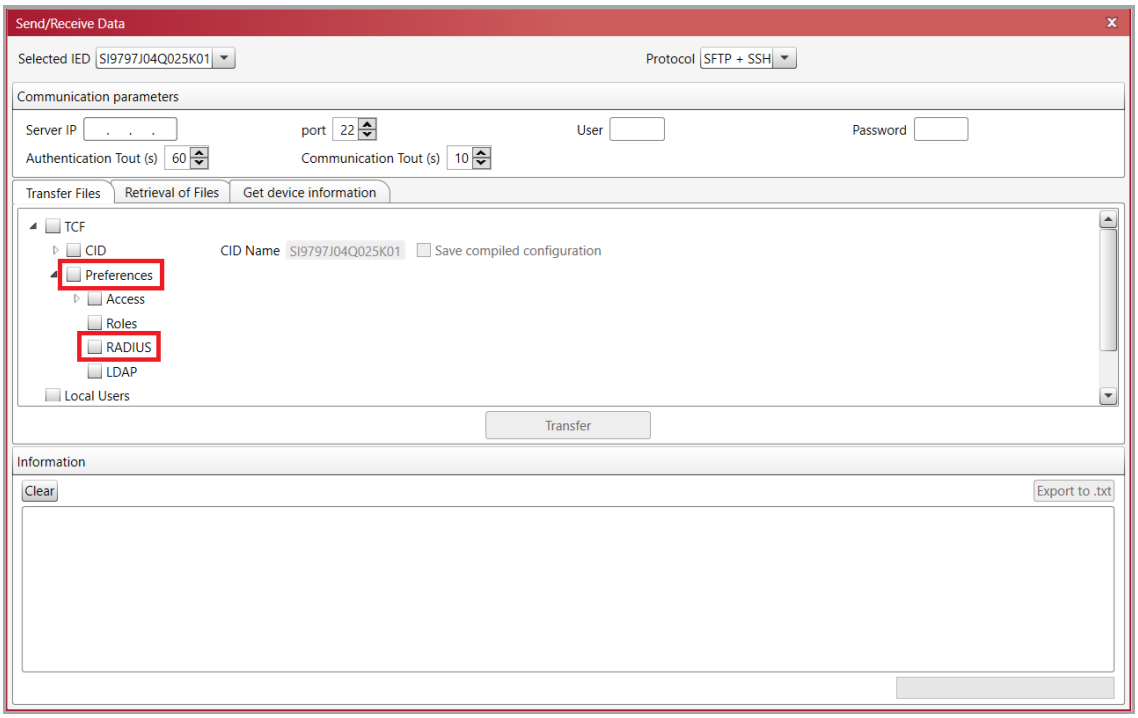


Figure F.30 Sending RADIUS Settings with Configuration Tool.

To retrieve the RADIUS settings of the device, proceed as indicated in the **User and Role Management from ZIV e-NET Tool®** section for the roles, as it is only possible to retrieve the complete *DevicePreferences* file.

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- LDAP Configuration:

  To configure LDAP, in the ***Navigation View*** go to the ***Preferences→Security→LDAP*** option.

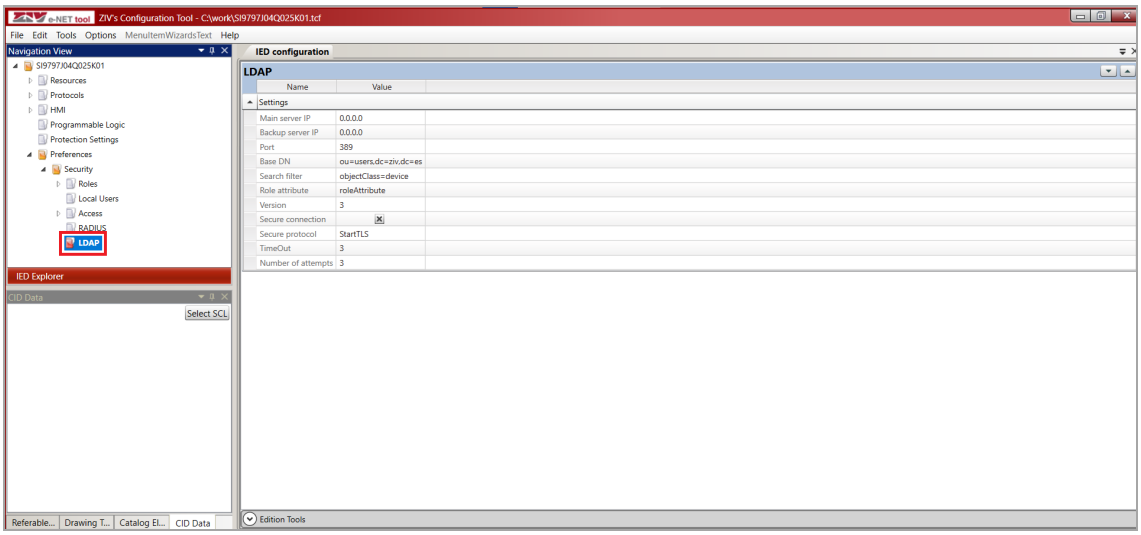


Figure F.31 LDAP Configuration with Configuration Tool.

By right-clicking on this option ***Preferences→Security→LDAP***, you can export the LDAP settings to a *DevicePreferences* file or import them from a previously configured *DevicePreferences* file.

The LDAP settings are part of the *DevicePreferences* file. This is an XML file whose LDAP section has the following format:

Node	Description	Child nodes	Attributes
device	Root node.	ROLES, RADIUS, **LDAP**, ACCESS	**tversion**: file version. **filetype**: type of file ("DevicePreferences").
LDAP	Parameters for LDAP remote authentication.	-	**IpAuth**: IP address of the primary LDAP serve. **IpAuth2**: IP address of the secondary LDAP serve. **port**: LDAP server port. **tRetryAuth**: LDAP server response time. **NRetryAuth**: authentication attempts against the LDAP server. **base_dn**: organizational unit (OU) in which users are stored on the LDAP server. **search_filter**: additional search filter for the user. **role_attribute**: name of the attribute containing the user role. **version**: LDAP version.

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Node	Description	Child nodes	Attributes
LDAP	Parameters for LDAP remote authentication.	-	**secure_cx**: indicates whether the LDAP connection is secure or not. **secure_protocol**: indicates the secure protocol to be used.

Example of *DevicePreferences* file (only with LDAP section):

```
<?xml version="1.0" encoding="utf-8"?>
<device tversion="0.1" fileType="DevicePreferences">
  <LDAP tRetryAuth="3" NRetryAuth="3" port="389" IpAuth="192.168.1.69"
  IpAuth2="0.0.0.0" role_attribute="perfil-usu" version="3" secure_cx="Yes"
  secure_protocol="StartTLS" base_dn="ou=usuarios,dc=ziv,dc=es"
  search_filter="objectClass=equiposSAS" />
</device>
```

To transfer LDAP settings to the device, access the ***Tools→Device access*** menu. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Transfer Files*** tab, check the ***TCF→Preferences*** option (if you want to transfer the entire *DevicePreferences* file) or the ***TCF→Preferences→LDAP*** option (if you want to transfer only the LDAP section) and click ***Transfer*** to upload the information to the device. The upload progress is indicated in the ***Information*** window. If it has been successfully uploaded to the device, the **Configuration uploaded successfully** cybersecurity event is generated. However, if there is any error in the validation by the device, the **Configuration upload failed - invalid configuration** cybersecurity event is generated.

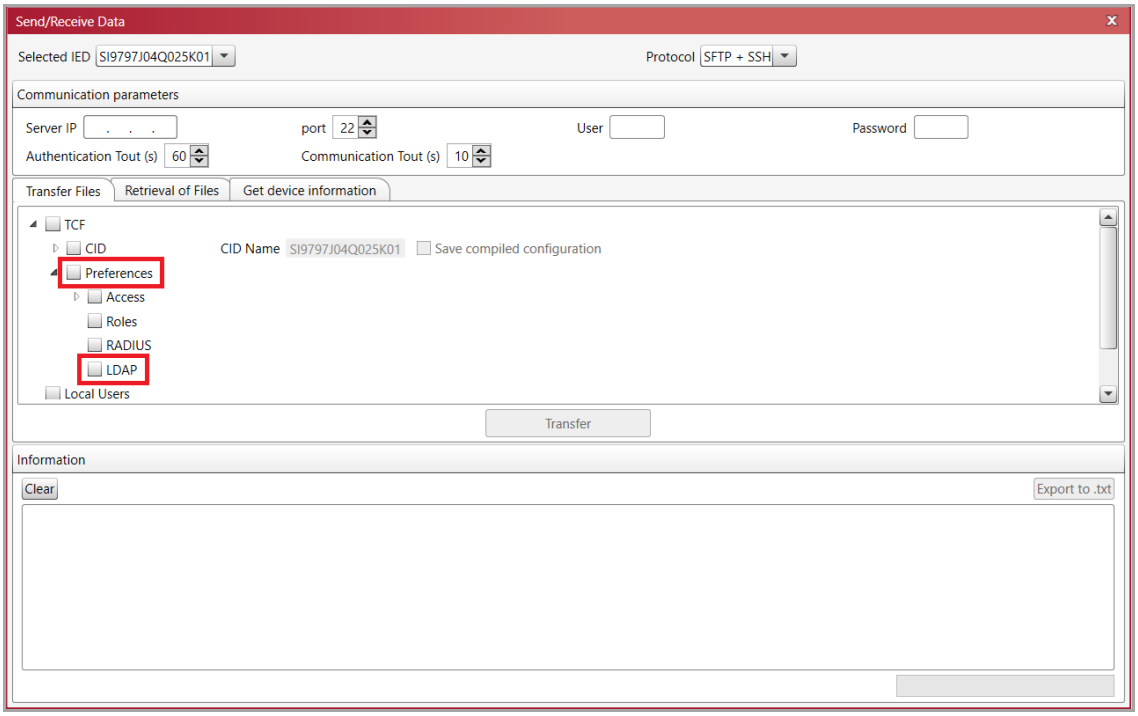


Figure F.32 Sending LDAP Settings with Configuration Tool.

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To retrieve the LDAP settings of the device, proceed as indicated in the **User and Role Management from ZIV e-NET Tool®** section for the roles, as it is only possible to retrieve the complete *DevicePreferences* file.

F.5 Communication with Configuration Tool using PROCOME

Zivercomplus® and ***ZIV e-NET Tool®***[1] communications with the device use PROCOME protocol. This PROCOME protocol has been strengthened so that communications are authenticated and encrypted (the latter only in the case of LAN port communication).

Authentication is based on a new private ASDU that includes user and password, replacing ASDU 116, which only uses a password.

On the other hand, for LAN port communications, there is the possibility for the protocol to use encryption, using TLS v1.2.

The different instances of communication with PROCOME protocol that can be present in the device are:

- Local Port.
- Remote Port 1 and 2.
- LAN ports: one fixed PROCOME instance and four more configurable instances (TCP/IP Protocol 1, 2, 3 and 4).

The settings for configuring whether each of the PROCOME instances is authenticated and/or encrypted (the latter only in case of LAN port communication) are detailed in Chapter 1, **Description and Start-up**, **Communication Settings** section.

By default, all instances are set with authentication except for the local port. Therefore, any session opened through an authenticated connection will require the user/password to be entered on the device at the start of the connection.

The authenticated local port setting can only be adjusted from HMI.

Only instances that communicate over LAN ports (PROCOME Protocol and TCP/IP Protocols), can be configured to work with encryption, and by default they are adjusted to encrypted mode. For more details on the type of encryption used, see **Secure Sockets** section. Each of these instances also has an adjustable logical port number.

In TCP/IP protocols, encryption and authentication only affect the PROCOME protocol. The other configurable protocols, DNP3 and MODBUS, are not affected by these settings.

*When communicating the configuration tools with the device via LAN, the user must configure the **secure** / **non-secure** communications option in the tool, according to the corresponding PROCOME instance that has been configured as **encrypted** / **not encrypted** on the device. If they do not match, communication will not be possible.*

[1] ***ZIV e-NET Tool®*** also uses other protocols such as SFTP and SSH to communicate with the device.

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F.6 Secure Sockets

In order to prevent communications from being spied on, a suitable countermeasure is to encrypt communications using secure sockets.

The device uses the secure (encrypted) versions of the following protocols:

Protocol	Secure Version
Telnet	SSH
FTP	SFTP
HTTP	HTTPS
PROCOME	PROCOME over TLSv1.2
LDAP	LDAPS/StartTLS

F.6.1 SSH (Secure Shell)

Secure Shell is a cryptographic network protocol for securing communications. It establishes a secure channel over an insecure network in a client/server architecture.

In the case of the device, it provides an SSH server that allows SSH clients to connect in an authenticated manner (login) for maintenance functions by using the command line interface (CLI).

This protocol is a direct and secure replacement for the Telnet interface.

The encryption used by SSH provides confidentiality and data integrity over an insecure network, such as the Internet.

SSH uses public key cryptography to authenticate the remote machine and allow the user to authenticate.

The protocol version used on the device is SSH Version 2 (SSHv2).

The device supports both Telnet and SSH (see **Ports and Communication Services** section to see how to enable / disable one, the other or both).

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F.6.2 SFTP (SSH File Transfer Protocol)

SSH File Transfer Protocol (also known as Secure File Transfer Protocol) is a network protocol that provides file access, file transfer and file management functionality over SSH. It works together with SSH to provide secure file transfer capabilities.

This protocol assumes that it is running on a secure channel, such as SSH, that the server has already authenticated the client, and that the client's user identity is available to the protocol.

The encryption and authentication aspects for this protocol are handled by the SSH server also running on the device. Therefore, the encryption and authentication methods are identical to those for SSH described above.

The device supports both FTP and SFTP (see **Ports and Communication Services** section for how to enable/disable one, the other or both).

F.6.3 TLS / SSL (Transport Layer Security / Secure Socket Layer)

Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols designed to provide communication security over a TCP/IP network. They use the X.509 certificate and, therefore, asymmetric cryptography to authenticate the machine they are communicating with and to exchange a symmetric session key. This session key is used to encrypt the data flowing between the two parties. This allows data confidentiality and message authentication codes for message integrity and, in addition, message authentication.

In Internet Protocol Suite, TLS and SSL encrypt the network connection data at the application layer. In OSI model equivalencies, TLS/SSL is initialized at layer 5 (session layer) and functions as layer 6 (presentation layer). The session layer has a link protocol that uses asymmetric encryption to set up encryption configurations and a shared key for that session. The presentation layer then encrypts the rest of the communication using symmetric encryption and that session key. In both models, TLS and SSL work on behalf of the underlying transport layer, whose segments carry encrypted data.

In the device, TLS is only used for the Secure Web Server (HTTPS) application and for PROCOME, which is explained in the **Communication with Configuration Tool using PROCOME** section.

The TLS version supported is TLSv1.2. During TLS negotiation, the most secure option common to both client and server is always chosen.

The SSL1, SSL2, SSL3, TLSv1.0 and TLS v1.1 protocols are not available on the device as they are considered insecure.

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F.6.4 HTTPS (Secure Web Server)

The Secure Web Server application uses the Hypertext Transfer Protocol (HTTPS) which is a communications protocol for secure communication over a network.

Technically it is not a protocol per se but is the result of simply placing the Hypertext Transfer Protocol (HTTP) over the SSL/TLS protocol (explained in the previous section), thus adding the security capabilities of SSL/TLS for standard HTTP communications.

The security of HTTPS is that of the underlying SSL / TLS, which uses long-term public and secret keys to exchange a short-term session key to encrypt the data flow between a client and a server.

The X.509 certificate is used to ensure that you are communicating to the peer you want to communicate with.

In its popular implementation on the Internet, HTTPS provides authentication of the website and the associated web server. In addition, it provides bi-directional encryption of communications between a client and a server, which protects against eavesdropping and manipulation and / or falsification of the communication content.

A website must be fully supported over HTTPS, without having some of its content uploaded over HTTP, or the user will be vulnerable to some attacks and surveillance.

The device supports both HTTP and HTTPS (see **Ports and Communication Services** section for how to enable/disable one, the other or both).

F.6.5 Mutual Authentication

Mutual authentication or two-way authentication (not to be confused with two-factor authentication) refers to two ends of a communication authenticating each other at the same time in an authentication protocol. Mutual authentication is a desired feature in verification schemes that transmit sensitive data, in order to ensure the security of such data. Mutual authentication can be achieved with two types of credentials: user/password and public key certificates.

Two scenarios are distinguished in the device:

- Communications using TLS protocol:
  Mutual authentication is performed based on X.509 certificates. The device sends its certificate so that it can be validated by the other end and additionally requires the remote end to send its certificate to perform the pertinent checks and validate it. In HTTPS and PROCOME communications over TLS (in this second case if it is configured to be authenticated) a second authentication factor consisting of user and password is additionally required.
- Communications using SSH protocol:
  Mutual authentication is performed as follows:
  - Server authentication is performed based on the server's public key. That is, all clients communicating with the device using SSH will need to include the public key of the device among their known hosts if they want to check the validity of the server.
  - Client authentication is based on username/password authentication. In other words, clients connecting to the device must enter username and password in order to be validated by the device (they will be checked against remote servers or against local users, as explained in the **Remote User Authentication** section).

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The device manages a single common private key for TLS and SSH communications. There is, therefore, a single place where the private key and certificate of the device are configured. When new credentials (private key/certificate) are uploaded to the device, the public key used by SSH is derived internally from those credentials by software within the device.

Root certificates, used to validate remote certificates received by the device during TLS communications, are common to all services using TLS (HTTPS, secure LDAP or encrypted PROCOME LAN). They correspond to the list of Certificate Authorities (hereinafter CA) of the device. When a device has a list of CAs configured (by default the device is configured with the ZIV CA), the device will require TLS mutual authentication, although this mutual authentication can be disabled per service as explained in the **Credential Management** section.

Devices with basic cybersecurity do not perform TLS mutual authentication.

The process for validating a remote certificate is as follows:

- The remote certificate is validated against the list of CAs of the device. If the certificate is not trusted (not signed by any of the CAs present in the list), the communication is rejected and the **Certificate validation failed - certificate signature check failed** cybersecurity event is generated.

- The revocation of the remote certificate is checked against the CRL (Certificate Revocation List) of the device. If the certificate is revoked, the communication is rejected and the **Certificate validation failed - certificate revoked** cybersecurity event is generated.

- The remote certificate is checked for expiration (the certificate is expired or not yet valid). If the certificate is expired, the communication is rejected and the **Certificate validation failed - certificate expired** cybersecurity event is generated.

- Additional validations can be performed on the remote certificate expressed in an authorization policy file based on certificate details (fingerprint and CN and OU fields) which are detailed in the **Credential Management** section. If the certificate does not comply with these authorization policies, the communication is rejected and the **Certificate validation failed - certificate does not comply with authorization policies** cybersecurity event is generated.

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F.7 Credential Management

Credential management refers to the way in which the entire public key infrastructure (hereinafter PKI) is managed within the device. The following shows how the certificate and private key of the device are managed (the only thing available in devices with basic cybersecurity), as well as the list of certification authorities (CAs), the certificate revocation list (CRLs) and the authorization policy file for devices with enhanced cybersecurity.

F.7.1 Devices with Basic Cybersecurity

In devices with basic cybersecurity, the PKI consists only of a certificate and private key that allow the device to perform secure communications without TLS mutual authentication capability, i.e., without performing any type of remote certificate verification.

By default, the devices at the first boot up generate a self-signed X.509 certificate with a 2048-bit RSA public key and a 2048-bit private key, both in PEM format.

The self-signed certificate generated has the following identifiers and validity period:

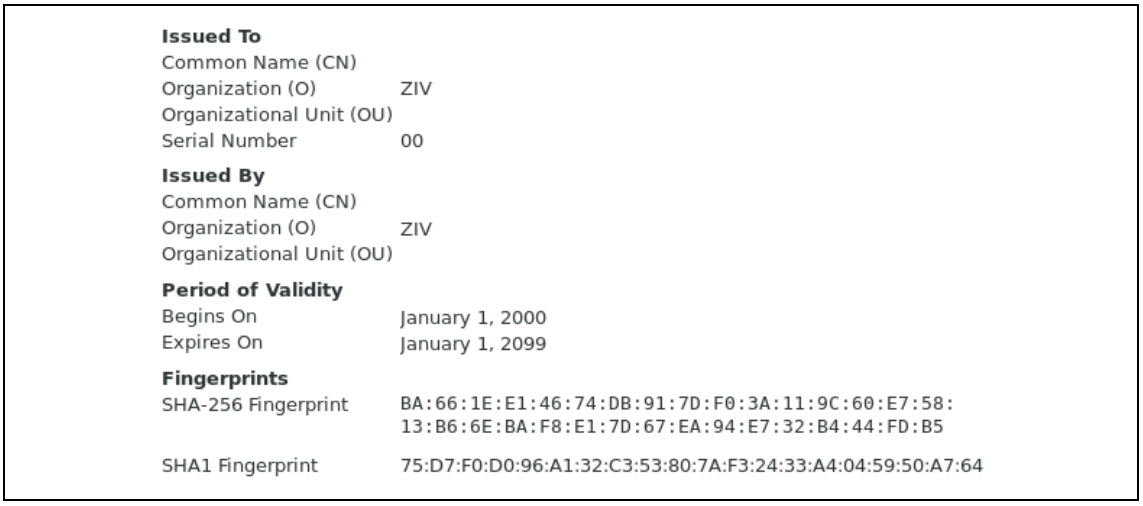


Figure F.33 Characteristics of the Self-Signed Certificate for Devices with Basic Cybersecurity.

This certificate and its private key are provisional and should be replaced by the client with a trusted certificate and its corresponding private key. For this purpose, the device has a menu on the website that allows the upload of a new certificate and private key, as well as the download of the current certificate.

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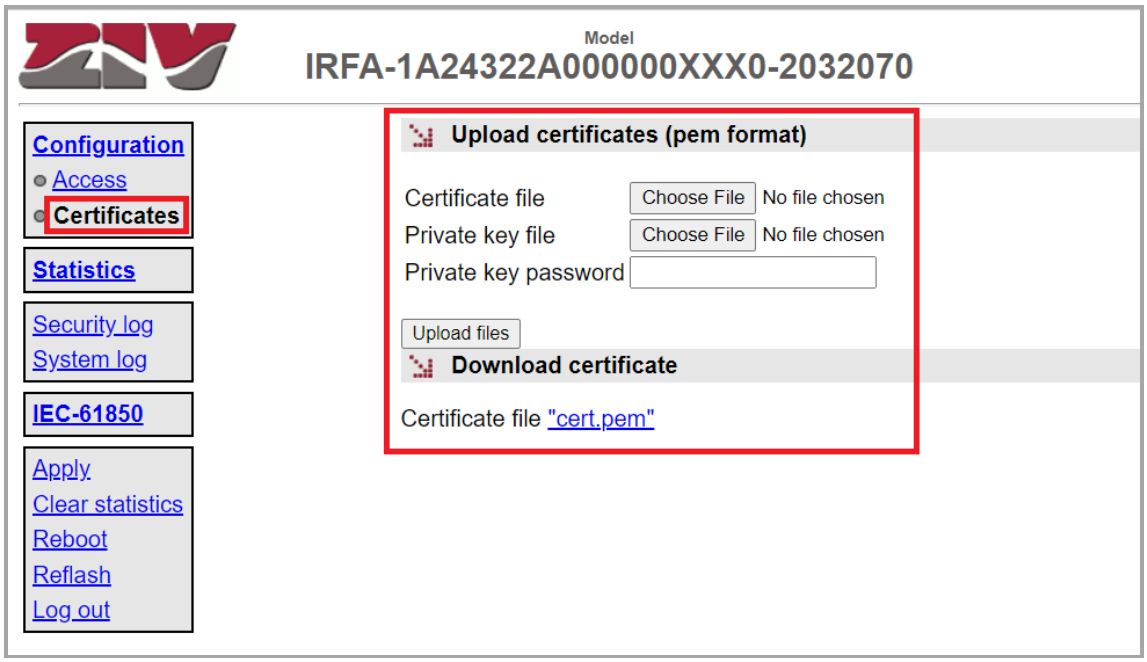


Figure F.34 Certificate and Private Key Configuration on Website for Devices with Basic Cybersecurity.

The certificate management operation is as follows:

- Access to the certificate menu of the device is only possible with a user with *user management* permission.
- The certificate and private key upload option are only available with HTTPS connections. In case of using an unsecured connection (HTTP), only the certificate download is allowed.
- Only certificates and private keys in PEM format can be uploaded to the device. The private key can be either clear or encrypted with AES encryption.
- From the website you can select the certificate (***Certificate File***), the private key (***Private Key File***) and the encryption key of the private key (***Private Key Password***).
- You can upload the certificate and the private key individually or simultaneously with the ***Upload files*** button, selecting the ***Choose File*** button to choose the file corresponding to the certificate and/or the private key.
- When only the certificate is uploaded, it must be paired with the private key already stored in the device, or else a verification error will occur. In this case, the uploaded file is discarded. The same thing happens with the private key.
- If no value is entered in the encryption key of the private key, then the private key is considered not to be encrypted. If the password is entered, the private key is decrypted with said password and re-encrypted with a password specific to the device using the AES 256 CBC algorithm. The password entered by the user is not stored in the device in any case.

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- After pressing the ***Upload files*** button, a certificate and/or private key check is performed. If there is an error, it will be indicated to the user with a message and the uploaded files will be discarded.

- From the website it is possible to download the current certificate (***Download Certificate***), but in no case the private key.

- Once the files have been uploaded, it is necessary to apply the changes to the device (press the ***Apply*** button) so that the new certificate and/or private key files take effect.

F.7.2 Devices with Enhanced Cybersecurity

In devices with enhanced cybersecurity, the PKI consists not only of a certificate and a public key, but also of a series of additional files (list of CAs, list of CRLs, authorization policy file) that allow the device both to perform secure communications with mutual authentication capability and to check the correct securization of the firmware.

A device with enhanced cybersecurity capability can be manufactured without such enhanced cybersecurity in terms of PKI at the request of a customer who does not wish to include the features described below. In this case, in terms of credential management, it will behave as described in the previous **Devices with Basic Cybersecurity** section.

The files that make up the PKI are the following:

- Master password:
  Used to encrypt certain sensitive information (private key/certificate) when it is sent to the device for updating. The sensitive information is encrypted inside the device using an own password of the device with AES 256 CBC algorithm.
  When you want to update this password in the device, the file sent with the new master password must be encrypted AES 256 CBC with the current master password.

- Certificate / Private key:
  This is the private key and certificate similar to those explained in the previous section (**Devices with Basic Cybersecurity**). In this case they are not self-generated and the certificate is not self-signed, different ones are installed for each device during the manufacturing process and the certificate is signed by the ZIV CA and is valid for 20 years. The key is 4096-bit RSA.
  When you want to update the device, either only the certificate or both, certificate and private key, you must use a PKCS#12 file whose key is the current master password of the device.

- List of Certification Authorities (CAs):
  This is a file containing all the root certificates that will be used to verify both the remote certificates in the case of TLS mutual authentication (verifying that they are signed by one of the CAs on the list), and the signatures of the firmware as explained in the **Digital Firmware Securization** section. The file format is PEM and contains a concatenation of all the possible CAs managed by the device, both for communications and for firmware signature verification.

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- Certificate Revocation List (CRLs):
  This is a file containing all the certificate revocation lists (CRLs) associated with all the CAs of the device, which are going to be used to verify the revocation of remote certificates in the case of TLS mutual authentication, as well as of the firmware signatures. The file format is PEM and contains a concatenation of all possible CRLs managed by the device.

- Authorization policy file:
  This is a file that includes a set of policies that allow checking additional parameters of the remote certificates in the case of TLS mutual authentication, as well as the signatures of the firmware.
  Of course, the validity of the certificates must first be checked: signing by CAs, revocation and expiration. Then these additional rules (policies) are checked. Each policy affects one service (firmware signature verification, PROCOME communications, HTTPS communications) and you can select whether any or all certificates must comply with these rules. The rules are specified per certificate and can include the certificate fingerprint (of the subject and/or issuer), the CN attribute (of the subject and/or issuer) and/or the OU attribute (of the subject and/or issuer).
  The file format is XML and is as follows:

Node	Description	Child nodes	Attributes
AuthPolicy	Root node.	**Policy** (only one)	-
Policy	Authorization policy.	**Certificate** (several)	**effect**: indicates the service to which the policy applies. Possible values are: - **allow-signature-verify**: firmware signature verification service. After verification that the firmware is signed by the certificate(s) and that the certificate(s) is (are) signed by a CA from the list of CAs of the device and is (are) neither expired nor revoked, the certificate(s) must comply with the rules of this policy for the firmware signing process to be valid for the device. - **allow-procome-connection**: PROCOME TLS communications service. After verifying that the remote certificate is signed by a CA from the list of CAs of the device and that it is neither expired nor revoked, the remote certificate must comply with the rules of this policy for the PROCOME TLS connection to be accepted by the device. - **allow-https-connection**: HTTPS communications service. Identical operation to **allow-procome-connection**, but for HTTPS communication.

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Node	Description	Child nodes	Attributes
Policy	Authorization policy.	**Certificate** (several)	**condition**: indicates whether the policy affects all certificates or only some of them. The possible values are: - **allow-if-any-certificate-matches**: the policy will be successful if any of the certificates used complies with the certificate rules included in the policy. - **allow-if-all-certificates-match**: the policy will be successful if all certificates used comply with the certificate rules included in the policy. - **allow-always**: only for TLS communication, it is used when you do not want to use mutual authentication despite having configured the list of CAs and CRLs in the device. This option allows you to disable mutual authentication by service (PROCOME or HTTPS). This value is ignored for firmware signature verification.
Certificate	Rules to check for a certificate.	**Thumbprint**, **CN**, **OU** (up to 2 of each)	-
Thumbprint	Fingerprint of the certificate. The fingerprint (SHA256) of the certificate to be checked (**from**="subject") or of the certificate signing the certificate to be checked (**from**="issuer") must match this attribute for the rule to be successful.	-	**from**: indicates whether the rule (Thumbprint) is to be checked for the subject or issuer of the certificate.
CN	CN attribute of the certificate. The CN attribute of the subject (**from**="subject") or issuer (**from**="issuer") of the certificate to be checked must contain this attribute (case sensitive) for the rule to be successful.	-	**from**: indicates whether the rule (CN) is to be checked for the subject or the issuer of the certificate.
OU	OU attribute of the certificate. The OU attribute of the subject (**from**="subject") or issuer (**from**="issuer") of the certificate to be checked must contain this attribute (case sensitive) for the rule to be successful.	-	**from**: indicates whether the rule (OU) is to be checked for the subject or the issuer of the certificate.

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An example of the file is as follows:

```
<?xml version="1.0" encoding="utf-8"?>
 <AuthPolicy>
  <Policy effect="allow-signature-verify" condition="allow-if-all-
  certificates-match">
   <Certificate>
   <Thumbprint
   from="issuer">3500c3951b03ef20e4954575705fe50b9b0b69ee32e46b72ab0f5a1b170
   42010</Thumbprint>
   <CN from="subject">ziv-firmware-signing</CN>
   <OU from="subject">ZIV</OU>
   </Certificate>
  </Policy>
  <Policy effect="allow-https-connection" condition="allow-if-any-
  certificate-matches">
   <Certificate>
   <CN from="issuer">ziv-ca</CN>
   </Certificate>
  </Policy>
  <Policy effect="allow-procome-connection" condition="allow-always">
  </Policy>
 </AuthPolicy>
```

Credentials management must be performed by a user with *user management* permission and is done using the ***ZIV e-NET Tool***® configuration tool.

To manage the credentials of the device from the ***ZIV e-NET Tool***® it is necessary that some of the LAN ports and the SSH and SFTP services are enabled.

This is accessed from the ***Tools→Device access*** menu.

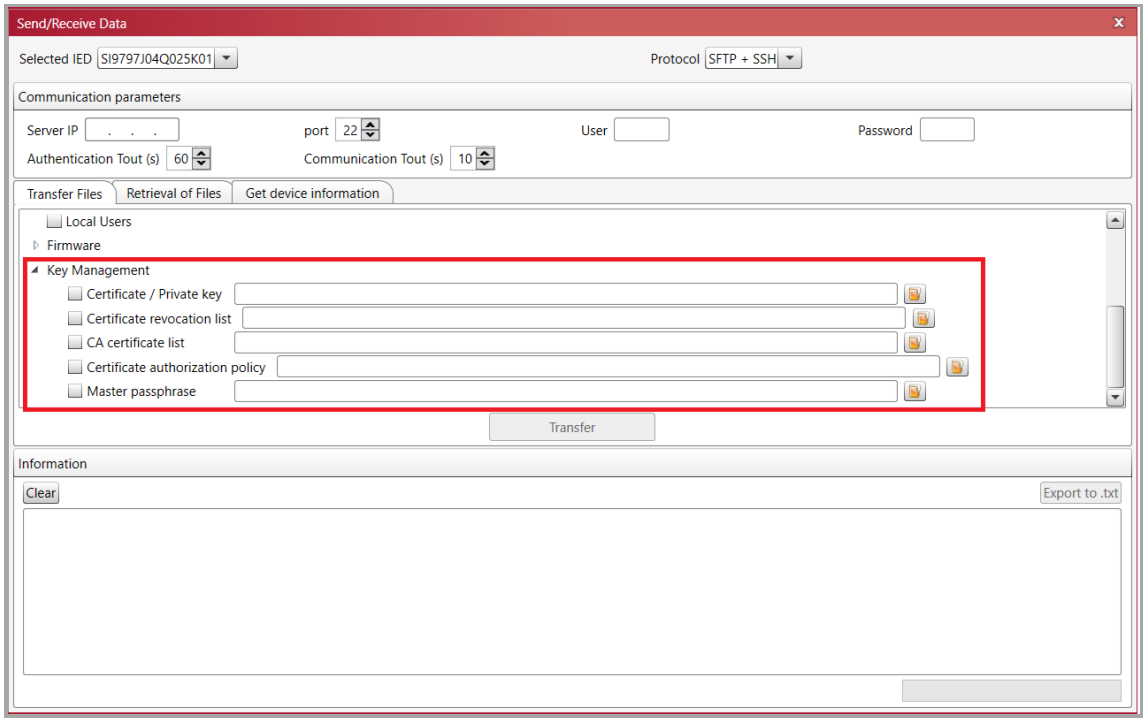


Figure F.35 Sending of PKI Files with Configuration Tool.

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In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (username and password). In the ***Transfer Files*** tab, under the ***Key Management*** option, there are several options for sending the different PKI files available on the device:

- ***Certificate / Private key***: Option to upload a certificate or a certificate + private key to the device. A file in PKCS#12 format must be used whose key is the current master password of the device. If it contains only the certificate, it must be paired with the current private key of the device.
- ***Certificate revocation list***: Option to upload a certificate revocation list (CRLs). A file in PEM format must be used and must contain a concatenation of all possible CRLs managed by the device. It cannot be empty; it must contain at least one CRL.
- ***CA certificate list***: Option to upload a list of CA certificates to the device. A file in PEM format must be used and it must contain a concatenation of all the possible CAs managed by the device, both for communications and for firmware signature verification. It cannot be empty; it must contain at least one CA and the CAs cannot be revoked or expired.
- ***Certificate authorization policy***: Option to upload an authorization policy file to the device. The XML format file explained above must be used.
- ***Master passphrase***: Option to upload a new master password to the device. A file must be used in which the new master password is encrypted AES 256 CBC with the current master password of the device.

To select the PKI file to be sent, press the button  on the right. After selecting the desired option (only one option must be selected at a time), the ***Transfer*** button is used to upload the PKI file to the device. The upload progress is displayed in the ***Information*** window. If the PKI file is successfully uploaded to the device, the **Security credentials changed successfully** cybersecurity event is generated. However, if any error occurs in the validation of the PKI file by the device, the **Security credentials change failed** cybersecurity event is generated.

When a list of CAs is sent to the device, it checks that, for each CA present in the list, its associated CRL is present in the device. If not, the device rejects the list of CAs.

When a list of CRLs is sent to the device, the device checks that, for each CA present in the device, its associated CRL is present in the list. If not, the device rejects the list of CRLs.

That is, in the device, for each CA, there must be its associated CRL (only one CRL for each CA) and other additional CRLs may also be present.

Therefore, when you want to add one or more CA+CRLs to the device, you must first send the list of CRLs and then the list of CAs; and when you want to remove one or more CA+CRLs from the device, you must first send the list of CAs and then the list of CRLs.

To retrieve the PKI files from the device, access the menu ***Tools→Device access***. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (user and password). In the ***Retrieval of Files*** tab, under the ***Key Management*** option, there are several options to collect the different PKI files available from the device:

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- ***Certificate***: Option to download the certificate of the device in PEM format.
- ***Certificate revocation list***: Option to download the Certificate Revocation List (CRLs) of the device in PEM format.
- ***CA certificate list***: Option to download the CA certificate list of the device in PEM format.
- ***Certificate authorization policy***: Option to download the authorization policy file of the device in XML format.

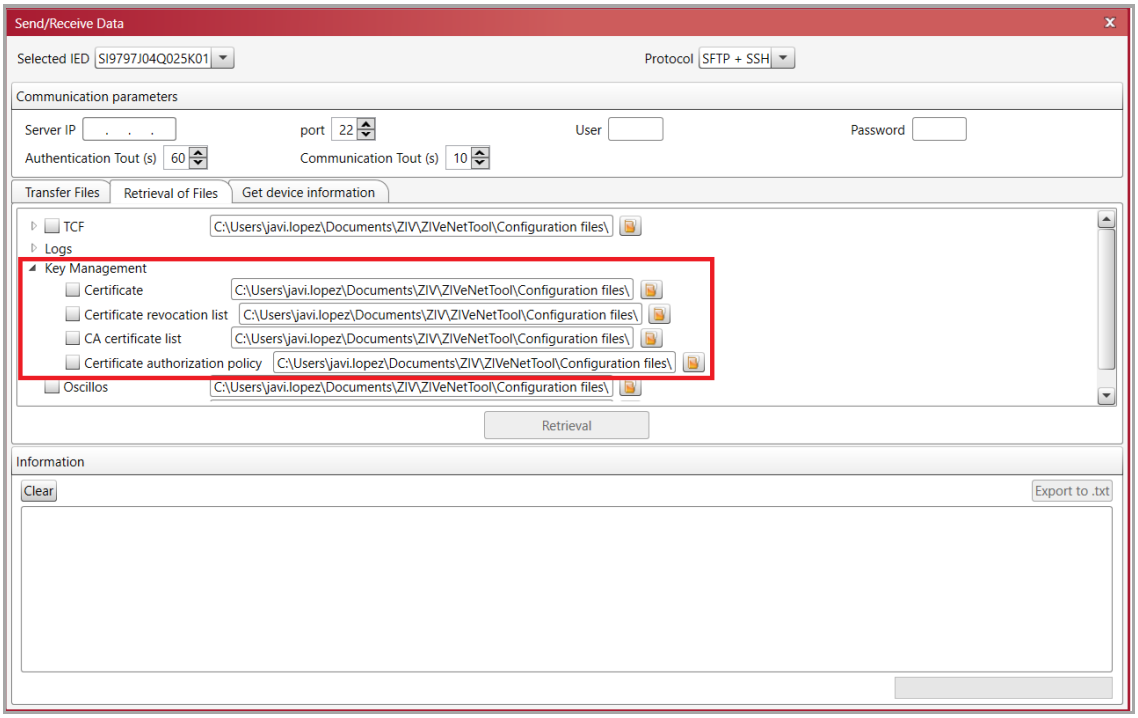


Figure F.36 Retrieval of PKI files with configuration tool.

To select the destination directory for each PKI file, click the button on the right. After selecting the desired options, click on the ***Retrieval*** button to download the PKI files from the selected device. The download progress is displayed in the ***Information*** window.

F.8 Digital Firmware Securization

In the world of cybersecurity and due to its continuous evolution, it is very common that certain security measures become insecure over time, security gaps are discovered in software components and it is necessary to update the firmware of the devices to eliminate such security gaps.

Firmware upload is one of the most critical processes for devices. It is vital to ensure that the firmware uploaded to the device is valid and has not been altered or modified by third parties.

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F.8.1 Devices with Basic Cybersecurity

For devices with basic cybersecurity, firmware securization consists of including a hash of the firmware and performing encryption using fixed criteria known by manufacturer and devices, which provides confidentiality and integrity.

When new firmware is uploaded to the device (via website), the device decrypts the firmware, checks the hash, performs additional internal checks to ensure that the firmware structure is valid, and only then restarts to take the new firmware, generating the **Firmware uploaded successfully** cybersecurity event. If something fails in the validation process of the new firmware, the device remains with the firmware it had uploaded before the failed update, generating the **Firmware upload failed - Invalid firmware** cybersecurity event.

F.8.2 Devices with Enhanced Cybersecurity

In devices with enhanced cybersecurity, firmware securization is more sophisticated. The firmware of the devices is digitally encrypted, which provides confidentiality. In addition, the encrypted firmware is signed based on X.509 certificates using CMS/PKCS#7 DER format, allowing multiple signatures (in addition to the original signature by ZIV), which provides integrity.

Signatures may be associated with a set of metadata (manifest), encoded as signed attributes of the CMS/PKCS#7 signature (*signedAttributes*). In general, this manifest will have a common structure that includes generic information about the manifest and a particular structure for each type of manifest. Specifically, for the ZIV signature, the following signed attributes have been defined to include firmware related information. For each one, the internal name, its ***OID*** (identifier) and its meaning are indicated:

- *manifestInformation* (***1.3.6.1.4.1.15732.8191.1***): general information about the manifest. It includes the following sequential information (SEQUENCE):
  - *class*: is an enumerated (ENUMERATED) indicating the type of manifest. At the moment it only takes the value 0 (firmware). In the future it may take other values for possible client signatures.
  - *version*: is an integer (INTEGER) indicating the version of the manifest. At the moment it only takes the value 1.
  - *owner*: a text string (VISIBLE STRING) from 0 to 256 characters indicating the owner of the manifest. The value is ZIV.
  - *copyright*: in a text string (VISIBLE STRING) from 0 to 256 characters indicating the manifest copyright. The value is ZIV.

- *basicFirmwareInformation* (***1.3.6.1.4.1.15732.8191.2.1***): basic firmware information. It includes the following sequential information (SEQUENCE):
  - *version*: in a text string (VISIBLE STRING) from 1 to 64 characters indicating the full firmware version, e.g., 0.10.0-0C03-02.
  - *description*: is a text string (VISIBLE STRING) from 0 to 512 characters indicating the following information:
    - A first text string **Firmware** indicating that it corresponds to the complete firmware of the device (at the moment the device firmware is atomic, it is uploaded in full). In the future it may contain other words to indicate that it is a security patch or a specific part of the firmware.
    - The character | to separate both text strings.

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  - A second text string indicating the complete firmware model, including hardware and software parts, e.g., **IRFA-mA14mA00000000x0xX-2032070**.

  Example: **Firmware|IRFA-mA14mA00000000x0xX-2032070**.
- *supportedModels*: this is a sequence (SEQUENCE) of text strings (VISIBLE STRING) from 1 to 256 characters indicating the list of hardware models for which the signed firmware is valid. Examples: **IRFA-1A140A00000000XXXX**, **IRFA-1A142A00000000XXXX**, **IRFA-1A143A00000000XXXX**, **IRFA-1A146A00000000XXXX**, **IRFA-1A147A00000000XXXX**, **IRFA-2A140A00000000XXXX**, **IRFA-2A142A00000000XXXX**, **IRFA-2A143A00000000XXXX**, **IRFA-2A146A00000000XXXX**, **IRFA-2A147A00000000XXXX**.

These signed attributes can be viewed by applying a CMS/PKCS#7 viewer or analyzer to the signed firmware.

When new firmware is uploaded to the device (either via website or using the ***ZIV e-NET Tool***®), it performs the following checks on the received firmware file:

- Verify that the firmware is correctly signed by certificates that comply with the PKI of the device explained in the **Credential Management** section. The certificates of the sigantures, therefore, must be signed by CAs contained in the list of CAs of the device, must not be revoked (checked using the list of CRLs of the device) or expired and must comply with the firmware signature verification authorization policy. If any of these checks are not met, an invalid firmware message is displayed due to a signing error and the firmware upload process is aborted.
- Verify that the signed attribute information (if available, only mandatory for ZIV signing) *manifestInformation* and the particular attribute (*basicFirmwareInformation* in the case of ZIV signing) is correctly structured and valid. If it is not, an invalid firmware message is displayed due to an error in the associated information and the firmware upload process is aborted.
- Extracts the firmware version from the signed *basicFirmwareInformation* attribute. From the website you can simply upload firmware and upgrade and downgrade is always allowed. But from the ***ZIV e-NET Tool***® it is possible to upgrade and downgrade separately. In this case, the device compares the current firmware version with that of the new firmware you are trying to upload.
  - If the new version is later than the current version and the operation is a downgrade, an invalid firmware message is displayed because it is not possible to downgrade to a later version and the firmware upload process is aborted.
  - If the new version is lower than the current version and the operation is an upgrade, an invalid firmware message is displayed because it is not possible to upgrade to a previous version and the firmware upload process is aborted.
  - If the new version is the same as the previous one, both upgrade and downgrade operations are allowed.
- Checks that the new firmware is valid for the hardware model of the device, comparing that the current hardware model of the device is included in the hardware models for which the firmware is valid present in the signed *basicFirmwareInformation* attribute. If it is not valid, an invalid firmware message is displayed because the model is not supported and the firmware upload process is aborted.
- It proceeds to decrypt the firmware with a key uploaded during the device manufacturing process. If it fails to decrypt it, an invalid firmware message is displayed because of a decryption error and the firmware upload process is aborted.

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Finally, the device performs additional internal checks to ensure that the firmware structure is valid and, only then, reboots to take the new firmware, generating the **Firmware uploaded successfully** cybersecurity event. If something fails in the validation process of the new firmware (cases detailed above), the device remains with the firmware it had uploaded before the failed update, generating the **Firmware upload failed - Invalid firmware** cybersecurity event.

A device with enhanced cybersecurity capability may be manufactured without such enhanced PKI cybersecurity at the request of a customer who does not wish to include this enhanced firmware securization feature. In that case, in terms of firmware securization, it will behave as a device with basic cybersecurity and both upgrade and downgrade options of ***ZIV e-NET Tool***® will work the same, without version checking.

F.8.3 Firmware Upload Methods

In order to upload firmware, the user must have *firmware change* permission.

There are two methods to upload firmware to the device:

- Website. To upload firmware from the web interface, one of the LAN ports and the HTTP or HTTPS services must be enabled. It is recommended to use HTTPS connection instead of HTTP because the data is encrypted. Access the ***Reflash*** menu, authenticating first if necessary.

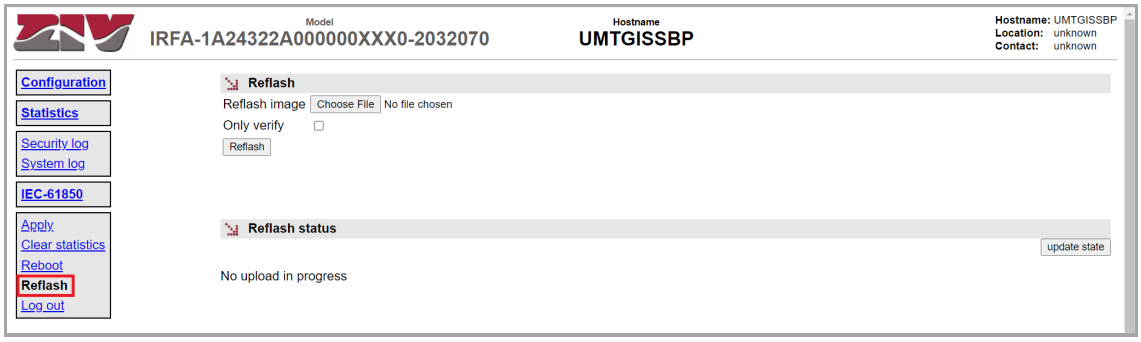


Figure F.37 Uploading Firmware via Website.

The firmware file to be uploaded to the device is selected by clicking on the ***Choose File*** button.

The ***Only verify*** option is used to validate if the firmware is valid, but without updating the device with the new firmware.

Pressing the ***Reflash*** button starts the firmware upload process to the device (or validation if ***Only verify*** is checked). The firmware upload/validation progress is displayed in the ***Reflash status*** window. This progress is refreshed periodically or can be refreshed on demand by pressing the ***update state*** button.

As indicated above, from the website it is always possible to upgrade and downgrade the firmware version, no version checking is performed.

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- Configuration tool. To upload firmware from the ***ZIV e-NET Tool***® it is necessary that some of the LAN ports and the SSH and SFTP services are enabled. This is accessed from the ***Tools→Device access*** menu.

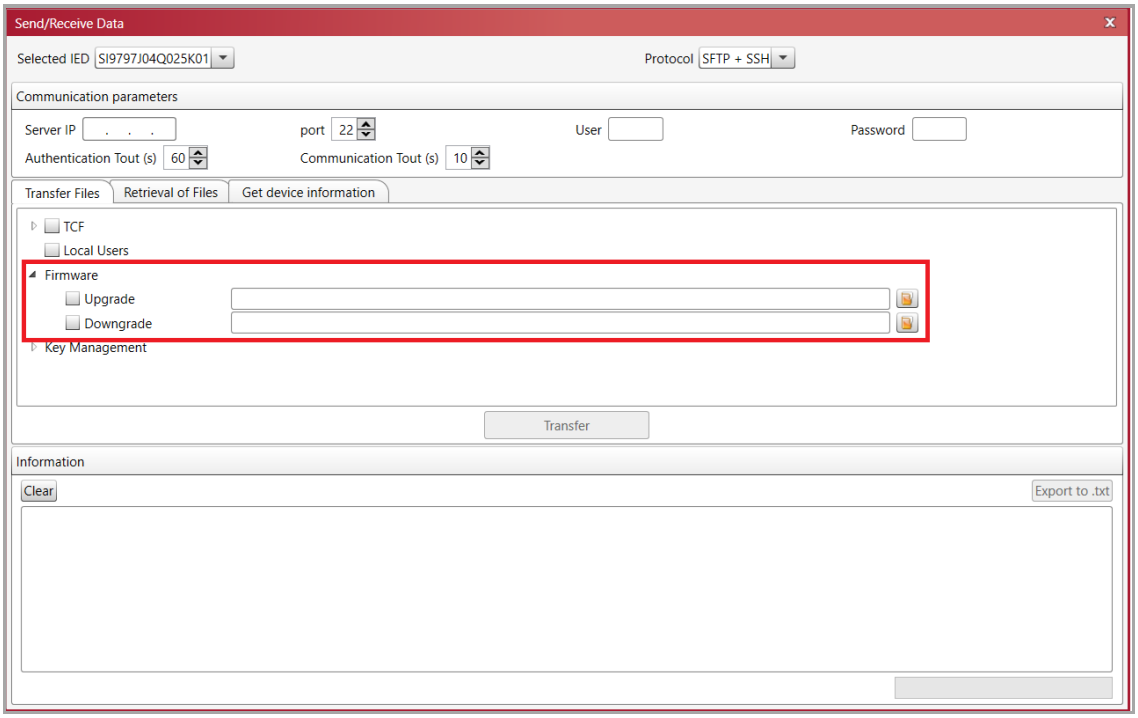


Figure F.38 Firmware Upload with Configuration Tool.

In this window it is verified that **SFTP + SSH** is selected in ***Protocol***, the device IP address and port data are configured (it must coincide with the SSH/SFTP port of the device) and the user credentials (user and password) are entered. In the ***Transfer Files*** tab, under the ***Firmware*** option, there are two options:

- ***Upgrade***. Option for uploading a firmware version equal to or higher than the current one.
- ***Downgrade***. Option to upload a firmware version equal to or lower than the current version.

In both options, the firmware file to be sent to the device must first be selected by pressing the button on the right. After selecting the desired option, the firmware is uploaded to the device by clicking on the ***Transfer*** button. The firmware upload progress is indicated in the ***Information*** window.

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F.9 Registration of Activities

One of the classic cybersecurity requirements is *non-repudiation*, which is to avoid the possibility of denying that the device performed an action or claiming that the device performed an action when it really did not. The main countermeasure to ensure *non-repudiation* is the recording of cybersecurity activities or events.

The device has a cybersecurity event log. These events, in addition to being displayed online on the website of the device and stored in a file for later collection, can be sent to a centralized cybersecurity system using the **Syslog** protocol, complying with RFC5424. This will allow the centralized system to analyze cybersecurity events instantly and detect and mitigate possible attacks, including coordinated attacks on several devices simultaneously.

F.9.1 Syslog Format

For the Syslog format of cybersecurity events and their transmission to possible Syslog servers, see Annex G, **Syslog Protocol**.

F.9.2 Events

The cybersecurity events that can be generated in the device are listed in the following table. For each event, its universal identifier (see ***EventID*** field in Annex G, **Syslog Protocol**), its severity (event or alarm), its associated text (see ***EventText*** field in Annex G, **Syslog Protocol**) and a brief description are indicated.

Id	Severity	Text	Description
***Access Control* Events**			
0000001	Event	Login successful	Successful login (authentication).
0000038	Event	Logout	Logout (manual or automatic).
0000039	Event	Login failed	Authentication failure.
0000069	Alarm	Login failed – too many user sessions	Authentication failed due to no sessions available.
0000070	Alarm	Login failed – user rejected due to role concurrency	Authentication failed because it cannot authenticate due to role concurrency.
0000071	Alarm	Logout – session closed by other user	Logout due to being expelled by a user.
0000072	Event	CLI access initiated	CLI access initiated (may be by SSH or Telnet).
0000073	Event	FTP access initiated	FTP access initiated (via SSH).

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Id	Severity	Text	Description
***User and Credential Management* Events**			
0000030	Event	User account created successfully	User created.
0000031	Event	User account modified successfully	User modified.
0000032	Event	User account deleted successfully	User deleted.
0000043	Event	Role created successfully	Role created
0000044	Event	Role modified successfully	Role modified
0000045	Event	Role deleted successfully	Role deleted
0000065	Alarm	Security credentials changed successfully	Successful change of operation PKI credentials.
0000066	Alarm	Security credentials change failed	Failed change of operation PKI credentials.
0000067	Event	LDAP repository not accessible	The LDAP remote authentication server is not available.
0000068	Event	RADIUS server not accessible	The RADIUS remote authentication server is not available.
0000111	Alarm	Default security credentials changed successfully	Successful change of default PKI credentials.
0000112	Alarm	Default security credentials change failed	Failed change of default PKI credentials.
0000113	Alarm	Security credentials restored to default due to integrity problems	An integrity error has been detected in the PKI information and certain values have been restored to their default values.
***Settings and Configuration Change* Events**			
0000012	Event	Parameters changed successfully	Change of settings. The number of settings that have been changed is indicated in parentheses.
0000015	Event	Configuration downloaded	Successful configuration download.
0000016	Event	Configuration uploaded successfully	Successful configuration upload.
0000018	Alarm	Configuration upload failed – invalid configuration	Wrong configuration upload (invalid file).
***Firmware Change* Events**			
0000020	Event	Firmware uploaded successfully	Successful firmware upload.
0000022	Alarm	Firmware upload failed – invalid firmware	Wrong firmware upload (invalid firmware).
***Device Restart* events**			
0000023	Alarm	Device reset to factory default	Device reset to factory settings.
0000024	Alarm	Manual reset	Device manually restarted.
0000025	Alarm	IED startup	Device started.

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Id	Severity	Text	Description
		***Hardware Change* Events**	
0000026	Alarm	Hardware change detected	Hardware change detected (valid model, HW compatible).
0000027	Alarm	Hardware change detected – invalid hardware	Hardware change detected (invalid model, HW incompatible).
		***Hardware/Software Error* Events**	
0000075	Alarm	Critical error - Read/write settings error	Existence of incorrect settings or loss of the value of a setting. Corresponds to alarm 0x00000001 of the device.
0000076	Alarm	Non-critical error - Local port HW error	Error when operating on the front USB communications port. Corresponds to alarm 0x00000002 of the device.
0000077	Alarm	Critical error - Protection error	Protection error, protection not operative. Corresponds to alarm 0x00000004 of the device.
0000078	Alarm	Critical error - ADC error	Error in the ADC or in the auxiliary microcontroller that receives and controls the samples. Corresponds to alarm 0x00000008 of the device.
0000079	Alarm	Critical error - Digital I/O error	Problems in the digital I/O module. Corresponds to alarm 0x00000010 of the device.
0000080	Alarm	Critical error - Flash error	Flash memory problems. Corresponds to alarm 0x00000020 of the device.
0000081	Alarm	Critical error - Internal power failure	Internal power failure. Corresponds to alarm 0x00000040 of the device.
0000082	Alarm	Non-critical error - IEC 61850 error	Problems with data files, CID attached to the SW, unknown device model, inability to choose a data model or error interpreting a previously validated CID. Corresponds to alarm 0x00000080 of the device.
0000083	Alarm	Non-critical error - Error in configuration	The error occurs if the system cannot be configured with the requested configuration. Corresponds to alarm 0x00000100 of the device.

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Hardware/Software Error Events			
0000084	Alarm	Critical error - Program error	Unexpected problems in the SW that prevent its operation. Corresponds to alarm 0x00000200 of the device.
0000085	Alarm	Non-critical error - Remote port 1 error	Remote port 1 hardware error. Corresponds to alarm 0x00000400 of the device.
0000086	Alarm	Critical error - Hardware error	Incorrect hardware configuration. The HW detected by the device does not correspond to the internal models provided by the SW. Corresponds to alarm 0x00000800 of the device.
0000087	Alarm	Critical error - Microcontroller error	Error in the communication with the auxiliary microcontroller that controls the different boards. Corresponds to alarm 0x00001000 of the device.
0000088	Alarm	Non-critical error - RTC error	Problems with RTC. Corresponds to alarm 0x00002000 of the device.
0000089	Alarm	Critical error - Transducer input error	Error in the communication with the input transducer. Corresponds to alarm 0x00004000 of the device.
0000090	Alarm	Non-critical error - Remote port 2 error	Remote port 2 hardware error. Corresponds to alarm 0x00008000 of the device.
0000091	Alarm	Critical error - External flash error	Problem in flash memory external to the CPU board. Corresponds to alarm 0x00010000 of the device.
0000092	Alarm	Critical error – 87L microcontroller error	Internal communications error between microcontrollers of the 87L communications board. Corresponds to alarm 0x00020000 of the device.
0000093	Alarm	Non-critical error – 87L communication error	Error in the communication with the 87L communications board. Corresponds to alarm 0x00040000 of the device.

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Id	Severity	Text	Description
***Communication Certificate Validation* Events**			
0000114	Alarm	Certificate validation failed – certificate expired	The certificate received by communications is expired (or not yet valid).
0000115	Alarm	Certificate validation failed – certificate revoked	The certificate received by communications is revoked.
0000116	Alarm	Certificate validation failed – certificate signature check failed	The certificate received by communications is not trusted (it has not been successfully validated against the list of CAs of the device).
0000117	Alarm	Certificate validation failed – certificate does not comply with authorization policies	The certificate received by communications does not comply with the authorization policies (it has not been successfully validated against the authorization policy file of the device).
***Ports Enabling / Disabling* Events**			
0000049	Event	Local port disabled	Local port disabled.
0000050	Event	Local port enabled	Local port enabled.
0000051	Event	Remote port 1 disabled	Remote port 1 disabled.
0000052	Event	Remote port 1 enabled	Remote port 1 enabled.
0000053	Event	Remote port 2 disabled	Remote port 2 disabled.
0000054	Event	Remote port 2 enabled	Remote port 2 enabled.
0000055	Event	LAN port 1 disabled	LAN port 1 disabled
0000056	Event	LAN port 1 enabled	LAN port 1 enabled
0000057	Event	LAN port 2 disabled	LAN port 2 disabled
0000058	Event	LAN port 2 enabled	LAN port 2 enabled
0000059	Event	LAN port 3 disabled	LAN port 3 disabled
0000060	Event	LAN port 3 enabled	LAN port 3 enabled
0000061	Event	LAN port 4 disabled	LAN port 4 disabled
0000062	Event	LAN port 4 enabled	LAN port 4 enabled
0000063	Event	USB port disabled	USB port disabled
0000064	Event	USB port enabled	USB port enabled

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Other events			
0000028	Event	Date and time set successfully	Change in device date/time > 100ms.
0000029	Event	Security events log downloaded	Cybersecurity events log downloaded.
0000041	Event	USB connected	It occurs when a USB pendrive is connected to the USB-A port.
0000042	Event	USB disconnected	It occurs when a USB pendrive is disconnected from the USB-A port.
0000074	Alarm	Unauthorized physical access detected	Detection of unauthorized physical access, for the moment, removal/insertion of hardware boards (except CPU and power supply) with the device powered up.
0000106	Event	CLI command performed “XXXX”	Indicates that the XXXX command has been successfully executed by CLI. XXXX corresponds to the complete command executed on the CLI.

F.9.3 Storage File

The device has the capacity to hold at least 2048 cybersecurity events in a circular buffer (FIFO).

The events are stored in a FLASH file, so that they are not lost in the event of a shutdown.

The size of the file is 256 kB, and the number of events it can hold will depend on the text occupied by each event with its additional information, but always greater than 2048 events.

The file is called */audit/security.log* and cannot be modified or deleted in any way.

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F.9.4 Viewing and Downloading the File

Only a user with *audit log* permission can view the cybersecurity events and/or download the file.

There are several ways to access the cybersecurity event file (*security.log*):

- By FTP or SFTP file transfer. In this case the file location is */audit/security.log*.
- From the website, ***Security log*** menu. The events are displayed directly on the web page in order of occurrence. In addition, the file can be downloaded by clicking the ***Download File*** button.

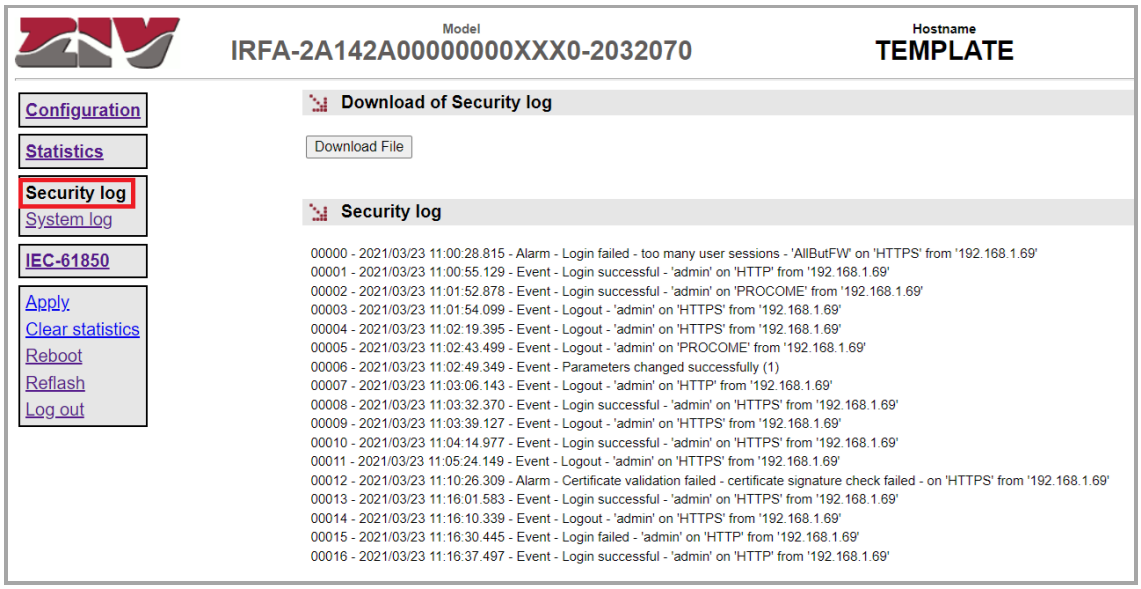


Figure F.39 Display of Cybersecurity Events on Website.

- Using the ***ZIV e-NET Tool***® configuration tool. To collect cybersecurity events using the ***ZIV e-NET Tool***®, access the ***Tools→Device access*** menu. In this window, check that **SFTP + SSH** is selected in ***Protocol***, configure the device IP address and port data (it must match the SSH/SFTP port of the device) and enter the user credentials (username and password). In the ***Retrieval of Files*** tab, check the ***Logs→Security Events*** option and click ***Retrieval*** to download the cybersecurity events file. The download progress is displayed in the ***Information*** window.

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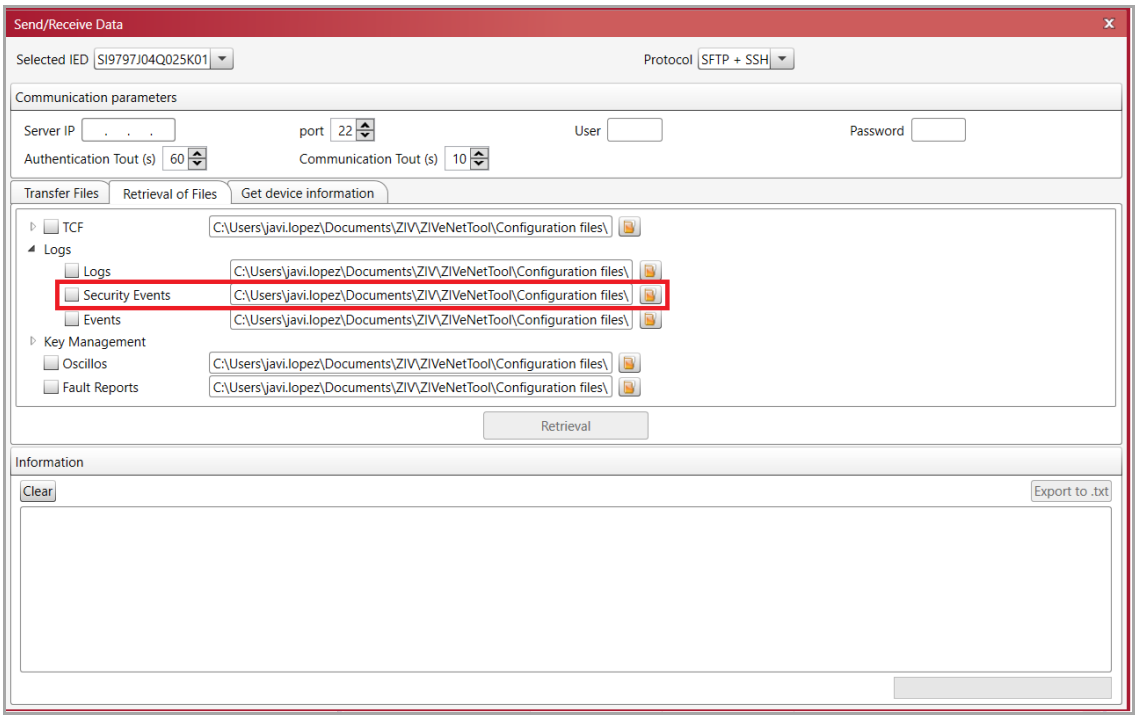


Figure F.40 Collection of Cybersecurity Events with Configuration Tool.

Each time the cybersecurity event file is downloaded from the device, the **Security events log downloaded** cybersecurity event is generated.

Cybersecurity events are displayed on the website and stored in the file *security.log* with the following format:

YYYY/MM/DD hh:mm:ss.mmm - eveala - evtext - 'user' on 'service' from 'ipaddr' (interface)

where:

- ***YYYY/MM/DD hh:mm:ss.mmm***: it is the date and time of the event (up to milliseconds). Corresponds to the TIMESTAMP field of the Syslog HEADER.
- ***eveala***: reflection of Syslog HEADER field PRI. It will be able to take the values:
  - Event (PRI=<108>)
  - Alarm (PRI=<105>)
- ***evtext***: text of the event. It is the faithful reflection of the *EventText* field of Syslog's STRUCTURED_DATA. If after ***evtext*** there is no more information to show or it is only shown (*interface*), then the hyphen (-) following ***evtext*** will not be shown. Otherwise, it will be shown.
- ***user***: username. It is the faithful reflection of the *User* field of the Syslog STRUCTURED_DATA. If the *User* field is not present or has a NILVALUE ("-") value, then the text "*user*" will not be presented in the event.
- ***service***: name of the service. It is the faithful reflection of the PROCID field of the Syslog HEADER. If the PROCID field is set to NILVALUE ("-"), then the text "*on service*" will not be presented at the event.

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- ***ipaddr***: IP address of the device causing the event. It is the faithful reflection of the *PeerIpAddress* field of the Syslog STRUCTURED_DATA. If the *PeerIpAddress* field is not present or is set to NILVALUE ("-"), then the text "*from ipaddr*" will not be presented in the event.
- ***interface***: physical interface through which the event occurred. It is the faithful reflection of the *Interface* field of the Syslog STRUCTURED_DATA. If the *Interface* field is not present or is set to NILVALUE ("-"), then the text "(*interface*)" will not be presented in the event.

The following are examples of event format in file:

- Successful authentication of user "admin" by SSH from IP=192.168.1.69 with device SI3197E1Q11F01:
  `2016-04-17 22:36:41.358 - Event - Login successful - 'admin' on 'SSH' from '192.168.1.69'`

- Starting up of device TEMPLATE:
  `2016-04-171:24:32.498 - Alarm - IED startup`

- Logout of user "Ramon.Perez" by HMI in the device SWT650:
  `2016-04-17 23:35:49.423 - Event - Logout - 'Ramon.Perez' (HMI)`

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G.1 General

Due to its simplicity and wide acceptance and use, the format chosen for sending events is Syslog. Throughout the evolution of Syslog, several RFCs have been published, all with the aim of achieving greater compatibility and security between the different implementations. Of these, RFC 5424 is used, as it is widely accepted and provides all the required features.

The equipment has a cybersecurity event log. These events, in addition to being viewed online on the unit's web page and stored in a file for later collection, can be sent to a centralized cybersecurity system using the **Syslog** protocol, in compliance with RFC5424. This will allow such a centralized system to analyze cybersecurity events instantaneously and detect and mitigate possible attacks, including coordinated attacks on several devices simultaneously.

The equipment also has a Protection event record. By configuring the appropriate settings, as explained in the chapter Event Record, the user can configure protection events to be stored in a second log called **SYSLOGSOE**. All events stored in this log are automatically sent through the Syslog protocol.

The following acronyms and structures will be used throughout this Annex:

UTF-8-STRING	= *OCTET (UTF-8 string as specified in RFC 3629).
OCTET	= Characters from %d00 to %d255.
SP	= Blank space (%d32), used as field separator.
PRINTUSASCII	= Characters from %d33 to %d126.
NONZERO-DIGIT	= Characters from %d49 to %d57.
DIGIT	= Character %d48 + NONZERO-DIGIT.
NILVALUE	= “-“

The structure of a Syslog event is as follows:

HEADER SP **STRUCTURED-DATA** [SP **MSG**]

The **HEADER** field has the following structure:

HEADER = PRI VERSION SP TIMESTAMP SP HOSTNAME SP APP-NAME SP PROCID SP MSGID

The **STRUCTURED-DATA** field has the following structure

STRUCTURED-DATA	= 1 * SD-ELEMENT
SD-ELEMENT	= "[" SD-ID *(SP SD-PARAM) "]"
SD-ID	= SD-NAME
SD-PARAM	= PARAM-NAME "=" %d34 PARAM-VALUE %d34
PARAM-NAME	= SD-NAME
PARAM-VALUE	= UTF-8-STRING; the characters ‘”’ (double quotation mark: %d34)’, ’\’ (%d92) and ’]’ (close bracket: %d93) must be escaped using the character ’\’ (%d92).
SD-NAME	= 1*32 PRINTUSASCII, except for the characters ’=’ (equals: %d61), ’ ‘ (blank space: %d32), ’]’ (close bracket: %d93) and ‘”’ (double quotation mark: %d34).

The details of the different fields are explained below for cybersecurity and protection events (SOE).

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G.2 Syslog Format for Cybersecurity Events

This format is used by models with Basic Cybersecurity (see Model Selection chapter, digit 26 of Firmware Model Selection with value 1). The rest of models will use the format detailed in the next section.

For cybersecurity events, the MSG field is not used and, therefore, will never be present in the generated Syslog events.

Therefore, the structure of a cybersecurity Syslog event is as follows:

HEADER SP **STRUCTURED-DATA**

G.2.1 HEADER Format

RFC 5424 Information Fields		

HEADER	***PRI***	= "<PRIVAL>"
		Priority of the event:
		The ***PRIVAL*** field (1~3 DIGIT) is calculated as follows
		PRIVAL = (8 x ***Facility***) + (***Severity***)
		- ***Facility***: The value log audit is set =13.
		- ***Severity***:
		  - Events have severity level of "Warning" = 4
		  Event → PRIVAL = 8 x 13 + 4 = *108*.
		  - Alarms have severity level of "Alert" = 1
		  Alarm → PRIVAL = 8 x 13 + 1 = *105*.

	VERSION	1
	TIMESTAMP	Date and time of the event. The format is: ***FULL-DATE "T" FULL-TIME*** ***FULL-DATE*** = ***DATE-FULLYEAR "-" DATE-MONTH "-" DATE-MDAY*** ***DATE-FULLYEAR*** = 4 DIGIT ***DATE-MONTH*** = 2 DIGIT (01-12) ***DATE-MDAY*** = 2 DIGIT (01-28, 01-29, 01-30, 01-31, depending on the month). ***FULL-TIME*** = ***PARTIAL-TIME TIME-OFFSET*** ***PARTIAL-TIME*** = ***TIME-HOUR ":" TIME-MINUTE ":" TIME-SECOND "." TIME-SECFRAC*** ***TIME-HOUR*** = 2 DIGIT (00-23) ***TIME-MINUTE*** = 2 DIGIT (00-59) ***TIME-SECOND*** = 2 DIGIT (00-59) ***TIME-SECFRAC*** = 3 DIGIT representing milliseconds 000~999 ***TIME-OFFSET***="Z" (represents the date/time in UTC). UTC format is always used. Example: 2016-04-17T22:36:41.358Z

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RFC 5424 Information Fields		
	HOSTNAME	Own IP (global or in service origin). Since the IED can have several IP addresses, the value of the HOSTNAME takes the value NIL = "-".
	APP-NAME	Name of the device where the event occurred (equipment name). When the equipment has IEC 61850, the name of the equipment obtained from the CID configuration file will be assigned. Otherwise, it can be modified from the website and from CLI.
	PROCID	Identifier of the service through which the event occurred. Text string with the following possible values: "HTTP", "HTTPS", "FTP", "Telnet", "SSH", "MMS" y "PROCOME".
	MSGID	Takes the fixed value "ZIV".

G.2.2 STRUCTURED-DATA Format

RFC 5424 Information Fields		
STRUCTURED-DATA (SD)	***SD-ID***	OID corresponding to the SMII Network management Private Enterprise Code: EventData@1.3.6.1.4.1.15732
	SOE	Event Sequence Counter. It is a sequential number, which is incremented with each cybersecurity event that occurs. It is a 32-bit unsigned integer. Therefore, possible values range from 0 to 4294967295. It is encoded with a text string of up to 10 characters. It is used to order events according to their occurrence, as the date/time could be altered.
	EventId	Universal identifier that identifies the event in a unique way. It is a text string of 7 characters. See column ***Id*** of the table in the ***Registration of Activities→Events*** section of the Cybersecurity Annex.
	EventText	Descriptive text of the event. It is a text string of up to 127 characters. See column ***Text*** of the table in the ***Registration of Activities→Events*** section of the Cybersecurity Annex.
	User	Identifier of the user who caused the event. Text string of up to 256 characters with the username that generated the event.
	Interface	A text string of up to 32 characters that identifies the physical interface through which the event occurred. This field is available for *access control* type events generated on interfaces other than LAN. Possible values are: "HMI", "LocalPort", "RemotePort1" and "RemotePort2". It is also available with the value "USB" in USB host port enable and disable events.
	PeerIpAddress	A text string of up to 39 characters that identifies the IP address (IP4 or IP6) of the machine that accessed the equipment and caused the event.

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G.2.3 Examples

Several examples of cybersecurity events in Syslog format are included below:

- Successful authentication of user "admin" by SSH from IP=192.168.1.69 with device SI3197E1Q11F01:

```
<108>1 2016-04-17T22:36:41.358Z - SI3197E1Q11F01 SSH
[EventData@1.3.6.1.4.1.15732 SOE=”131” EventId=”0000001”
EventText=”Login successful” User=”admin”
PeerIpAddress=”192.168.1.69”]
```

- Starting the device TEMPLATE:

```
<105>1 2016-04-17T21:24:32.498Z - TEMPLATE –
[EventData@1.3.6.1.4.1.15732 SOE=”128” EventId=”0000025”
EventText=”IED startup”]
```

- Logout of user "Ramon.Perez" by HMI on the device SWT650:

```
<108>1 2016-04-17T23:35:49.423Z - SWT650 –
[EventData@1.3.6.1.4.1.15732 SOE=”132” EventId=”0000038”
EventText=”Logout” User=”Ramon.Perez” Interface=”HMI”]
```


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G.3 Syslog Format for Cybersecurity Events (version 2)

For cybersecurity events, the MSG field is not used and, therefore, will never be present in the generated Syslog events.

Therefore, the structure of a cybersecurity Syslog event is as follows:

HEADER SP **STRUCTURED-DATA**

G.3.1 HEADER Format

RFC 5424 Information Fields		

HEADER	***PRI***	= "<PRIVAL>"
		Priority of the event:
		The ***PRIVAL*** field (1~3 DIGIT) is calculated as follows
		PRIVAL = (8 x ***Facility***) + (***Severity***)
		- ***Facility***: The value log audit is set =13.
		- ***Severity***:
		  - Events have severity level of "Warning" = 4
		  Event → PRIVAL = 8 x 13 + 4 = *108*.
		  - Alarms have severity level of "Alert" = 1
		  Alarm → PRIVAL = 8 x 13 + 1 = *105*.

	VERSION	1
	TIMESTAMP	Date and time of the event. The format is: ***FULL-DATE "T" FULL-TIME*** ***FULL-DATE*** = ***DATE-FULLYEAR "-" DATE-MONTH "-" DATE-MDAY*** ***DATE-FULLYEAR*** = 4 DIGIT ***DATE-MONTH*** = 2 DIGIT (01-12) ***DATE-MDAY*** = 2 DIGIT (01-28, 01-29, 01-30, 01-31, depending on the month). ***FULL-TIME*** = ***PARTIAL-TIME TIME-OFFSET*** ***PARTIAL-TIME*** = ***TIME-HOUR ":" TIME-MINUTE ":" TIME-SECOND "." TIME-SECFRAC*** ***TIME-HOUR*** = 2 DIGIT (00-23) ***TIME-MINUTE*** = 2 DIGIT (00-59) ***TIME-SECOND*** = 2 DIGIT (00-59) ***TIME-SECFRAC*** = 3 DIGIT representing milliseconds 000~999 ***TIME-OFFSET***="Z" (represents the date/time in UTC). UTC format is always used. Example: 2016-04-17T22:36:41.358Z

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RFC 5424 Information Fields		
	HOSTNAME	Own IP (global or in service origin). Since the equipment can have several IP addresses, the value of the HOSTNAME takes the value of the IP address of the first enabled LAN port, following the order LAN 1, LAN 2, LAN 3 and LAN 4.
	APP-NAME	Name of the device where the event occurred (equipment name). When the equipment has IEC 61850, the name of the equipment obtained from the CID configuration file will be assigned. Otherwise, it can be modified from the website and from CLI.
	PROCID	It takes the value NIL = "-", as stated in IEC 62351-14 standard.
	MSGID	It takes the value "IEC62351-14:1", as stated in IEC 62351-14 standard.

G.3.2 STRUCTURED-DATA Format

RFC 5424 Information Fields		
STRUCTURED-DATA (SD)	***SD-ID***	It takes the value "62351-14@41912", as stated in IEC 62351-14 standard.
	SOE	Event Sequence Counter. It is a sequential number, which is incremented with each cybersecurity event that occurs. It is a 32-bit unsigned integer. Therefore, possible values range from 0 to 4294967295. It is encoded with a text string of up to 10 characters. It is used to order events according to their occurrence, as the date/time could be altered.
	ID	Universal identifier that identifies the event in a unique way. It is a text string of 7 characters. See column ***Id*** of the table in the ***Registration of Activities→Events*** section of the Cybersecurity Annex.
	Text	Descriptive text of the event. It is a text string of up to 127 characters. See column ***Text*** of the table in the ***Registration of Activities→Events*** section of the Cybersecurity Annex.
	UsrID	Identifier of the user who caused the event. Text string of up to 256 characters with the username that generated the event.
	PeerInfo	A text string of up to 39 characters that identifies the IP address (IP4 or IP6) of the machine that accessed the equipment and caused the event.
	Param(0)	Identifier of the service through which the event occurred. HMI and USB are considered as possible services. Text string with the following possible values: "LDAP", "HTTP", "HTTPS", "FTP", "Telnet", "SSH", "MMS", "PROCOME", "HMI" and "USB".
	Param(1)	A text string of up to 32 characters that identifies the physical interface through which the event occurred. This field is available for access control type events generated on interfaces other than LAN. Possible values are: "LocalPort", "RemotePort1" and "RemotePort2".

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G.3.3 Examples

Several examples of cybersecurity events in Syslog format are included below:

- Successful authentication of user "admin" by SSH from IP=192.168.1.69 with device SI3197E1Q11F01 with IP=192.168.1.81:

```
<108>1 2016-04-17T22:36:41.358Z 192.168.1.81 SI3197E1Q11F01 - IEC62351-
14:1 [62351-14@41912 ID="0000001" Text="Login successful" SOE="131"
UsrID="admin" PeerInfo="192.168.1.69" Param(0)="SSH"]
```

- Starting the device TEMPLATE with IP=192.168.2.81:

```
<105>1 2016-04-17T21:24:32.498Z 192.168.2.81 TEMPLATE - IEC62351-14:1
[62351-14@41912 ID="0000025" Text="IED startup" SOE="128"]
```

- Logout of user "Ramon.Perez" by HMI on the device SWT650 with IP=192.168.3.81:

```
<108>1 2016-04-17T23:35:49.423Z 192.168.3.81 SWT650 - IEC62351-14:1
[62351-14@41912 ID="0000038" Text="Logout" SOE="132" UsrID="Ramon.Perez"
Param(0)="HMI"]
```

- Failed authentication of user "secadm" by PROCOME using Local Port on the device IED_TEST with IP=192.168.4.81:

```
<108>1 2016-04-17T14:29:36.187Z 192.168.4.81 IED_TEST - IEC62351-14:1
[62351-14@41912 ID="0000039" Text="Login failed" SOE="189" UsrID="secadm"
Param(0)="PROCOME" Param(1)="LocalPort"]
```


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G.4 Syslog Format for Protection Events (SOE)

The structure of a Syslog protection event (SOE) is as follows:

HEADER SP **STRUCTURED-DATA** SP **MSG**

G.4.1 HEADER Format

RFC 5424 Information Fields		
HEADER	***PRI***	= "<PRIVAL>" Event priority: PRIVAL = (8 x ***Facility***) + (***Severity***) ***Facility***: 13 log audit 16 local use 0 (local0) 17 local use 1 (local1) 18 local use 2 (local2) ***Severity***: 2 Critical: critical conditions 4 Warning: warning conditions 6 Informational: informational messages 7 Debug: debug-level messages
	VERSION	1
	TIMESTAMP	Date and time of event. The format is: ***FULL-DATE "T" FULL-TIME*** ***FULL-DATE*** = ***DATE-FULLYEAR "-" DATE-MONTH "-" DATE-MDAY*** ***DATE-FULLYEAR*** = 4 DIGIT ***DATE-MONTH*** = 2 DIGIT (01-12) ***DATE-MDAY*** = 2 DIGIT (01-28, 01-29, 01-30, 01-31, depending on the month) ***FULL-TIME*** = ***PARTIAL-TIME TIME-OFFSET*** ***PARTIAL-TIME*** = ***TIME-HOUR ":" TIME-MINUTE ":" TIME-SECOND "." TIME-SECFRAC*** ***TIME-HOUR*** = 2 DIGIT (00-23) ***TIME-MINUTE*** = 2 DIGIT (00-59) ***TIME-SECOND*** = 2 DIGIT (00-59) ***TIME-SECFRAC*** = 3 DIGIT representing ms 000~999 (000 when not in use) ***TIME-OFFSET***="Z" (represents the date/time in UTC). UTC format is always used. Example: 2016-04-17T22:36:41.358Z
	HOSTNAME	Own IP (global or in service origin). Since the equipment can have several IP addresses, the value of the HOSTNAME takes the value of the IP address of the first enabled LAN port, following the order LAN 1, LAN 2, LAN 3 and LAN 4.

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RFC 5424 Information Fields		
	APP-NAME	Name of the device where the event occurred (equipment name). When the equipment has IEC 61850, the name of the equipment obtained from the CID configuration file will be assigned. Otherwise, it can be modified from the website and from CLI.
	PROCID	It takes the value NIL = "-", as stated in IEC 62351-14 standard.
	MSGID	It takes the value "IEC62351-14:1", as stated in IEC 62351-14 standard.

G.4.2 STRUCTURED-DATA Format

RFC 5424 Information Fields		
STRUCTURED-DATA (SD)	***SD-ID***	It takes the value "62351-14@41912", as stated in IEC 62351-14 standard.
	SOE	Circular event sequence counter from 0 to 4294967295 (INT32U although it is really a string of 10 characters). It is used to order the events according to their occurrence, since the date/time could be altered. There is one SOE counter per facility: - SOE counter for facility 13 (log audit). - SOE counter for facility 16 (local0). - SOE counter for facility 17 (local1). - SOE counter for facility 18 (local2).
	ID	Universal identifier that identifies the event in a unique way. It is a text string of 7 characters. The range of *ID* is 0 to 9999999 (0 to 3446435 for cybersecurity events and 3446436 to 9999999 for SOE protection events). ***ID*** = (100 * *REG* + *BIT*) + *Offset_SEC_ID* - *REG* is the PROCOME registration number defined for the event. - *BIT* is the bit number of the event in the PROCOME register. - *Offset_SEC_ID* is the number following the highest *ID* defined for cybersecurity events (3446436). Example: The user event "ON RFT HV OPENING" is configured in REG=40021 BIT=23 => *ID* = (100 * 40021 + 23) + 3446436 = 7448559. This is the way the user knows the *ID* of the event he/she configures.
	Text	Descriptive text of the event, along with the value and quality of the event, all separated by the character "|" (e.g. "*Phase A Instantaneous unit 1 Trip|On|Good*"). It is a text string of up to 127 characters. This is the same text as the event log.

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G.4.3 MSG Format

MSG is the part of the message where the values of the magnitudes related to the event are shown when the event occurred. All these magnitudes are the same as those corresponding to the events in the protection event record.

[DESC1 : MAG1 UNIT1 DESC2 : MAG2 UNIT2 …. DESC12 : MAG12 UNIT12]:

RFC 5424 Information Fields		
MSG	***DESCX***	Label of the magnitude configured in *Settings\Records\Events\ Events Magnitudes\Magnitude* ***X***. The size is up to 21 characters.
	MAGX	Value of the magnitude configured in *Settings\Records\Events\ Events Magnitudes\Magnitude* ***X***. The size is 5 characters.
	UNITX	Unit of magnitude configured in *Settings\Records\Events\ Events Magnitudes\Magnitude* ***X***. The size is up to 10 characters (the longest unit description is currently 4 characters).

where ***X*** = 1..12.

G.4.4 Examples

The following is an example of a Protection event (SOE) in Syslog format:

```
<110>1 2020-04-29T12:25:35.231Z 192.168.1.81 IRF1Q11F01 - IEC62351-14:1-nocyb
[62351-14@41912 ID=”7446544” Text=”On Phase A Instantaneous unit 1
Trip|On|Good” SOE=”1234567890”]
[VA63.1VVB34VVC63.41VVG26.87VIA13.81AIB24AIC13.41AIG23.87AIGS4.75A]
```


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G.5 Syslog Format for Based on IEC 61850 Events (SOE)

The structure of a Syslog protection event (SOE) is as follows:

HEADER SP **STRUCTURED-DATA** SP **MSG**

G.5.1 HEADER Format

RFC 5424 Information Fields		
HEADER	***PRI***	= "<PRIVAL>" Event priority: PRIVAL = (8 x ***Facility***) + (***Severity***) ***Facility***: Configuration parameter *facility*. ***Severity***: Configuration parameter *severity*. E.g.: *110*.
	VERSION	It takes the value of the parameter *version.* E.g.: *1*
	TIMESTAMP	Date and time of event. The format is: ***FULL-DATE "T" FULL-TIME*** ***FULL-DATE*** = ***DATE-FULLYEAR "-" DATE-MONTH "-" DATE-MDAY*** ***DATE-FULLYEAR*** = 4 DIGIT ***DATE-MONTH*** = 2 DIGIT (01-12) ***DATE-MDAY*** = 2 DIGIT (01-28, 01-29, 01-30, 01-31, depending on the month) ***FULL-TIME*** = ***PARTIAL-TIME TIME-OFFSET*** ***PARTIAL-TIME*** = ***TIME-HOUR ":" TIME-MINUTE ":" TIME-SECOND "." TIME-SECFRAC*** ***TIME-HOUR*** = 2 DIGIT (00-23) ***TIME-MINUTE*** = 2 DIGIT (00-59) ***TIME-SECOND*** = 2 DIGIT (00-59) ***TIME-SECFRAC*** = 3 DIGIT representing ms 000~999 (000 when not in use) ***TIME-OFFSET***="Z" (represents the date/time in UTC). UTC format is always used. Example: 2016-04-17T22:36:41.358Z
	HOSTNAME	It takes the value interpreted from the configuration parameter hostname. E.g.: *192.168.1.81*
	APP-NAME	It takes the value interpreted from the configuration parameter *appName*. E.g.: *L45GISDB*
	PROCID	It takes the value NIL = "-", as stated in IEC 62351-14 standard.
	MSGID	It takes the value of the configuration parameter *msgId*. E.g.: *IEC62351-14:1-nocyb*.

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G.5.2 STRUCTURED-DATA Format

RFC 5424 Information Fields		
STRUCTURED-DATA (SD)	***SD-ID***	It takes the value of the configuration parameter *sdId*. E.g.: *62351-14@41912*.
	SOE	Circular event sequence counter from 0 to 4294967295 (INT32U although it is really a string of 10 characters). It is used to order the events according to their occurrence, since the date/time could be altered.
	ID	Universal identifier that identifies the event in a unique way. It takes the interpreted value of the configuration parameter *idSyslog*. E.g.: e8ca5212bec076cc
	Text	Descriptive text of the event. It takes the interpreted value of the configuration parameter *textSyslog* E.g.: *INT502|ED-2|BREAKER 52 CLOSED|ON|good*

G.5.3 MSG Format

MSG is the part of the message where the values of the magnitudes related to the event are shown when the event occurred. It is important to remark that the magnitudes shown in each event can be different from each other and the values of these magnitudes will be always primary values.

The field MSG will have a limit of 1000 characters. If the field is bigger than this limit, then the field will be truncated to 1000 characters.

There are different fields depending on which magnitude has been configured:

- *desc*: Description of the magnitude according to the configuration parameter *descSyslog*.
- *Val*: Value of the magnitude in primary values.
- *Unit1*: Unit of the magnitude. It will be empty if the magnitude does not have unit.
- *Ang*: Angle of the magnitude.
- *Unit2*: Unit of angles (º).

The rules to form the MSG field are the following ones:

- If the value and the angle of a magnitude have been configured, then the *desc* field will take the value of the configuration parameter *descSyslog* of the configured value (*desc=ValUnit1,AngUnit2*).
- If only the value or the angle of a magnitude has been configured, then the *desc* field will take the value of the configuration parameter *descSyslog* of the configured value or angle: (*desc=ValUnit1*) or (*desc=AngUnit2*).
- The character comma (,) is used to separate a value from its angle.
- The character blank space ( ) is used to separate magnitudes.

E.g.: The magnitudes MMXU1.A.phsA.instCVal.mag.f, MMXU1.A.phsA.instCVal.ang.f, MMXU1.PhV.phsA.instCVal.mag.f y MMXU1.PhV.phsA.instCVal.ang.f are configured, then MSG field will be as follows: IA=123.567A,90.000º VA=38.956kV,2.087º

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G.5.4 Examples

The following is an example of a Protection event (SOE) in Syslog format:

```
<110>1 2020-04-29T12:25:35.231Z 192.168.1.81 IRF1Q11F01 - IEC62351-14:1-nocyb
[62351-14@41912 ID="e8ca5212bec076cc" Text="INT502|ED-2|BREAKER 52
CLOSED|ON|good" SOE="1234567890"] VA=0.000V,0.000° VB=0.000V,0.000°
VC=0.000V,0.000° VG=0.000V,0.000° IA=0.000A,0.000° IB=0.000A,0.000°
IC=0.000A,0.000° IG=0.000A,0.000° IGS=0.000A,0.000°
```

G.6 Syslog Transmission

The device can send events via Syslog protocol to up to 3 Syslog servers.

To communicate these events in Syslog format to said servers, the UDP protocol (standard port UDP/514), as specified in RFC 5426, or the TCP protocol, as specified in RFC 6587, can be used. Regarding the TCP protocol, the octet counting framing method is used.

To connect to each of the 3 possible Syslog servers, the following settings can be modified from the configuration tool and from HMI, corresponding to the IP addresses of each server and the logical port to communicate with it:

Syslog Transmission Settings - Server 1				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
IP Address	IP Address	ddd.ddd.ddd.ddd		0.0.0.0
Port	Port	1 - 65535	1	514
Protocol	Protocol	UDP TCP		UDP

Syslog Transmission Settings - Server 2				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
IP Address	IP Address	ddd.ddd.ddd.ddd		0.0.0.0
Port	Port	1 - 65535	1	514
Protocol	Protocol	UDP TCP		UDP

Syslog Transmission Settings - Server 3				
Configuration Tool	**HMI**	**Range**	**Step**	**Default**
IP Address	IP Address	ddd.ddd.ddd.ddd		0.0.0.0
Port	Port	1 - 65535	1	514
Protocol	Protocol	UDP TCP		UDP

Sending events to a server can be disabled by setting the IP address of the Syslog server to 0.0.0.0. The Syslog client can also be deactivated by disabling the Syslog service, as described in the section **Ports and Communication Services** in the Cybersecurity Annex.

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