2IRX

Integrated Protection, Control and Metering IED

Instructions Manual for **2IRX** Models
M2IRXA1910Iv05

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Chapter 1.

Description and Start-Up

1.1 Functions

The IED generically called **IRX** integrates protection, control and metering functions for a great variety of applications, such as feeders, machine lines, frontier points, etc. These IEDs use the most advanced digital technology based on a potent microprocessor and DSPs that incorporate Directional and Non-Directional Overcurrent Protection, Overvoltage, Undervoltage, Over/Underfrequency, Synchronism, Power Inversion, Thermal Image, Recloser function and others.

IRX systems are designed for medium voltage lines, transformers, generators and feeders in general where a protection, control and measurement device is required.

This instruction manual refers to different models whose particular features are stated on paragraph 1.5, Model Selection.

1.1.1 Phase and Ground Overcurrent Protection (3x50/51 + 50N/51N)

Depending on the model, there are four overcurrent measuring units (three phase and one ground unit). Each unit contains three time and three instantaneous elements with an additional adjustable timer.

The time units have a wide range of selectable time-current curves according to IEC and IEEE/ANSI standards: Fixed Time, Moderately Inverse, Inverse, Very Inverse, Extremely Inverse, Long-Time Inverse, Short-Time Inverse, RI Inverse, as well as any of them configured with a Time Limit, and one User-Defined Curve.

When time elements have been configured to operate in accordance with an inverse curve, one can select whether this should be instantaneously reset when values registered fall below a specific threshold, or in accordance with an emulation of the disc for electromechanical relays.

These models have independent LED targets for each element for the pickup and trip of the phase and neutral time and instantaneous units. They can be directed to any logic signal.

1.1.2 Sensitive Ground Overcurrent Protection (50Ns/51Ns)

Depending on the model, there is also one Sensitive Ground metering unit made up of a time unit and an instantaneous element with an additional adjustable timer.

The characteristics of the time unit are identical to those indicated in the preceding case.

1.1.3 Negative Sequence Overcurrent Protection (50Q/51Q)

All the models have Negative Sequence Overcurrent measuring units. These units are made up of three time and three instantaneous elements with an additional adjustable timer.

1.1.4 Directional Units (3x67 + 67N + 67Q + 67Ns)

Depending on the model, it is possible to set any of the previously mentioned overcurrent units as directional units.

As regards **IRX-A**, since this lacks analog voltage inputs, directionality for overcurrent elements cannot be provided. Directional sensitive ground functions are not available in model **IRX-C**.

1.1.5 Ground Overcurrent Protection Schemes (85-67N/67Q)

Depending on the model, Ground and Negative Sequence Directional Overcurrent elements can be provided with the following Protection Schemes:

- Direct Transfer Trip.
- Permissive Overreach Trip.
- Directional Comparison Blocking.

Apart from the Protection Schemes available, any other protection scheme can be configured, through the equipment programmable logic.

1.1.6 Neutral (Ungrounded / Petersen Coil) Overcurrent Protection

Model **IRX-C** counts on ground elements and an isolated neutral directional element to detect ground-faults. That unit can be also applied in systems solidly grounded through a Petersen coil; in such situations the unit behaves as a compensated ground unit.

1.1.7 Voltage Dependent Phase Overcurrent Protection (3x51V)

All the models with voltage analog inputs have three Voltage Dependent Overcurrent units (three phases) each with a definite time delay element. Operation can be set as voltage restrained units or voltage controlled units.

1.1.8 Undervoltage Units (3x27)

There are three Undervoltage Units (three phases) independently selectable as Line or Phase voltage for models with voltage analog inputs. Each consists of three instantaneous elements with an additional adjustable timer.

You can set the trip of each unit as single-phase or three-phase undervoltage. There are status contact inputs for blocking minimum voltage trip.

1.1.9 Overvoltage Units (3x59)

There are three Overvoltage Units (three phases) independently selectable as Line or Phase voltage for models with voltage analog inputs. Each consists of three instantaneous elements with an additional adjustable timer.

You can set the trip of each unit as single-phase or three-phase overvoltage. There are status contact inputs for blocking maximum voltage trip.

1.1.10 Ground Overvoltage Unit (1x59N)

Models with voltage analog inputs have one residual overvoltage metering unit which take the measurement obtained by calculating the three phase voltages available in the IED (1x59N).

This metering unit consists of two instantaneous elements with an additional adjustable timer. There are status contact inputs for blocking ground overvoltage trip.

1.1.11 Negative Sequence Overvoltage Unit (47)

There is a Negative Sequence Overvoltage metering unit with an adjustable timer for models with voltage analog inputs.

1.1.12 Underfrequency (81m), Overfrequency (81M) and Rate of Change (81D) Protection

The models with analog voltage inputs have an analog voltage input for obtaining the frequency and twelve metering units (4 Underfrequency, 4 Overfrequency and 4 Frequency Rate of Change). Each of these units contains one element with an adjustable timer. You can set it as instantaneous.

There are status contact inputs for blocking trips induced by any of these frequency units.

Underfrequency / Rate of Change and Overfrequency units 1 can be programmed to perform a load shedding and reset step. For more steps, it is necessary to use the programmable logic and configure it using the signals generated by the rest of the frequency units.

1.1.13 Breaker Failure Function (50/62BF)

All the models have a built-in (three-phase trip) Breaker Failure function, which sends trip commands to one or more other breakers.

1.1.14 Open Phase Unit (46)

All the models have an unit to detect the opening or unbalance of one or more phases. When this is detected, the unit trips and eliminates the unbalance.

It operates on a time characteristic with a fixed time adjustable timer.

1.1.15 Residual Current Detection Unit (61)

The purpose of the Residual Current Detection unit is to generate a trip as soon as it detects the circulation of zero sequence current (that does not reach the fault level) in a pre-set time interval. The circulation of this current indicates that there is an unbalance of currents in the installation.

All the models have a unit of this type. This unit operates on a time characteristic with additional adjustable timer.

1.1.16 Synchronism Check Unit (25)

In models with voltage analog inputs there is a synchronism check unit that checks various values, such as the existence of voltage in buses and bay IED and the magnitude, angle and frequency difference between the two so that the breaker can reset (internal synchronism).

Each criterion of the four mentioned can be disabled separately. The existence of synchronism for any of the possible criteria is also indicated separately. Moreover, it can be directed to the IED's configurable logic.

You can also check external synchronism. You only need to activate an external digital input of synchronism to allow the reset.

The synchronism unit can supervise both the manual resets as well as the resets given by the Recloser function.

1.1.17 Out-of-Step Element (78)

The models with voltage analog inputs have an Out-of-Step element to detect perturbations on the system and quickly disconnect the synchronous generators connected to it. This detection is based on phase A voltage passing by zero, since the half-wave in which the anomaly occurs is a different length from the preceding half-waves.

This unit operates on a time characteristic with additional adjustable timer.

1.1.18 Thermal Image Unit (49)

The IED has a Thermal Image unit that uses the current circulating through the wires to estimate their thermal status in order to trigger a trip when they have reached high temperatures.

This module is prepared to protect bay IEDs, motors and transformers from overheating according to the setting available for that purpose in the IED. You can also enable or disable it with another setting in the IED.

The unit provides an alarm or a trip independently. You can direct both to the IED's configurable logic.

1.1.19 Power Directional Unit (32P/Q)

The Models with voltage analog inputs have two Power Directional units. Both can be set to operate with active or reactive power or one for each type. When the operating angle is set other than 0º or other than a multiplier of 90º, the units will operate as Apparent Power Directional units.

Through the corresponding angle setting, it can supervise values of positive or negative active power, values of positive or negative reactive power, or a combination of the two depending on the value of the angle selected. In all cases, the units follow a time characteristic with an adjustable timer.

1.1.20 Undercurrent Protection (3x37)

All the models have three Undercurrent (three phase) metering units. They consist of a time element with an adjustable timer.

A setting in the relay allows you to select the magnitude to monitor, either the value of the positive sequence current or the value of the three phase currents.

1.1.21 Restricted Earth Fault Unit (87N)

The **IRX-B** model has a restricted earth fault unit for use with transformers. The idea is to detect faults in Grounded wye connected windings, since the value of the fault current produced can be very small depending on the impedance to ground and on the bay of the fault on the winding itself.

This unit operates on a time characteristic with an adjustable timer.

1.1.22 Cold-Load Pick-Up

All models are provided with a Cold-Load Pick-Up unit. The purpose of this function is to avoid trips when reconnecting heavy loads. This is achieved by temporarily selecting a different settings group.

1.1.23 Three-Phase Recloser (79)

The Recloser function offers the possibility of coordinating with an external protection device in addition to the IED's built-in protection. Reclosing sequences for phase and ground faults can be set independently.

Reclosing is selectable up to a maximum of four attempts with independent settings for recloser timers and reset times. The sequence is controlled by the Reclose Initiate signal and the position of the breaker as well as by the presence of voltage and the existence of synchronism.

The trip units and reclose attempts enabled during a fault clearing and reclosing sequence are selectable. Manual closing can be initiated from the Recloser. In this instance is supervised and controlled in the same way as any reclosing following a trip from the protection units.

1.1.24 Current Measurement Supervision (60CT)

All models have a system for the supervision of the set of elements that make up the system for measuring phase currents, ranging from external current transformers to the copper cables that connect elements to the relay, to internal magnetic modules for the **IRX** equipment.

1.1.25 Fuse Failure Detector (60VT)

Models with analog voltage inputs have a Fuse Failure Detector that can block the operation of the elements based on voltage measurements (phase undervoltage and overvoltage, ground overvoltage, negative sequence overvoltage, synchronism, etc.) if any of the voltages in the secondary voltage transformer disappear.

All the protection functions described have 4 selectable setting groups (one active and three alternative groups) for their corresponding rating under various system conditions. Each function can be enabled or disabled during configuration or by commands transmitted via the communications ports, operator interface (HMI) or digital inputs.

They all have independent LED targets for each element (to which the phase distinction is applied) for the pickup and trip of the phase and ground time and instantaneous elements. They can be directed to any logic signal.

1.2 Additional Functions

1.2.1 Local Control

You have programmable and function buttons on the front of the IED for operating on the system's configurable elements in the IED (Breaker, Sectionalizers, Recloser Function, Automatic Control Functions, Protection Units, Local/Remote, Active Group of Settings, etc.) and for resetting the operation LEDs.

1.2.2 Programmable Logic

An operational logic can be programmed in order to set up blockings, automatic controls, control and trip logic functions, command hierarchy, etc through logic gates combined with any captured or equipment-calculated signal.

All the signals generated by the equipment will be available to the events, fault reports, oscillograph records, digital inputs and outputs, HMI and communications according to how their programmable logic has been configured.

The processing of the input signals produces logical outputs that can be assigned to existing connections between the **IRX** and the exterior: auxiliary output contacts, display, communications, LEDs, HMI…

1.2.3 Ports and Communications Protocols

IRX relays are provided with different types of communications ports:

- **1** front **Local Port** type RS232C.
- **1** front **Local Port** type USB.
- Up to **3 Remote** fiber optic ports (ST glass or 1mm plastic), electrical interface RS232/RS485, or LAN on connector RJ45 for ETHERNET-type communications. One of these remote ports can be used for BUS connection with CAN protocol.
- 2 LAN ports with RJ45 or glass fiber optic ST connectors for ETHERNET type communications.

The IED also has the following communications protocols: PROCOME 3.0, DNP 3.0, MODBUS. (you can assign any one of them to both remote ports, CAN -electric BUS CAN- and, in the case of PROCOME and DNP 3.0, also to the LAN ports). The local port supports the PROCOME 3.0 Protocol. It is for parameter setting, configuration and retrieval of information about the IED.

Protocol changeover trailers are totally independent for each port and same-protocol instances can be maintained in all of the remote ports.

1.2.4 Current Detection Unit (50D)

The IED has three units for detecting current by phases and, therefore, for knowing whether or not there is current in the bay IED to be protected. The indication of existence of this current in the bay IED can be directed to the logic of the IED.

1.2.5 Integrated Simulator

The equipment count on a special mode for testing and simulating the operation of implemented units by means of loading an external oscillogram into the device through the front communication port.

1.2.6 Supervision of the Switching Circuits

The IED has units for verifying the proper operation of the switching circuits of the breaker. They can monitor up to three coils. You can monitor both breaker positions (open and closed) or either one of them.

1.2.7 Selecting the Phase Sequence

You can configure the connection of the IED to the network sequence when the phase sequences are ABC or ACB.

1.2.8 Number of Voltage Transformers (Model IRX-B)

You can configure the IED to measure voltages with three transformers that measure phase-ground voltages or two that measure phase-phase voltages (UAB and UBC). In either case, the relay remains totally functional.

1.2.9 Breaker Monitoring

To have information for maintaining the breaker, the IED has an unit that sums and accumulates the kA^2s values each time it trips.

1.2.10 Excessive Number of Trips

This function prevents the breaker from making an undesirable number of operations in a given period of time, which may result in breaker damage. When the maximum number of trips allowed is surpassed, the Recloser function is blocked.

1.2.11 LED Targets

There are eight configurable LEDs and an additional one indicating equipment “In Service” on the equipment.

1.2.12 Digital Inputs

The number of digital inputs available will depend on each particular model (see 1.4, Model Selection). These can range from 8 to 18.

1.2.13 Auxiliary Outputs

The number of auxiliary outputs available will also depend on each particular model (see 1.4, Model Selection) and may vary from 3 up to 8. One of these outputs is not configurable as it is assigned to the relay “In Service” indication.

1.2.14 Time Synchronization

The IEDs include an internal clock with a resolution of 1 ms. This can be synchronized via GPS (IRIG-B 003 and 123 Protocol) or by communications through remote communications port (PROCOME 3.0 or DNP 3.0 Protocols).

1.2.15 Fault Locator

A Fault Locator is included (in models with voltage analog inputs), to determine the distance to the fault in miles, kilometers or percentage of total length

1.2.16 Event Recording and Programmable Metering Data Logging

Storage capacity of 400 annotations in a non-volatile memory. Event-generated signals can be selected by the user and are annotated with 1ms resolution and a maximum of 12 measurements also user-selected.

1.2.17 Fault Reporting

Storage capacity of up to 15 fault reports with relevant information, such as units picked up, units tripped, pre-fault values, fault values, current interrupted by breaker, etc.

1.2.18 Historical Metering Data Logging

Historical metering data logging allows for obtaining twelve maximum and twelve minimum values from a group of four magnitudes selected out of all available measurements (captured or calculated), except meters, for each time window. This window can be adapted to the application by adjustment of day and interval masks. Up to 168 records can be saved.

1.2.19 Oscillographic Register

The Oscillographic Recording function is composed of two different sub functions: **capture** and **display**. Both analog magnitudes and internal signals as well as digital equipment inputs will be recorded, up to a total of 64 oscillograms in a circular memory. Sampling and storing frequency is 32 samples per cycle with 15 seconds of total storage.

Oscillograms are delivered in format COMTRADE 99.

A program for the display and analysis of the captured oscillograms is supplied with the equipment.

1.2.20 Alphanumeric Display and Keypad

- Changing and displaying settings.
- Protection operations:
  - Last trip and Recloser status.
  - Units picked up.
  - Tripped units.
  - Contact input and output status.
  - Distance to the fault.
- Protection records (displayed via communication):
  - Event recording.
  - Fault report.
  - Log file of currents, voltages, powers, power factor and energies or other calculated values.
- Control records
- Metering values used by protection:
  - Phase and ground currents and their angles
  - Voltages of the three phases and ground and their angles
  - Synchronism voltage
  - Phase-to-phase voltages
  - Thermal image value
  - Maximum and minimum current
  - Maximum and minimum voltage
  - Positive, negative and zero sequence currents and their angles
  - Positive, negative and zero sequence voltages and their angles
  - Active, reactive and apparent powers and power factor
  - Maximum and minimum powers
  - Frequency
  - Energies
  - 2nd to 8th order harmonics of the current and voltage of phase A.

1.2.21 Self-Test Program

A continuously running diagnostic self-test program verifies the correct operation of the terminal unit and alerts the user of potential problems.

1.3 Local Interface: Alphanumeric Display and Keypad

1.3.1 Alphanumeric Display and Keypad

The resolution of the display is 320 pixels horizontally, and 240 vertically and it has a depth of colour consisting on 16 bits = 65536 colours. You can visualize alarms, settings, measurements, status, etc. from the display. Next to the display is the keypad. The next section explains the functions associated to these keys. Figure 1.3.1 represents the layout of the default display.

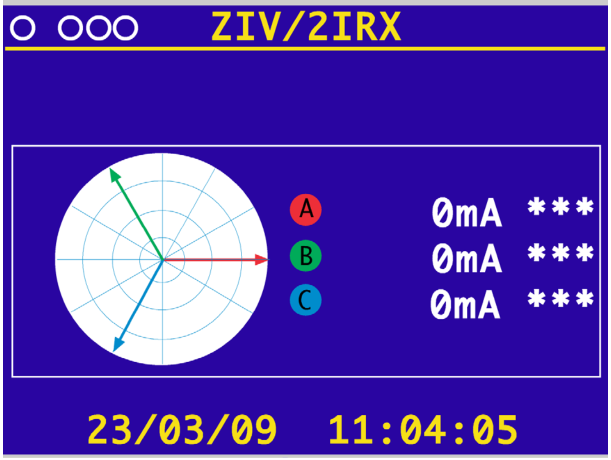


Figure 1.3.1 Alphanumeric Display.

- **Default Display**

As shown under Figure 1.3.1, the default display presents the model in question, the date and time, and the measurement of phase voltages and currents with their respective angles can be visualized in the same. The left-hand side of the top line also describes that communication has been established with a green light.

- **Command Panel Screen**

2IRX-*-****E0**** relays are provided with a graphic screen for HMI commands in which data on the status of the signals selected from the ***Zivercomplus***® are shown and commands configured from the ***Ziverlog***®, which are executed from the **SEL** command buttons , **I** (close) and **O** (open).

Texts on the relay's HMI are acronyms of the selected signals.

Access to the command panel is gained through the **SEL** key. The different windows can be scrolled using also the **SEL** key. The signals to be displayed on the windows can be defined through the ***Zivercomplus***® (**Command Panel – Digital Signals**). Also, texts displayed on the commands to be executed: **Activate / Deactivate**; **Block / Unblock**; **Enable / Disable**… can be configured in the ***Zivercomplus***®.

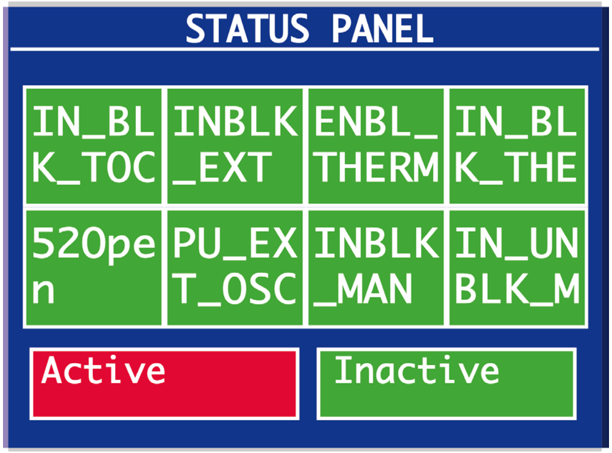


Figure 1.3.2 Example of Command Panel Screen.

All signals displayed on the command panel screen must be wired through ***Ziverlog***® programmable logic associating the signals related to the command to be executed through the buttons *(**O Panel X**)*(**I Close Panel X**) associated to the different windows.

(*) Up to 8 panels can be selected.

In the same command panel option, there exists the possibility to block the signals. In this way, when a selected signal is selected on digital signal blocking, the window will be blocked and it will not be possible to go through this window.

- **Keypad associated to the Alphanumeric Display**

The keypad has 4 keys, as follows:

▲ this key provides access to a display where events are visualized.

▶ this key enables you to visualize measurements.

▼ this key provides access to digital inputs and outputs.

◀ this key enables access to a display where faults are visualized.

The keypad also provides an **Enter** key (in the centre) and an **Escape** key (**ESC**).

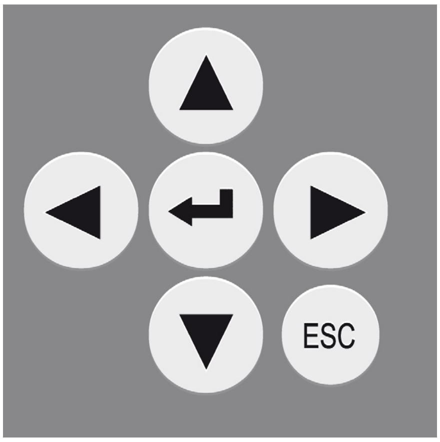


Figure 1.3.3 Keypad.

1.3.2 Control Buttons

Three buttons are available to operate the system elements, setting tables or protection units configured in the unit: buttons **I** and **O** (closing and open controls, respectively) and button **79** for reclosing.

Figure 1.3.4 Command Buttons.

In **2IRX-***-****E0**** relays access to the command panel is gained through the **SEL** key. This same button is used to scroll the command panel to select a window. Use buttons (**I**) and (**O**) to execute the commands configured in the logic through the ***Ziverlog***®.

Figure 1.3.5 Command Buttons in 2IRX-*-****E0** Relays.**

It must be taken into account that control buttons corresponding to open and closure are associated by default to 1 and 0 ◄ ►, hence, in principle, these could not be used for programmable logic, unless through the ***Ziverlog***® program, and under the section **Configuration of the Front Panel's Control Buttons**, this provides the option of disassociating the buttons and, thus, be able to use them for the logic, as displayed under figure 1.3.4.

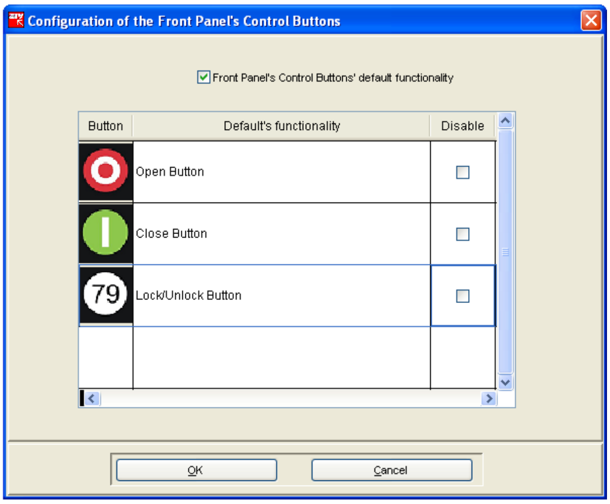


Figure 1.3.6 Configuration of Control Buttons.

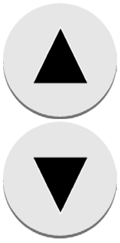
1.3.3 Keys, Functions and Operation Modes

The following is a description of the functions provided by available keys, both as regards the functions associated to the alphanumeric display and those of the keypad.

1.3.3.a 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.



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.

1.3.3.b 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.

The key ► is used for consulting the unit as regards the data pertaining to current, voltage, power, etc. measurements, and to reset the last trip indication and the LEDs.

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).

1.3.3.c Access to Options

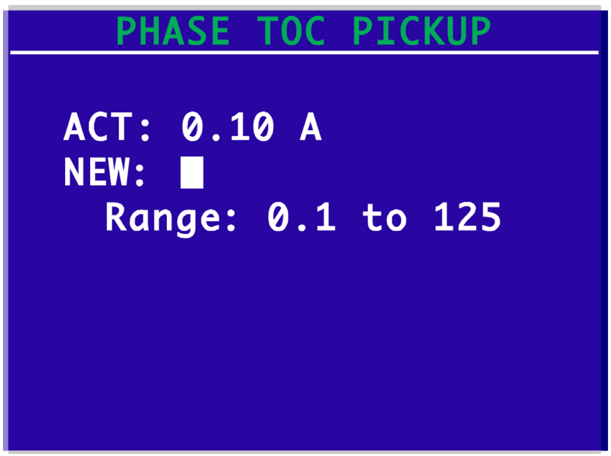
To access options, you must scroll around the menus using the selection keys and afterwards confirm the option selected by pressing **ENT**.

1.3.3.d Operation

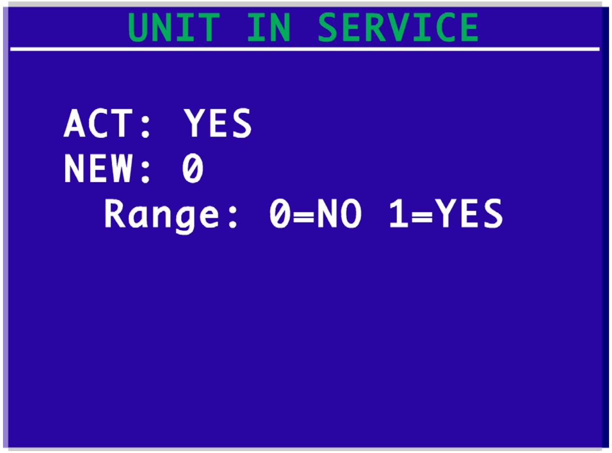
- **Range Settings**

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

The new function keys are used for editing the new value which must tally 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.

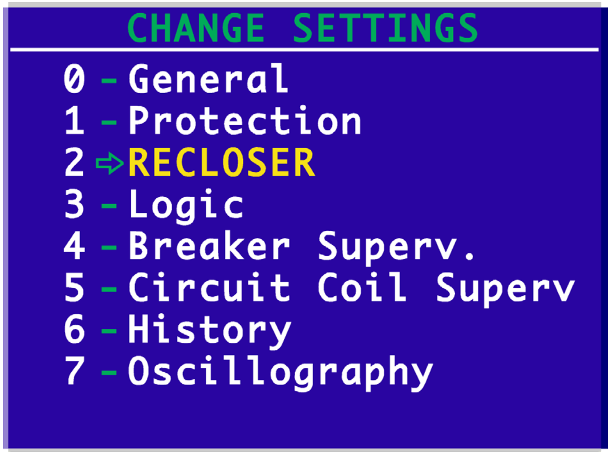


There is a type of setting that adjusts to this scheme, but its range is limited to options **YES** and **NO**. Keys ◄ (1) and ► (0) correspond in this case to values **YES** and **NO**. After this, press key ↵ to confirm the setting and return to the previous screen.



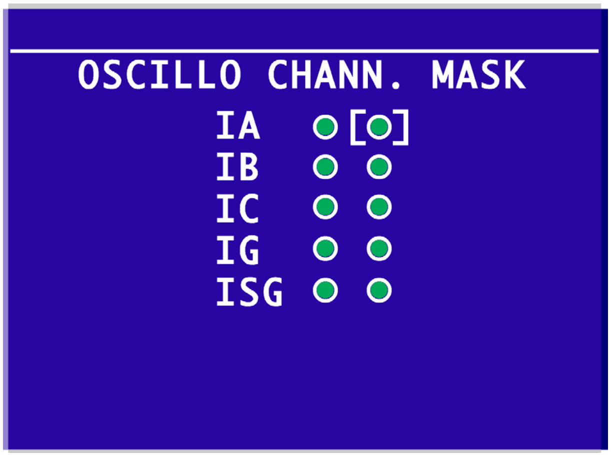
- **Settings for the Selection of an Option**

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.



- **Masks Settings**

As can be observed from the screen, the different options are presented in vertical order. Its current setting is: an empty circle or a filled circle 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.

- **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.

1.3.4 Last Trip Indication

If any trip has taken place, the terminal would display, in the first place, data regarding the same. This data would be visualized as follows:

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, Temp Current), and below this, all the elements and phases that have been involved (Temp1 A, Temp1 B,...). If various functions should trip, and thus do not all fit into one screen, you can access all the functions involved through the selection keys.

If, on the contrary, no trips have taken place since the last reset, this screen will not be displayed.

1.4 Model Selection

1.4.1 Model Selection

2IRX											
1	2	3	4	5	6	7	8	9	10	11	12

2	**Functions**			
	A	Basic model for solid or low-impedance neutral	**B**	Advanced model for solid or low impedance neutral with voltage channels
3	**Options**			
	1	Standard Model.	**6**	IEC61850 (MMS services and GOOSE service) v.4 (SBO) with Non-Redundancy, Bonding Redundancy or PRP Redundancy.
4	**Additional functions**			
	F	64 samples / cycle		
	N	Standard Model		
5	**Power Supply Voltage**			
	1	24 VDC (±20%) / 24 VAC (±10%)	**2**	48 - 250 VDC (±20%) / 48 - 230 VAC (±10%)
6	**Digital Inputs Voltage**			
	0	24 VDC	**3**	250 VDC
	1	48 VDC	**6**	125 VDC (Activ. Threshold >65% of rated voltage)
	2	125 VDC	**A**	125 VDC (Inputs 7 and 8 with common positive)
7	**Communication Interfaces for Remote Communication [LOC] [Port 1] [Port 2] [Port 3] [IEC61850 ports LAN1-LAN2]**			
	0	[RS232+USB] [--] [--] [--] [2xRJ45]	**C**	[RS232+USB] [RS232/RS485] [RS232/RS485] [--] [2xRJ45]
	1	[RS232] [ETHERNET] [RS232/RS485] [--] [--]	**D**	[RS232+USB] [--] [--] [--] [2xGFO ST]
	2	[RS232+USB] [ETHERNET] [RS232/RS485] [--] [2xRJ45]	**E**	[RS232+USB] [ETHERNET] [RS232 / RS485] [--] [2xGFO ST]
	3	[RS232+USB] [GFO ST] [GFO ST] [--] [2xRJ45]	**F**	[RS232+USB] [GFO ST] [GFO ST] [--] [2xGFO ST]
	4	[RS232+USB] [GFO ST] [RS232/RS485] [--] [2xRJ45]	**G**	[RS232+USB] [GFO ST] [RS232/RS485] [--] [2xGFO ST]
	5	[RS232+USB] [PFO] [PFO] [--] [2xRJ45]	**H**	[RS232+USB] [PFO] [PFO] [--] [2xGFO ST]
	6	[RS232+USB] [PFO] [RS232/RS485] [--] [2xRJ45]	**I**	[RS232+USB] [PFO] [RS232/RS485] [--] [2xGFO ST]
	7	[RS232] [GFO ST] [GFO ST] [--] [--]	**J**	[RS232+USB] [RS232/RS485] [RS232/RS485] [--] [2xGFO ST]
	8	[RS232] [GFO ST] [RS232/RS485] [--] [--]	**K**	[RS232] [ETHERNET] [GFO ST] [--] [--]
	9	[RS232] [PFO] [PFO] [--] [--]	**L**	[RS232] [ETHERNET] [PFO] [--] [--]
	A	[RS232] [PFO] [RS232/RS485] [--] [--]	**N***	[RS232] [ETHERNET] [--] [RS232/RS485] [--]
	B	[RS232] [RS232/RS485] [RS232/RS485] [--] [--]		
8	**Inputs and Outputs**			
	0	8DI + 2DO + 1 Trip Output + 1 Close Output + 1 Alarm Output	**2**	18DI + 7DO + 1 Trip Output + 1 Close Output + 1 Alarm Output + 1 Input Transducer for VDC Supervision (0-300VDC)
	1	18DI + 7DO + 1 Trip Output + 1 Close Output + 1 Alarm Output + 1 Input Transducer (0-5mA or ±2,5mA)		
9	**Spare (to be defined in the factory)**			
	G0	Only IRX-A: Reset of 51 units with disk emulation+ 60CT + 50BF / 62 BF (with Retrip) + Faults report with primary values (selectable by setting) + harmonic blocking for overcurrent units + HMI with graphic display for local controls panel + Command selection button (SEL) + special settings to identify the bay + Two access levels + autodimming disabled with trip indication	**J1**	Only IRX-B: F1 + reduced range for frequency activation timer
10	**Enclosure/Chassis**			
	G	4U x 19" 1/2 Rack (Inputs / Outputs type all.)		
11	**Protocols for Remote Communication**			
	L	[PROCOME 3.0 / DNP 3.0 (Profile v.2) / MODBUS SERIE and over ETHERNET for Remote Ports 1 & 2]	**N****	Standard [PROCOME 3.0 or DNP 3.0 (Profile v.2) or MODBUS RTU] two selectable protocols communicating simultaneously over one RJ45 port and Standard [PROCOME 3.0/DNP 3.0 (Profile v.2)/MODBUS RTU - SERIAL and over ETHERNET for Remote Port 3]
12	**Finishing**			
	--	NO Conformal Coated Circuit Boards for Bare Wire Terminals	**M**	NO Conformal Coated Circuit Boards for Ring Terminals
	L	NO Conformal Coated Circuit Boards for Bare Wire Terminals	**N**	Conformal Coated Circuit Boards for Ring Terminals

(*) Only available with N digit in the "Protocols for Remote Communication" (11) option.
(**) Only available when selected options in the "Communication Interfaces for Remote Communication" (7) contains port 3 option.

- **Functions**

ANSI	Functions	NUMBER OF UNITS	
		IRX-A	IRX-B
25	Synchronism Check	0	1
27	Phase Undervoltage	0	3
32	Directional Power (Active / Reactive)	0	2
37	Phase Undercurrent	1	1
46	Open Phase	1	1
47	Negative Sequence Overvoltage	0	1
49	Thermal Image	1	1
50	Phase Instantaneous Overcurrent	3	3
50BF	Breaker Failure	1	1
50N	Ground Instantaneous Overcurrent	3	3
50Ns	Sensitive Ground Instantaneous Overcurrent	1	1
50Q	Negative Sequence Instantaneous Overcurrent (I2)	3	3
51	Phase Time Overcurrent (inverse / definite)	3	3
51N	Ground Time Overcurrent (inverse / definite)	3	3
51Ns	Sensitive Ground Time Overcurrent (inverse / definite)	1	1
51Q	Negative Sequence Time Overcurrent (inverse / definite) (I2)	3	3
51V	Voltage Dependent Phase Overcurrent	0	1
59	Phase Overvoltage	0	3
59N	Ground Overvoltage	0	2
60CT	Current measurement supervision	1	1
60VT	Voltage measurement supervision	0	1
61	Residual Current Detection	1	1
67	Phase Directional	0	1
67N	Ground Directional	0	1
67Ni	Isolated Ground Directional	0	1
67Ns	Sensitive Ground Directional	0	1
67Q	Negative Sequence Directional	0	1
78	Out-of-Step	0	1
79	Recloser	1	1
81D	Frequency Rate of Change	0	4
81M/m	Overfrequency / Underfrequency	0	4/4
85	Overcurrent Teleprotection schemes	0	1
87N	Restricted Earth Faults	0	1
	Cold Load	1	1
	Fault Locator	0	1

- **Analog Channels**

Model	Analog Channels
IRX-A	IA, IB, IC, IN, INs
IRX-B	IA, IB, IC, IN, INs, Ipol, VA, VB, VC, Vsync

1.4.2 Models replaced by others with Higher Functionality and not Available Options

2IRX											
1	2	3	4	5	6	7	8	9	10	11	12

2	**Functions**			
	C	3x50/51+50N/51N+50Q/51Q+51V+3x67+67N+67 Q+67Na+67Nc+37+3x27+3x59+1x59N+47+81M/ m+81D+79+25+32+32Q+49+50BF+46+78+60CT +60VT+ Teleprotection Schemes		
3	**Options**			
	3	IEC61850 (MMS and GOOSEs services, without SBO)		
4	**Hardware Options**			
	R	Oscillographic expanded (20osc x 10s)		
	S	Integrated simulator		
7	**Communication Interfaces for Remote Communication [LOC] [Port 1] [Port 2] [Port 3] [IEC61850 ports LAN1-LAN2]**			
	M	[RS232] [ETHERNET] [--] [--] [--]		
9	**Spare (to be defined in the factory)**			
	00	Standard Model	**F0**	IRX-A: Reset of 51 units with disk emulation+ 60CT + 50BF / 62 BF (with Retrip) + Faults report with primary values (selectable by setting) + harmonic blocking for overcurrent units + HMI with graphic display for local controls panel + Command selection button (SEL). IRX-B: Like the IRX-A + 60VT + 49 funtion based on RMS or Fundamental value + Filter for capacitive VT + Positive sequencer directional unit + Fault Detector + Weak Infeed Logic
	A0	00+Units 51 Reset with Disk Emulation + 60CT		
	B0	A0 + 60VT + Function 49 based on RMS Value or Fundamental Value		
	D0	B0 + 50BF/62BF (with Retrip) + Capacitive Filtering VTs + Positive Sequence Directional + Fault Detector + Week-Infeed Logic		
	E0	B0 + HMI with Graphic Display for Commands		
			F1	Only IRX-B: Like the IRX-B(F0) + 67Ni or Ns (selectable by setting)
11	**Communications Protocols [COM1-LOC] [COM 2-REMP1 + COM3-REMP2] [COM4-REMP3]**			
	B	[PROCOME 3.0] [-] [-]	**M**	[PROCOME 3.0 + DNP 3.0 (Profile v.2) + MODBUS: two selectable protocols communicating simultaneously over same port(2)]
	K	[PROCOME 3.0] [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS (1)] [PROCOME 3.0/DNP 3.0 (Profile II)/MODBUS (1)]		
12	**Finishing**			
	--	Printed Circuit Board No Tropicalized	**Z**	Printed Circuit Board No Tropicalized + Without O, I and 79 Buttons.
	X	Printed Circuit Board Tropicalized + Commands Selection Button (SEL)		

(1) Selectable independently for COM2 and COM3.

1.5 Installation and Commissioning

1.5.1 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 **IRX** IED. They do not necessarily coincide with the final manufacturing tests to which each manufactured IED is subjected. The number, the type and the specific characteristics of the acceptance tests are model dependent.

1.5.2 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.

1.5.3 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 2.5 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.

1.5.4 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.

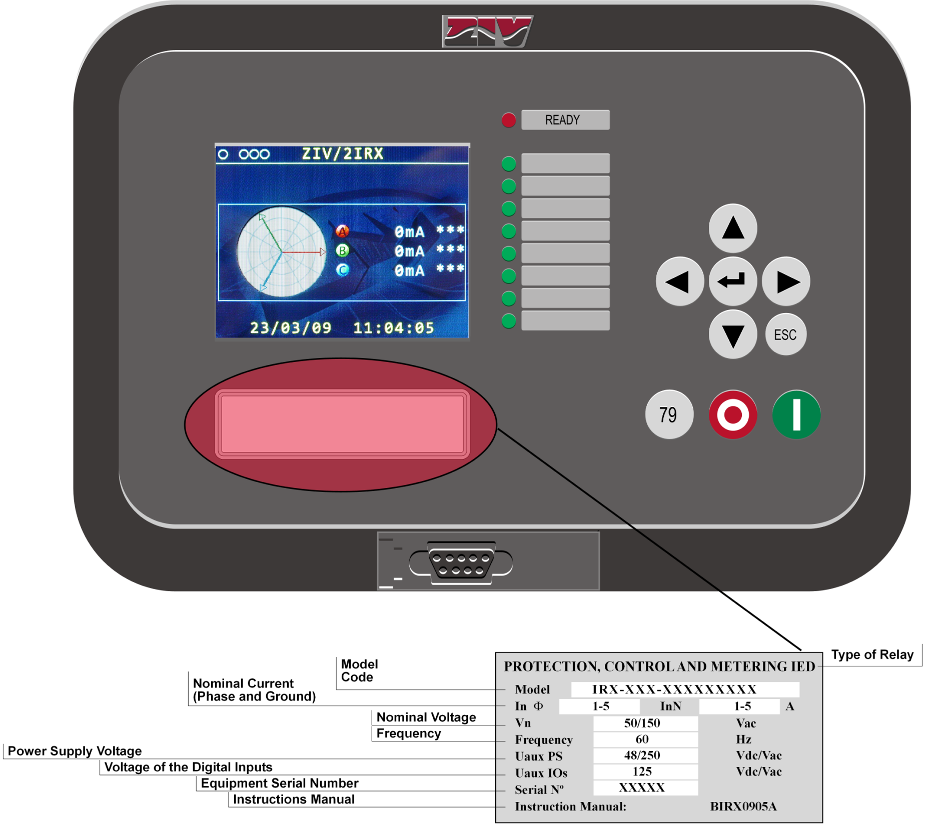


Figure 1.5.1 Name Plate (2IRX).

1.5.5 Tests

1.5.5.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 1,000 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.

1.5.5.b Power Supply Test

Connect the power supply as indicated in following table.

VDC PROT	CON1P	CON2P
C22(+) - C23(-)	C9-C10	C9-C11

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.

1.5.5.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	Freq. Applied (V > 20 Vac)	Freq. Measured (V > 20 Vac)
X	X ±1%	Y	Y ±1º	Z	Z ±5 mHz

Note: to check high current values, they are applied during the shortest possible time; for example, for 20 A, less than 8 seconds. To be able to view the angles, the phase A voltage must be applied the same as for measuring the frequency.

1.6 Onload Test

1.6.1 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 (magnitude 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).

1.6.2 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 2.1, Technical Data.

1.6.3 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 2.1, 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.

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 polarization channel and just in one phase analog input lagging 180º 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 polarization channel.

Chapter 2.

Technical Specifications and Physical Description

2.1 Technical Data

2.1.1 Power Supply Voltage

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

48 - 250 Vdc/Vac (±20%)
24 Vdc (±20%) / 24 Vac (±10%)

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

2.1.2 Power Supply Burden

Quiescent	**7 W**
Maximum	**<12 W**

2.1.3 Current Analog Inputs

Phase, Ground and Polarization Currents

Nominal Value	**In** = **5 A** or **1 A** (selectable in the IED)
Thermal withstand capability	**20 A** (continuously) **250 A** (for 3 s) **500 A** (for 1 s)
Dynamic limit	**1250 A**
Current circuit burden	**<0.2 VA** (In = 5 A or 1 A)

Ungrounded and Sensitive Ground Currents

Nominal Value	**In** = **20 mA**
Thermal withstand capability	**5 A** (continuously) **62.5 A** (for 3 s) **125 A** (for 1 s)
Dynamic limit	**300 A**
Current circuit burden	**<0.05 VA** (In = 1 A or 20 mA)

2.1.4 Voltage Analog Inputs

Nominal Value	**Un** = **50** to **230 VAC** (selectable in the IED)
Thermal withstand capability	**300 VAC** (continuously) **600 VAC** (for 10s)
Voltage circuit burden	**0.55 VA** (110/120 VAC)

2.1.5 Frequency

Operating range	**16 - 81 Hz**

2.1.6 Measurement Accuracy

Measured currents	**±0.15%** or **±2 mA** (the greater)
Phase and Ground	for 0.1*Inom≤I<2*Inom
	±0.2% for 2*Inom≤I≤5*Inom
Measured currents	
Sensitive Ground and Isolated Ground	**±0.1%** or **±0.5 mA** (the greater)
Sensitive Ground Current <1.5 A	**±0.15%** or **±1 mA**
Sensitive Ground Current ≥1.5 A	**±0.2%**
Calculated currents	
Phase-Phase	**±0.2%** or **±6 mA** (the greater)
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)
PH-GR, PH-PH, GR and Synchronism	for 0.2 V≤V<130 V
	±0.25% for 130 V≤V≤250 V
Calculated voltages	
Phase-Phase (0 to 300V)	**±0.3%** or **±75 mV** (the greater)
VGround, V1, V2 and V0	**±0.3%** or **±100 mV** (the greater)
	for 0.2 V≤V≤250 V
Active and reactive power (In = 5A e I_{phase}>1A)	
Angles 0º or ±90º or 180º	**±0.33% W/var**
Angles ±45º or ±135º	**±1.6% W/var**
Angles ±75º / ±115º	**±5% W / ±0.65 % var**
Angles	**±0.5º**
Active energy	**Class 0.5** (*IEC 62053-22*)
Reactive energy	**Class 1** (*IEC 62053-24*)
Power factor	**±0.013**
Frequency	**±0.005 Hz**

Signal processing.

Sampling function adjustment of analog input signals is made by means of zero pass count of one of the measured signals and works detecting the change in said signal period. The value of the calculated frequency is used to modify the sampling frequency used by the metering device attaining a constant sampling frequency of 32 samples per cycle. The frequency value is saved for later use in Protection and Control tasks.

Zero crossing is detected by the voltage channel VA or VAB. When VA phase voltage falls below 2 volts is not possible to measure frequency. In case of loosing phase voltage, the unit operates as follows:

If the measured phase voltage is equal or larger than 2V for VB or VC, the last sampling frequency is kept.
If all phase voltages are below 2V, the rated frequency is used as the sampling frequency.

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 32 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.

Harmonics are not completely damped for frequencies other than the nominal frequency. This is not a problem for small deviations of ±1Hz but, in order that a greater deviation from the working frequency can be allowed, the above-mentioned automatic adjustment of the sampling frequency is included. On lack of an adequate signal for sampling frequency adjustment, said frequency is adjusted to the corresponding nominal frequency (50/60Hz).

Angles reference for all the measurements displayed on the device corresponds to the channel VA.

2.1.7 Accuracy of the Pickup and Reset of the Overcurrent Elements

Overcurrent Elements

Pickup of Phases and Ground	**±3 %** or **±10mA** of the theoretical value (the greater) (In = 1A and 5A)
Reset of Phases and Ground	**1,5 cycles** for 50 and 60Hz
Pickup of Sensitive Ground	**±3 %** or **±1mA** of the theoretical value (the greater)
Reset of Sensitive Ground	**1.5 cycles** for 50 and 60Hz

Measuring Times

Fixed Time	**±1 %** of the setting or **±25 ms** (the greater)
Inverse Time	**Class 2** (E = 2) or **±35 ms** (the greater) (UNE 21-136, IEC 255-4) (for measured currents of 100 mA or greater)

2.1.8 Repeatability

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

2.1.9 Accuracy of the Pickup and Reset of the Voltage Elements

Overvoltage and Undervoltage Elements	
Pickup	**±2 %** or **±250 mV** of the theoretical value (the greater)
Reset	**1.5 cycles** for 50 and 60Hz
Measuring times	
Fixed Time	**±1 %** of the setting or **±25 ms** (the greater)

2.1.10 Accuracy of the Pickup and Reset of the Frequency Elements

Overfrequency Elements	
Pickup and reset	**±0.01 Hz** of the theoretical value
Underfrequency Elements	
Pickup and reset	**±0.01 Hz** of the theoretical value
Measuring times	
Fixed Time	**±1%** of the setting or **±25 ms** (the greater)

2.1.11 Accuracy of the Reclosing Cycle Times

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

2.1.12 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

2.1.13 Digital Inputs

Configurable inputs with polarity (all the digital inputs are DC)

Nominal Voltage	Maximum Voltage	Burden	V ON	V OFF
48 VDC	90 VDC	< 1 W	38V	25V
125 VDC	300 VDC	< 1 W	80V	60V
250 VDC	500 VDC	< 1 W	130V	96V

Undertaking coil circuit supervision limits the number of digital inputs available for other applications. Use of digital inputs is as follows:

Trip Coil Circuit Supervision	Used Inputs: DI1, DI2 and DI3
Coil Circuit 2 Supervision	Used Inputs: DI9, DI10 and DI11
Coil Circuit 3 Supervision	Used Inputs: DI9, DI12 and DI13

2.1.14 Breaker Trip and Close Outputs and Auxiliary Outputs

It has **2** contacts that are normally open for operations (TRIP and CLOSE), the first of which can be configured to close internally, and **3** or **8** (according to model) auxiliary contacts that are normally open, including EQUIP. ALARM. The characteristics of all of them, apart from the **OUT7** contact, are as follows:

I DC maximum limit (with resistive load)	**60 A** (1 s)
I DC continuous service (with resistive load)	**16 A**
Close	**5000 W**
Breaking capability (with resistive load)	**240 W** - max. 5 A - (48 VDC)
	110 W (80 VDC - 250 VDC)
	2500 VA
Break (L/R = 0.04 s)	**120 W** at 125 VDC
Switching voltage	**250 VDC**
Momentary close time trip contacts remain closed	**100 ms**
Break delay	**<150 ms**

OUT7 output has the following characteristics:

I DC maximum limit (with resistive load)	**30 A** (1 s)
I DC continuous service (with resistive load)	**8 A**
Close	**2500 W**
Breaking capability (with resistive load)	**150 W** - (48 VDC)
	55 W (110 VDC)
	1250 VA
Break (L/R = 0.04 s)	**60 W** at 125 VDC
Switching voltage	**250 VDC**

2.1.15 Input Transducers

0-5mA and ±2.5mA Input Transducers

Input impedance	**511 Ω**
Measurement accuracy	**±0.2 %** or **±3 mA** (the greater)

Voltage transducers (power supply monitoring for 125VDC and 250 VDC)

Measurement accuracy (between 70VDC and 350VDC)	**±0.2 %** or **±0.5 V** (the greater)

Voltage transducers (power supply monitoring for 24VDC and 48 VDC)

Measurement accuracy (between 10VDC and 70VDC)	**±0.2 %** or **±0.2 V** (the greater)

2.1.16 Communications Link

Local Communications Port (RS232C)
Remote Communications Ports (GFO, PFO, RS232C, RS485)

Glass Fiber Optics	
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**

Plastic Fiber Optics (1 mm)	
Wavelength	**660 nm**
Transmitter Minimum Power	**- 16 dBm**
Receiver Sensitivity	**- 39 dBm**

RS232C Port Signals	
Terminal unit DB-9 (9-pin) connectors	**Pin 5 - GND**
	Pin 2 - RXD
	Pin 3 - TXD

RS485 Port Signals	
Used signals	**Pin 4 - (A) TX+ / RX+**
	Pin 6 - (B) TX- / RX-

IRIG-B 123 and 003	B: 100pps	
	1: Amplitude modulated wave	0: By pulse width
	2: 1kHz/1ms	0: Without carrier
	3: BCD, SBS	3: BCD, SBS

Type BNC connector

Input Impedance	**211 Ω**
Maximum Input Voltage	**10 V**
Synchronization Accuracy	**± 1ms**

When the device is receiving a IRIG-B signal for synchronization both Date and Time settings will not be available through the HMI.

It is possible to configure one of the auxiliary outputs to check the IRIG-B signal status. This output will remain active as long as the IRIG-B signal reception is correct.

All the devices are also designed to give an indication for both the loss and recovery of such IRIG-B signal by generating the particular event.

2.2 Standards and Type Tests

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

2.2.1 Insulation

Insulation Test (Dielectric Strength)	*IEC-60255-5*
Between all circuit terminals and ground	**2 kV**, **50/60 Hz**, for 1 min; or **2.5 kV**, **50/60 Hz**, for 1s
Between all circuit terminals	**2 kV**, **50/60 Hz**, for 1min; or **2.5 kV**, **50/60 Hz**, for 1s
Measurement of Insulation Resistance	*IEC-60255-5*
Common mode	**R ≥ 100 MΩ** or **5μA**
Differential mode	**R ≥ 100 kΩ** or **5mA**
Voltage Impulse Test	*IEC-60255-5*
Common mode (analog inputs, DIs, AOs and PS)	**5 kV**; **1.2/50 μs**; **0.5 J**
Differential mode (AOs)	**1 kV**; **1.2/50 μs**
Differential mode (Power Supply)	**3 kV**; **1.2/50 μs**

2.2.2 Electromagnetic Compatibility

1 MHz Burst Test	*IEC-60255-22-1 Class III*
Common mode	**2.5kV**
Differential mode	**2.5kV**
Oscillatory Waves Immunity Test	*IEC-61000-4-12 100kHz and 1MHz Class III*
Common mode	**2.5kV**
Differential mode	**2.5kV**
Fast Transient Disturbance Test	*IEC-60255-22-4 Class IV* *(IEC 61000-4-4)* **4 kV ±10 %**
Radiated Electromagnetic Field Disturbance	*IEC 61000-4-3 Class III*
Amplitude modulated	**10 V/m**
Pulse modulated	**10 V/m**
Conducted Electromagnetic Field Disturbance	*IEC 61000-4-6 Class III*
Amplitude modulated	**10 V**
Electrostatic Discharge	*IEC 60255-22-2 Class IV* *(IEC 61000-4-2)*
On contacts	**±8 kV ±10 %**
In air	**±15 kV ±10 %**

Surge Immunity Test	*IEC-61000-4-5*
	(1.2/50µs - 8/20µs)
Between conductors	**4 kV**
Between conductors and ground	**4 kV**

Radiated Electromagnetic Field Disturbance at Industrial Frequency (50/60 Hz)	*IEC61000-4-8*

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

2.2.3 Environmental Test

Temperature	*IEC 60068-2*
Cold work	*IEC 60068-2-1* **-5º C**, **2 hours**
Cold work limit conditions	*IEC 60068-2-1* **-10º C**, **2 hours**
Dry heat	*IEC 60068-2-2* **+45º C**, **2 hours**
Dry heat limit conditions	*IEC 60068-2-2* **+55º C**, **2 hours**
Humid heat	*IEC 60068-2-78* **+40º C**, **93%** relative humidity, **4 days**
Quick temperature changes	*IEC 60068-2-14 / IEC 61131-2* IED open, **-25º C** for **3h** and **+70º C** for **3h** (**5 cycles**)
Changes in humidity	*IEC 60068-2-30 / IEC 61131-2* **+55º C** for **12h** and **+25º C** for **12h** (**6 cycles**)
Endurance test	**+55º C** for **1000 hours**
Operating range	From **-40º C** to **+ 85º C**
Storage range	From **-40º C** to **+ 85º C**
Humidity	**95 %** (non-condensing)

Climate Test (55º, 99% humidity, 72 hours)	

Time / Current Characteristic	*ANSI C37.60 Class II*

2.2.4 Power Supply

Power Supply Interference and Ripple	*IEC 60255-11* **< 20 %** and **100 ms**
Inverse Polarity of the Power Supply	*IEC 61131-2*
Resistance of Ground Connection	*IEC 61131-2* **< 0.1 Ω**
Gradual Stop / Start Test	*IEC 61131-2* (Test A)
Surge Capacity	*IEC 60044-1*

2.2.5 Mechanical Test

Vibration (sinusoidal) a) Answer: (equipment on). *Class II* b) Endurance: (equipment off). *Class I*	*IEC-60255-21-1*
Mechanical Shock and Bump Test	*IEC-60255-21-2 Class I*

The models comply with the EEC 89/336 standard of electromagnetic compatibility.

2.3 Physical Architecture

2.3.1 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.

The modules are mounted vertically and can be extracted by removing the front panel. Do not require the dismantling of the front of the unit. 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 for analogical inputs, and pointed hubs for digital inputs and outputs and for transducer inputs.

Depending on the terminal configuration, all the contact inputs / outputs may be used or some may remain as spare signals.

Figures 2.3.1, 2.3.2 and 2.3.3 represent the external appearance of the **2IRX** models.

Mounted on the front are the alphanumeric keypad and display, the local communication ports (RS232C and USB), the local control buttons and the LED targets.

Figure 2.3.1 Front of a 2IRX.

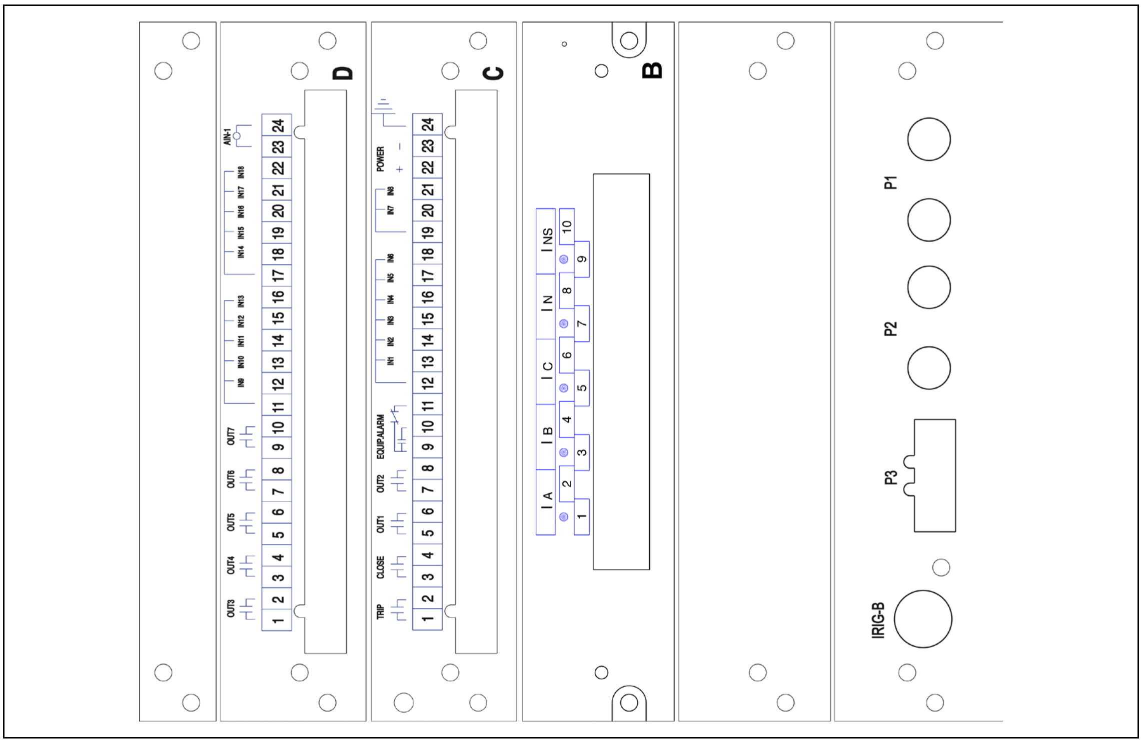


Figure 2.3.2 Rear of a 2IRX-A with Nomenclature.

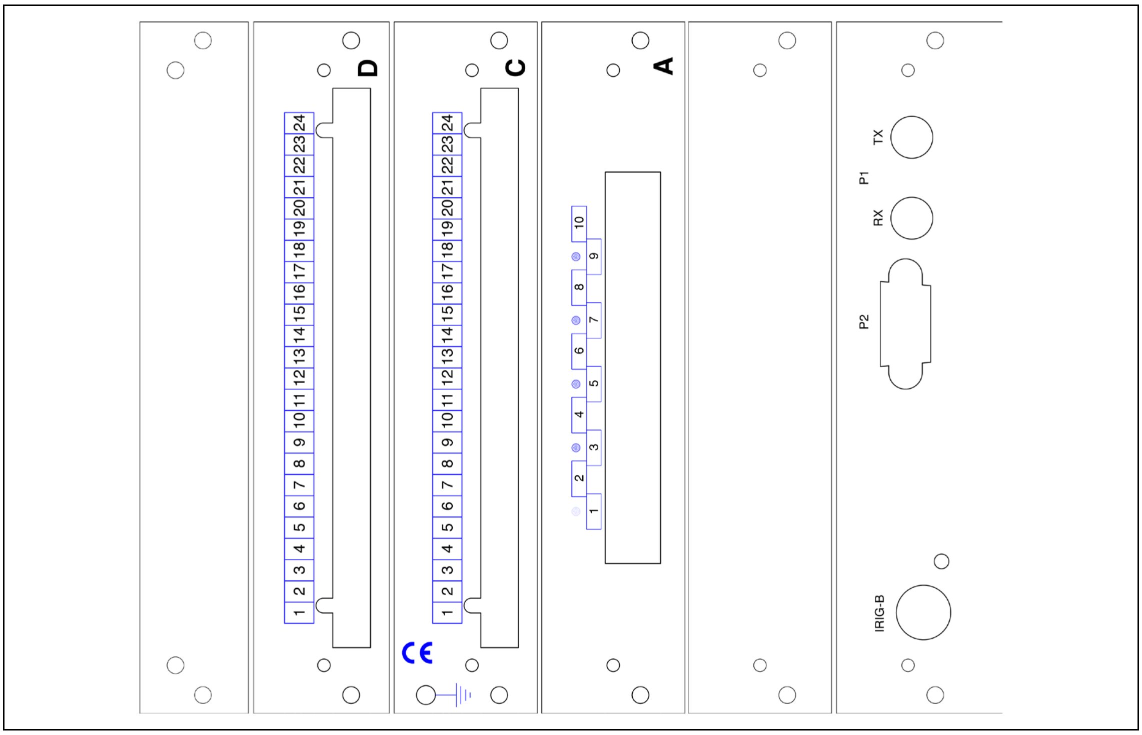


Figure 2.3.3 Rear of a 2IRX-A without Nomenclature.

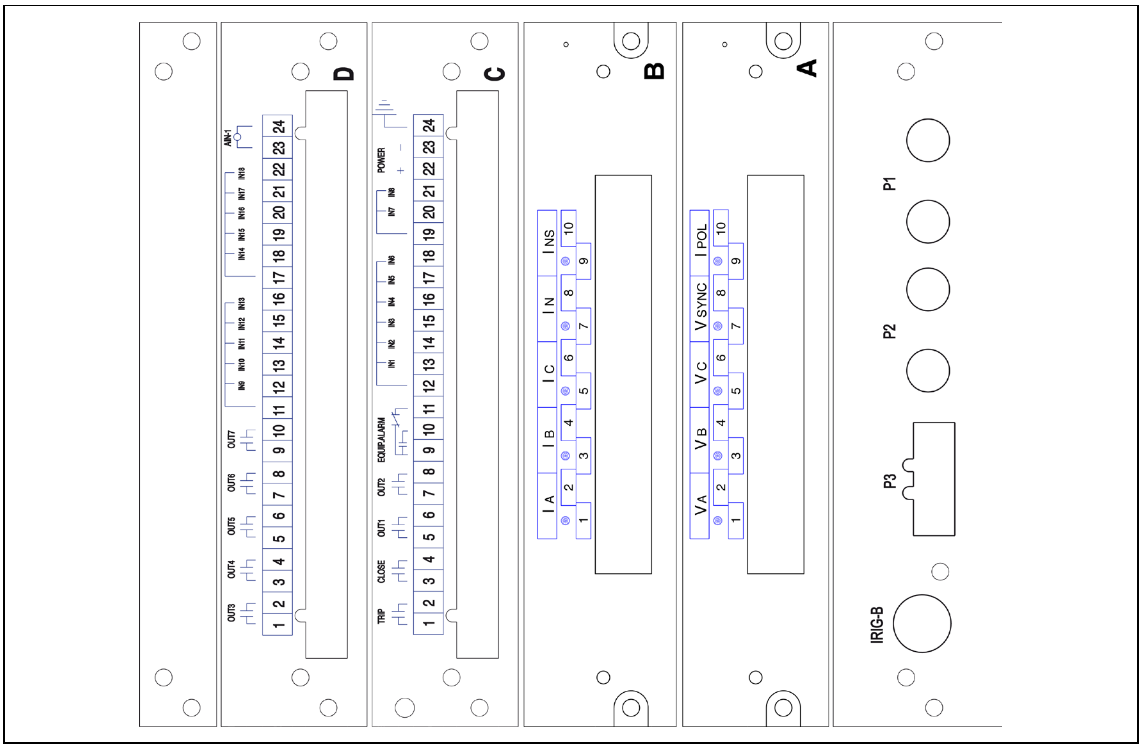


Figure 2.3.4 Rear of a 2IRX-B with Nomenclature.

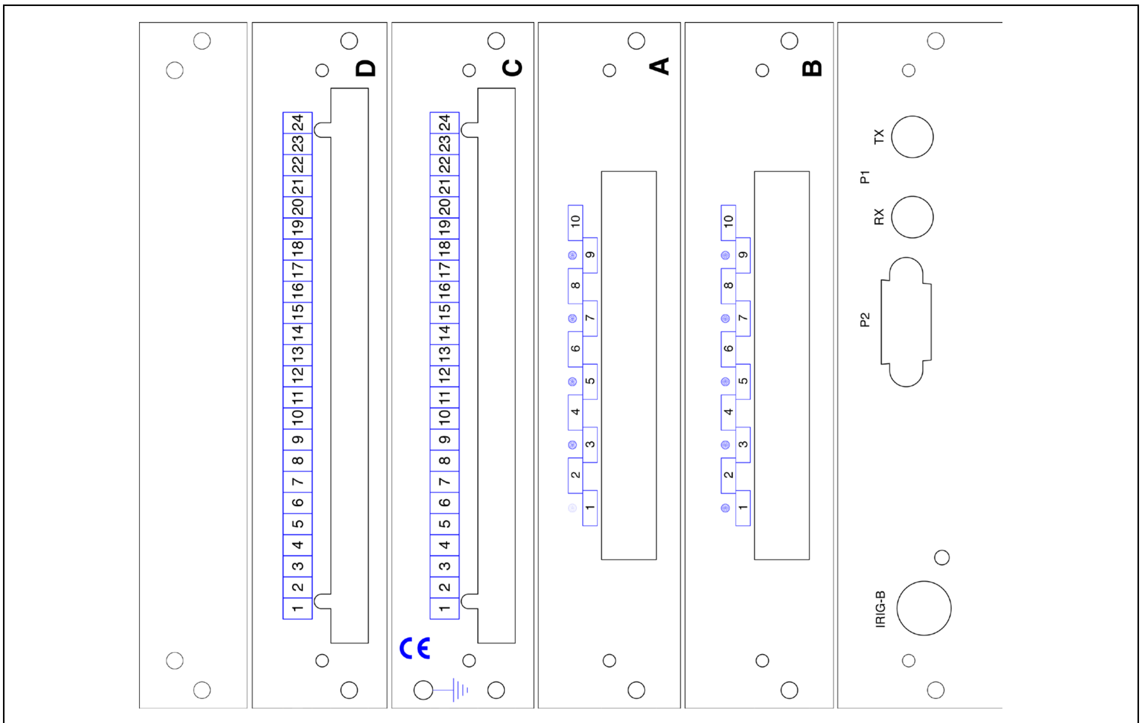


Figure 2.3.5 Rear of a 2IRX-B without Nomenclature.

2.3.2 Dimensions

The equipment is intended to be installed either semi-flush mounted on panels or inside a 19” rack. The enclosure is graphite gray. The dimensions are 1/2 19" rack and 4 standard units high.

2.3.3 Connection Elements

2.3.3.a Terminal Blocks

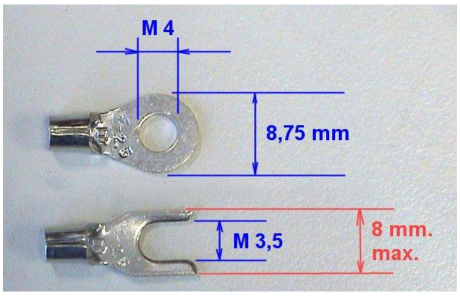
The number of connectors for the relays depend on the number of analogical inputs and the digital inputs / outputs of the specific model.

Terminal blocks are vertical as shown in the figures 2.3.2 and 2.3.3. The terminal arrangement is as follows:

- 1 column for all the communication and synchronization connectors.
- 1 or 2 columns with 1 terminal block of 10 terminals for analog currents/voltages.
- 1 or more columns with 1 terminal block of 24 terminals for power supply input, digital inputs, auxiliary outputs, trip and close contacts and one analog transducer input

The self-shorting ring lug terminals corresponding to the current analog inputs take wires up to #10 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 24 terminals block admit a #13 AWG (2.5 mm^2) cable. Use of pointed hubs is recommended to connect to terminals.

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

WARNING!

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 printed circuit board is 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**.

2.3.3.c Internal Wiring

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

Chapter 3.

Functions and Description of Operation

3.1 Overcurrent Elements

Overcurrent protection elements

Three phase instantaneous overcurrent elements (50PH1, 50PH2 and 50PH3)
Three (according to model) ground instantaneous overcurrent elements (50N1, 50N2 and 50N3)
Three negative sequence instantaneous overcurrent elements (50NS1, 50NS2 and 50NS3)
One sensitive ground instantaneous overcurrent element (50SG)
Three phase time overcurrent elements (51PH1, 51PH2 and 51PH3)
Three ground time overcurrent elements (51G1, 51G2 and 51G3)
Three negative sequence time overcurrent elements (51NS1, 51NS2 and 51NS3)
One sensitive ground time-overcurrent element (51SG)
One voltage dependent phase time overcurrent element (51V)
One ungrounded directional overcurrent element (67Na)

3.1.1 Phase, Ground and Sensitive Ground Instantaneous Elements

Phase, ground and sensitive ground instantaneous elements operate as a function of input current RMS value. Elements activate when RMS values exceed 1.05 times the pickup setting, and reset at 1 time the pickup setting.

Elements are provided with adjustable timers that allow for optional timing of instantaneous elements.

3.1.2 Negative Sequence Instantaneous Element

Negative sequence instantaneous element algorithm is the same as for phase, ground and sensitive ground.

The algorithm uses the criteria of negative sequence current RMS value calculated from phase current values.

3.1.3 Phase, Ground and Sensitive Ground Time Overcurrent Elements

In phase, ground and sensitive ground time overcurrent elements, the time overcurrent element operates on the input current RMS value. Element picks up when the measured value exceeds 1.05 times the setting value.

Element pickup enables the time delay function, which will make an integration of the measured values. This is carried out applying input current-dependant increments over a meter, the end of count of which governs the operation of the time overcurrent element.

These time elements, when inverse curve trip characteristics are used, count on two reset systems, as follows: “instantaneous” and “disc emulation”. The option “instantaneous” is adequate in applications that require coordination with static relays, while the option “disc emulation” can be used when the relay has to coordinate with electromechanical protections, mainly when they are facing the source that feeds the system.

Once the "instantaneous” reset system has been selected, the pickup reset takes place when the measured value drops to 1 time the setting value.

When the measured RMS value drops below the pickup setting, a quick integrator reset takes place. Output activation requires that the element remains picked up throughout the integration time; any reset will take the integrator to its initial conditions, such that a new operation will start counting from zero.

If “disc emulation” reset system is selected, the relay uses a reset process which is based on timer decrements, which starts up when the current drops below 100% of element pickup setting value, using the reset curve adequate to the trip characteristic employed.

Trip Time characteristics can be selected among the various types of curves according to **IEC**, **IEEE** (Standard IEEE C37.112-1996) and **US** standards:

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

The **RI Inverse Curve** may be added to the above curves, mainly used with electromechanical relays.

Time multiplier setting is the same as for **IEC**, **IEEE**, **US** and **RI Inverse** curves: range is 0.05 to 10 times.

Nevertheless, effective range for **IEC** curves is 0.05 to 1; for settings above 1, the maximum value of 1 is used. Effective range for the other curves (**IEEE**, **US** and **RI**) starts from 0.1 times; settings below this value operate as if they were set to the minimum value (0.1 times). Furthermore, although setting vary in steps of 0.01, the effective step for these three types of curve is 0.1; any setting other than a multiple of 0.1 will be rounded to the nearest tenth, namely, a setting of 2.37 will be applied as if it were 2.40 and a setting of 2.33 will be applied as if it were 2.30 (the setting 2.35 will be applied as if it were 2.40).

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.

Curves with **Time Limit** consist off the classic timed function with a time threshold, such that no trip is produced in a time less than specified. This means that after a given time, the trip curve becomes a horizontal straight line. This element operating limit matches the time setting used in the Fixed Time option, provided that this setting is less than the time given by the curve when the measured value exceeds 1.5 times the setting value.

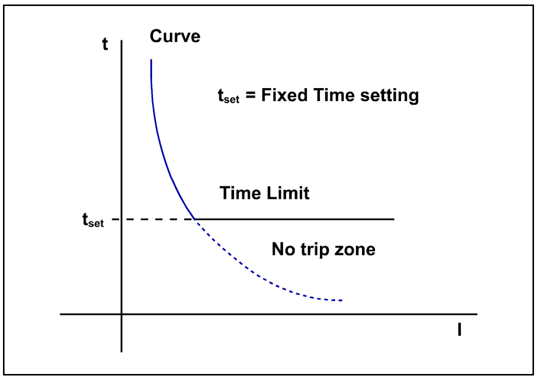


Figure 3.1.1 Diagram of a Curve with a Time Limit for a Time Overcurrent Element.

It may happen that the values set as Fixed Time are excessive with respect to the curve time for the different dials. In this case, provided the curve time (for the set dial and a current 1.5 times greater than the set current value) is less than the Fixed Time setting, the 1.5 times value is used as the element operating straight line limit. Thus, we may say that when the Fixed Time setting is above the curve time for a current 1.5 times the setting value, the operating time will be limited to the 1.5 times value, turning the trip curve into a horizontal straight line.

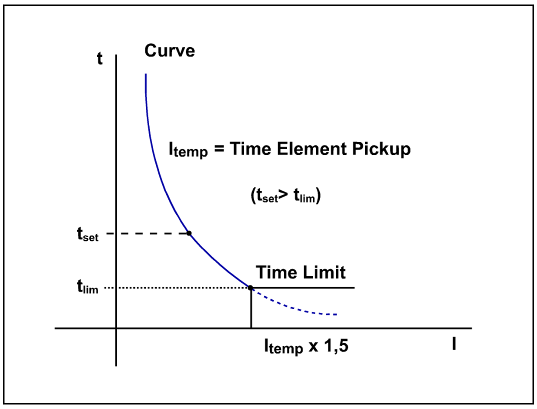


Figure 3.1.2 Time Limit of the Element when the Fixed Time is Greater than the Curve Time (in pickup x 1.5).

For any IEC, IEEE and US trip curve there is a characteristic that emulates the reset time of the electromechanical relays. The following is an equation that describes the duration of the reset time:

$$t_{RESET} = index \times \left[\frac{t_r}{1 - \left(\frac{I}{I_{pick-up}} \right)^2} \right]$$

where **tr** is the characteristic constant which varies depending on the trip curve selected.

The values for **tr** are those indicated in the following table:

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

The pickup reset, when inverse RI curve is selected, always takes place instantaneously, no matter the **Reset Type** setting.

Note: it is worth highlighting that although curves are defined for an input value of up to 40 times the tap, which is the pickup setting of each of the time overcurrent elements, said range cannot always be guaranteed.

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 $\frac{SaturationLimit}{ElementSetting} > 40$ **, curve operation is guaranteed for elements with said setting over the entire tap range (up to 40 times the setting).**

If $\frac{SaturationLimit}{ElementSetting} < 40$ **, 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 40 times the setting is injected, trip time will be the same as for said 40 times.

3.1.3.a Current / Time Characteristic: Trip Inverse Curves

Figures 3.1.3, 3.1.4, 3.1.5, 3.1.6 and 3.1.7 present the Trip Inverse Curves according to the IEC standards.

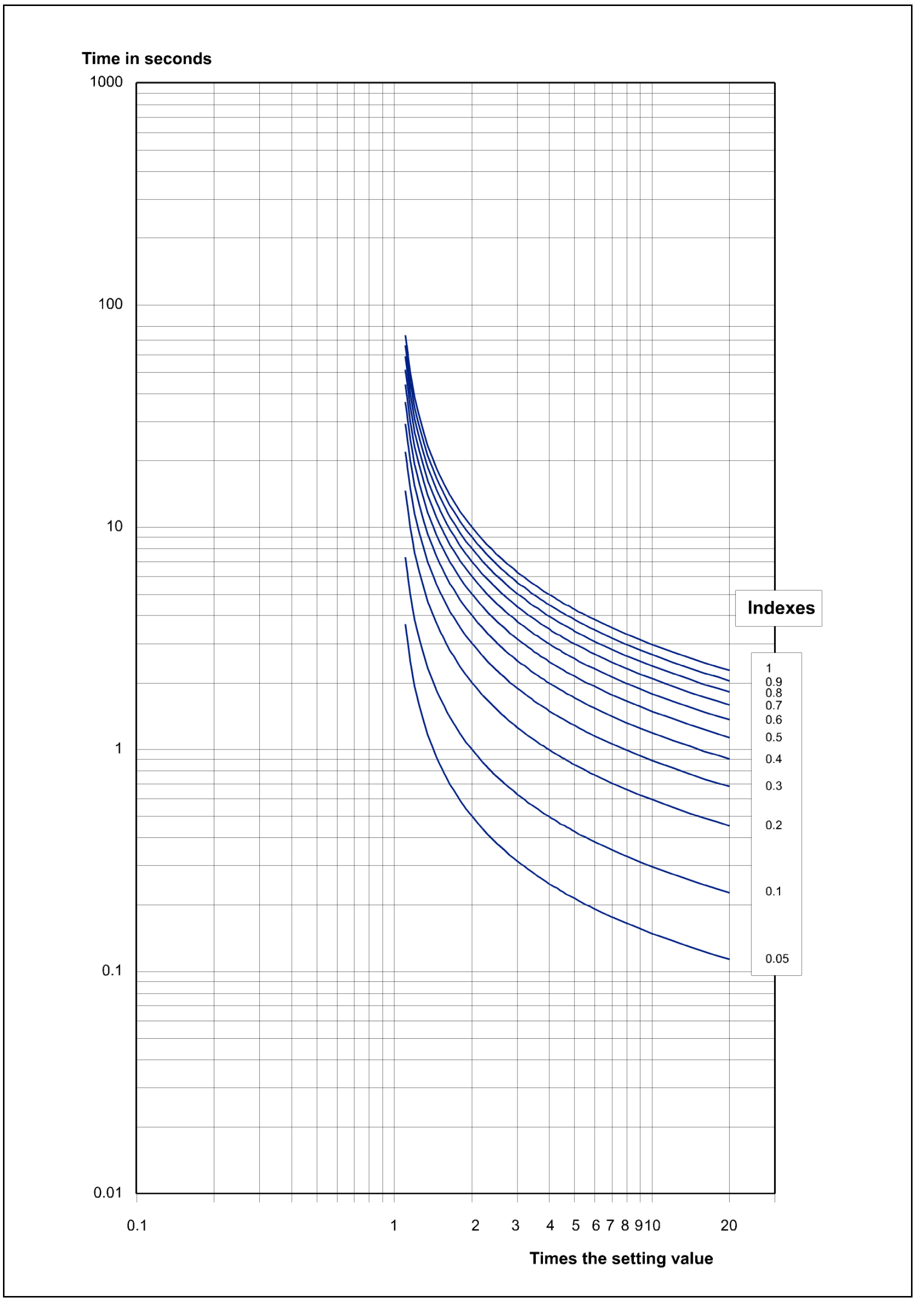


Figure 3.1.3 INVERSE Time Curve (IEC).

$t = \dfrac{0.14}{I_S^{\,0.02} - 1} \times \text{Index}$	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

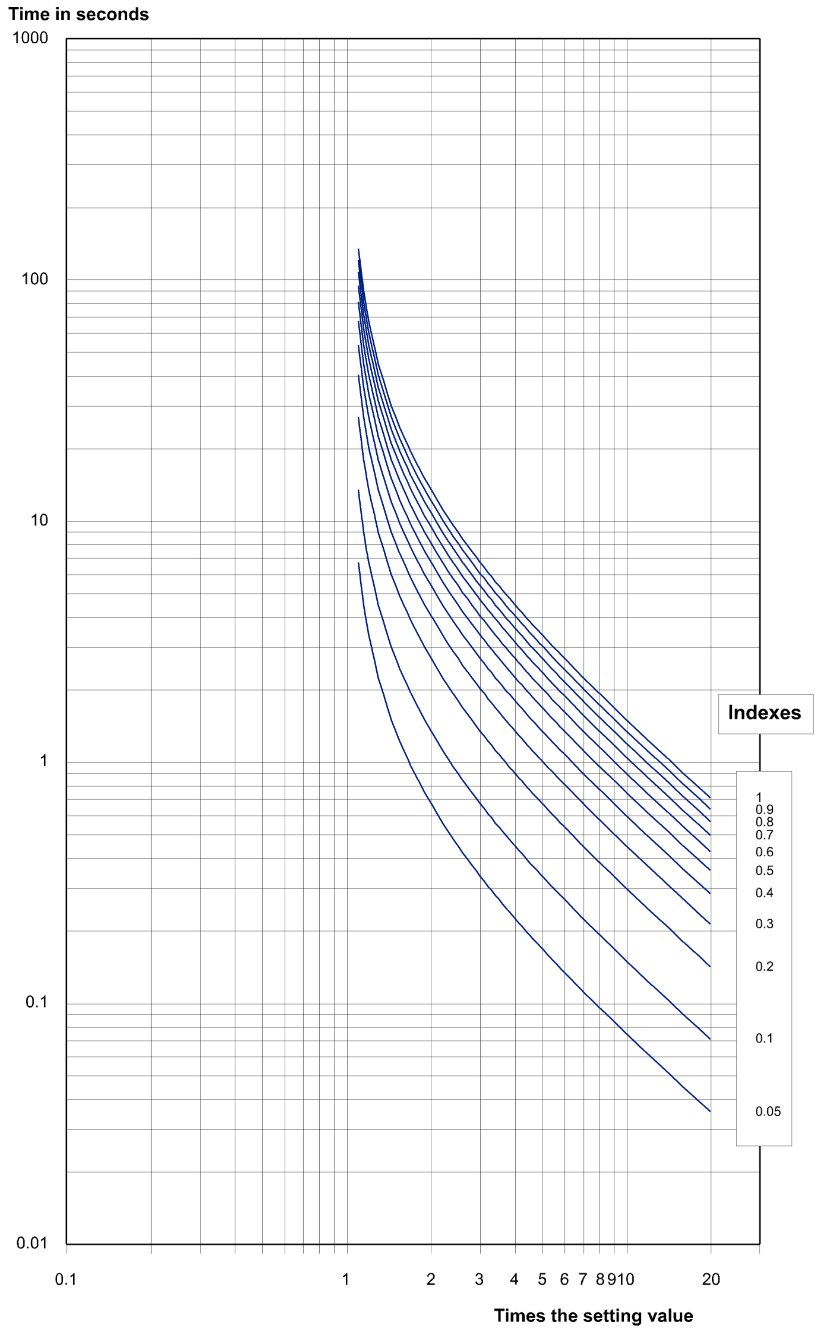


Figure 3.1.4 VERY INVERSE Time Curve (IEC).

$t = \frac{13.5}{I_S - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

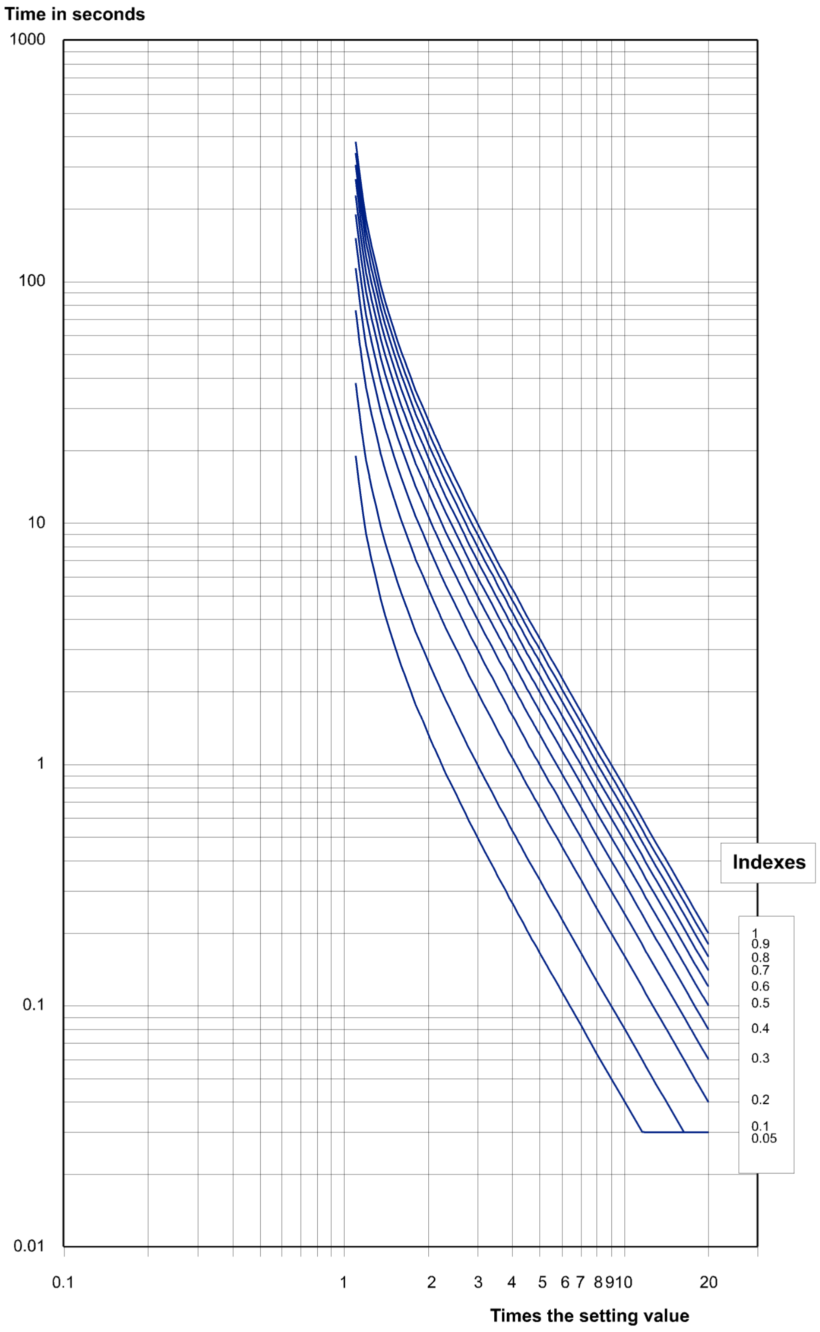


Figure 3.1.5 EXTREMELY INVERSE Time Curve (IEC).

$t = \frac{80}{I_S^{\,2} - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

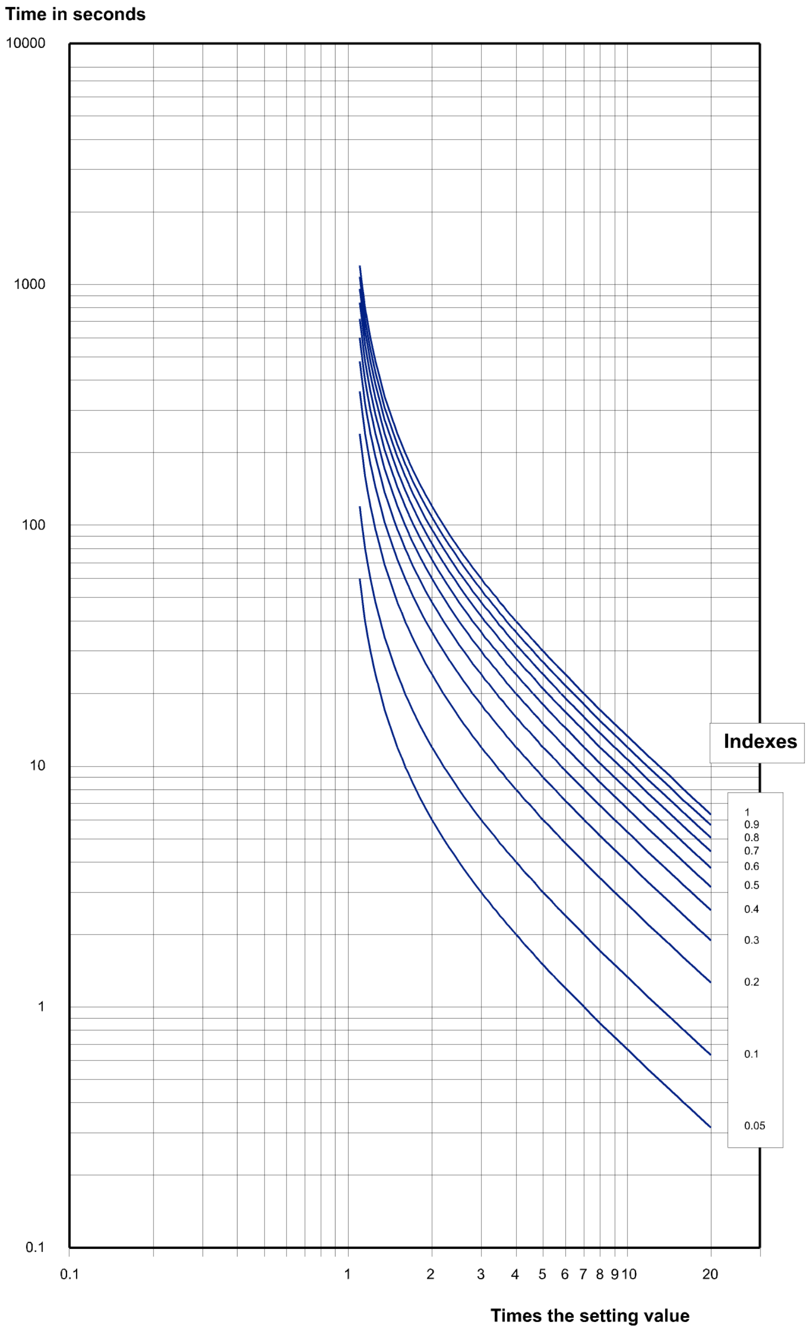


Figure 3.1.6 LONG TIME-INVERSE Curve (IEC).

$t = \frac{120}{I_S - 1}$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

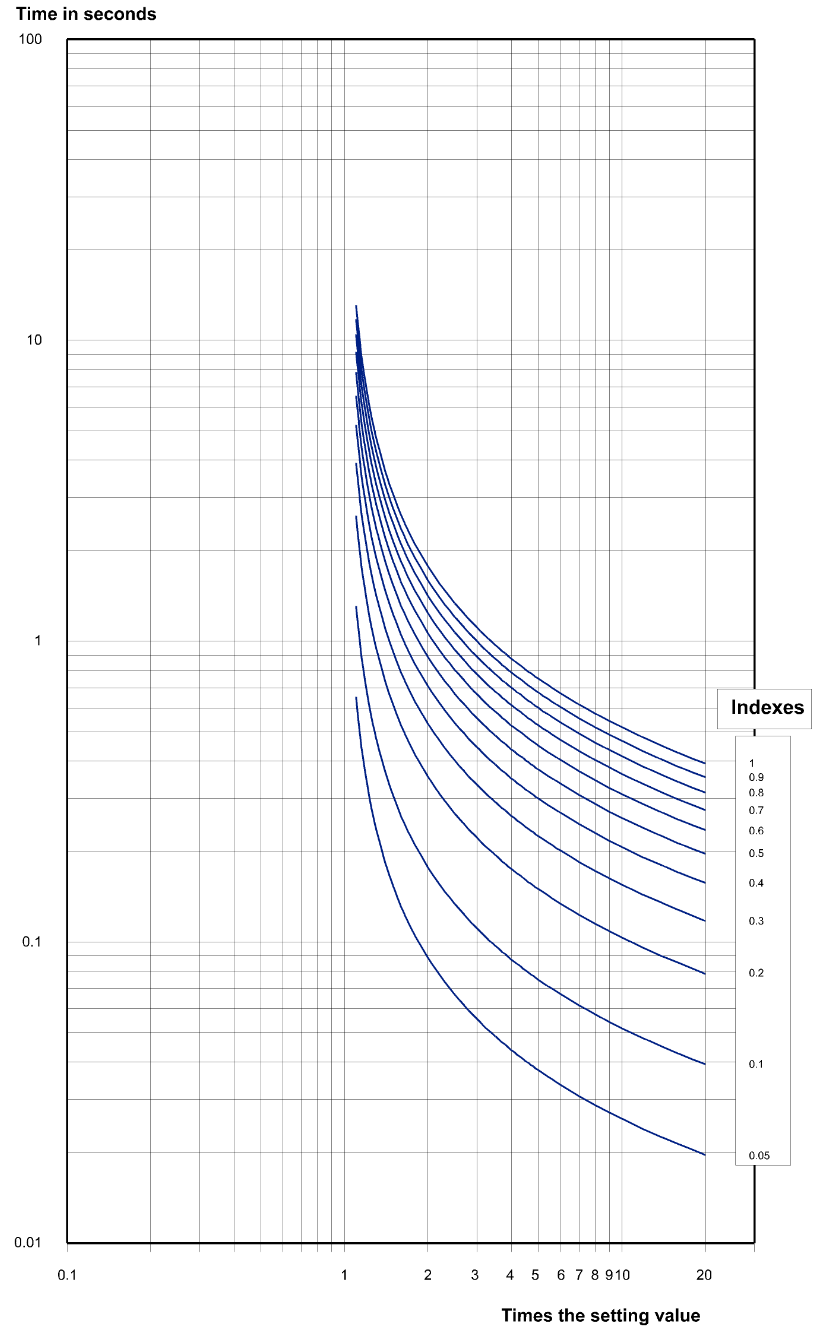


Figure 3.1.7 SHORT TIME-INVERSE Curve (IEC).

$t = \dfrac{0.05}{I_S^{\,0.04} - 1}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

Figures 3.1.8, 3.1.9, 3.1.10, 3.1.11, 3.1.12, 3.1.13, 3.1.14 and 3.1.15 present the inverse curves according to the IEEE and US standards.

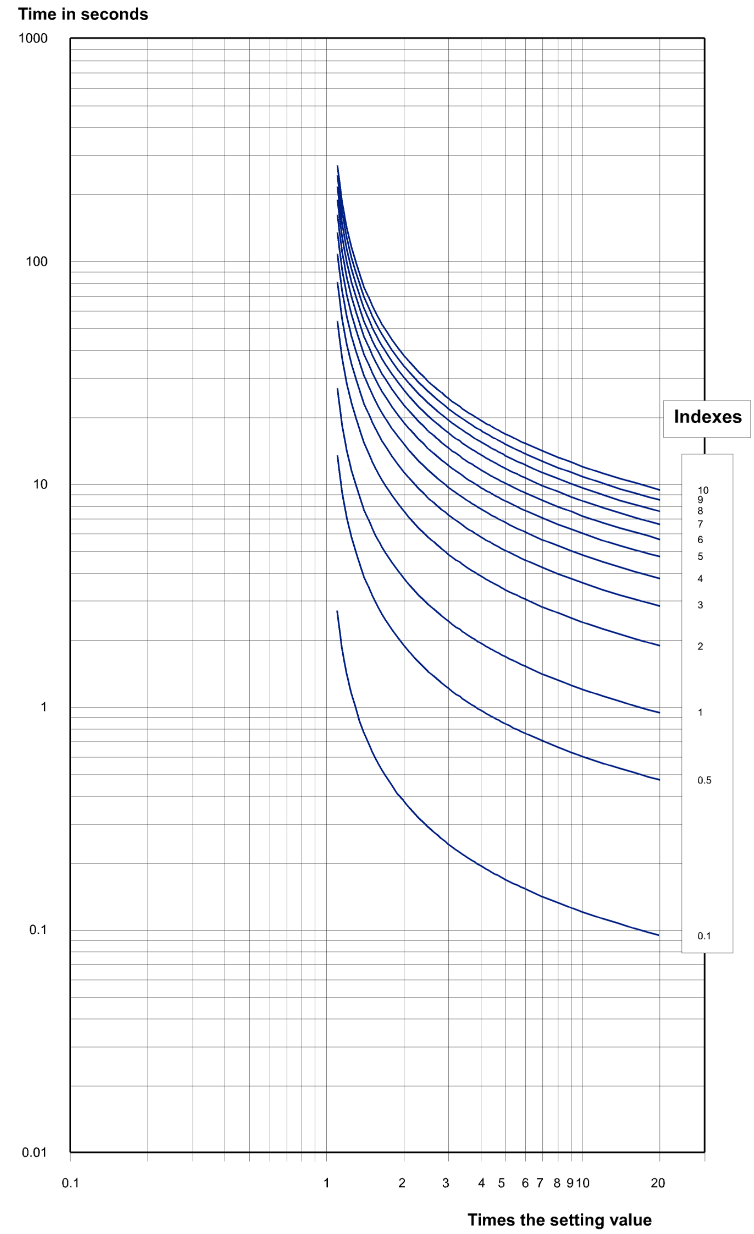


Figure 3.1.8 MODERATELY INVERSE Time Curve (IEEE).

$t = \left(0.114 + \dfrac{0.0515}{I_S^{\,0.02} - 1}\right)$ x Index	$I_S = \dfrac{I\ measured}{I\ pickup}$

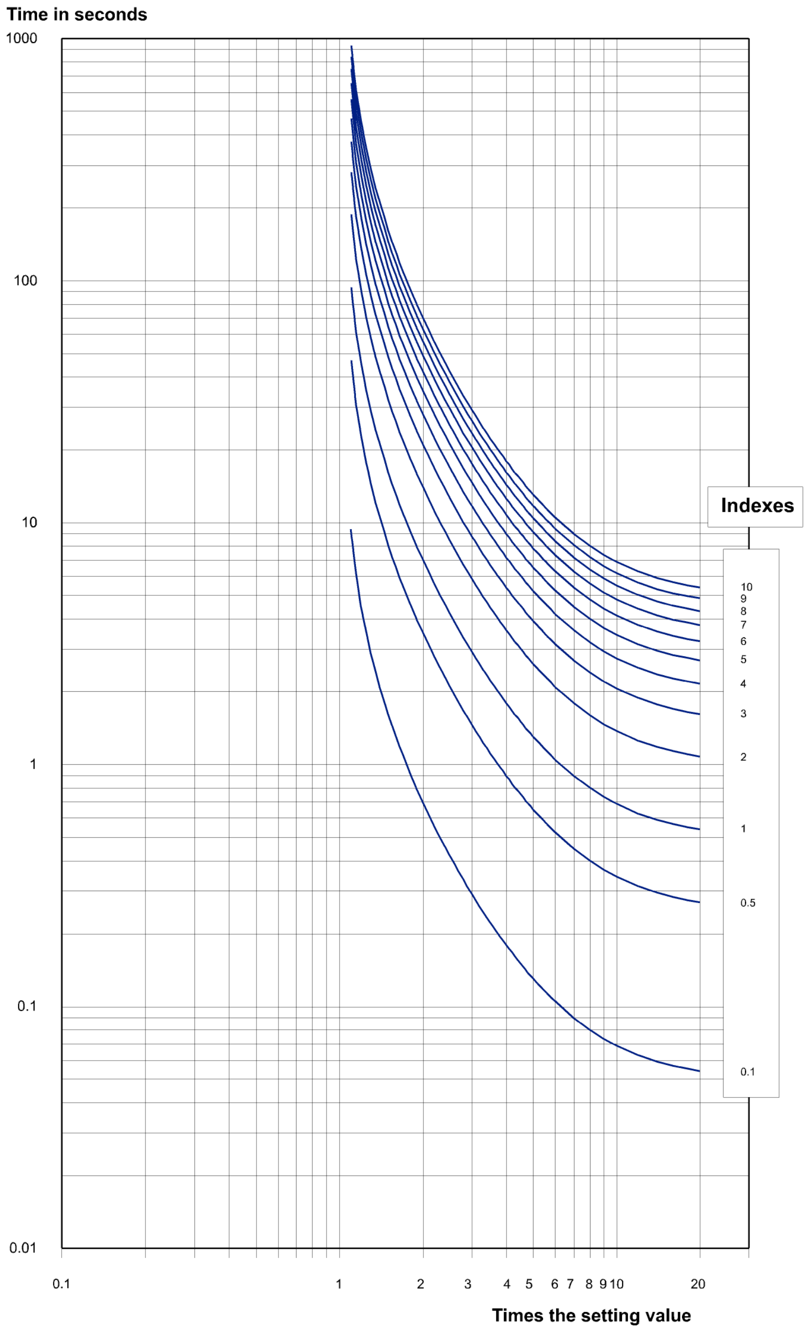


Figure 3.1.9 VERY INVERSE Time Curve (IEEE).

$t = \left(0.491 + \frac{19.61}{I_S^{2} - 1}\right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

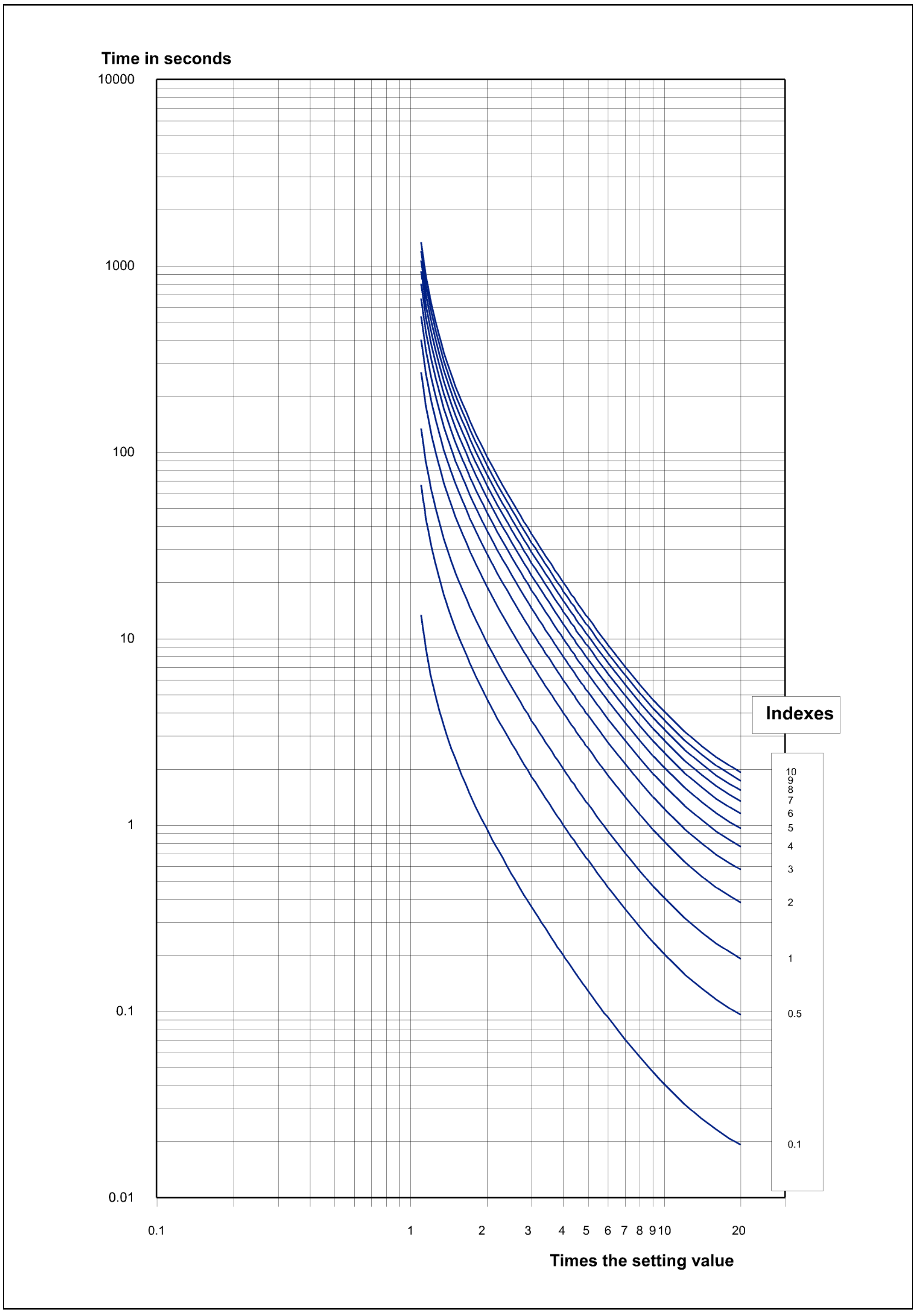


Figure 3.1.10 EXTREMELY INVERSE Time Curve (IEEE).

$t = \left(0.1217 + \dfrac{28.2}{I_S^2 - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

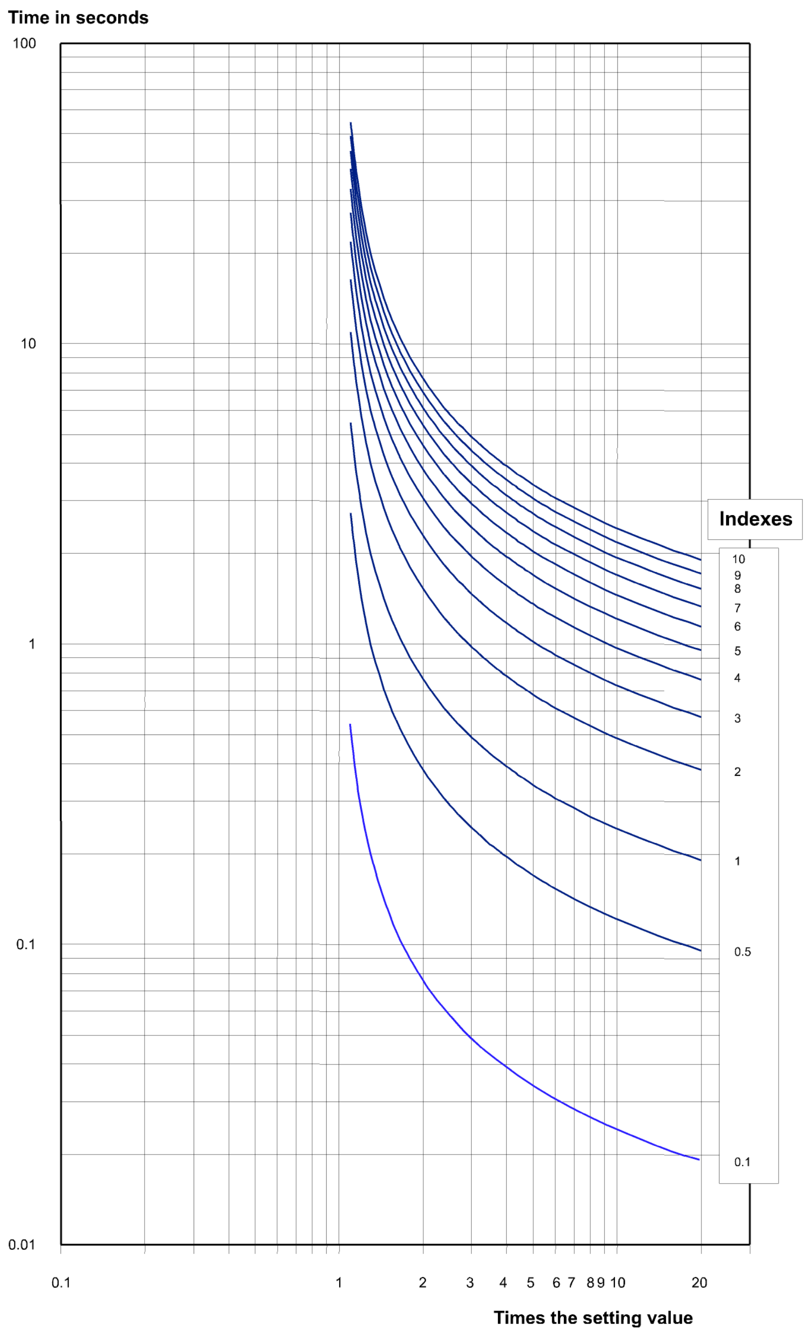


Figure 3.1.11 MODERATELY INVERSE Time Curve (U.S.).

$t = \left(0.0226 + \dfrac{0.0104}{I_S^{0.02} - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

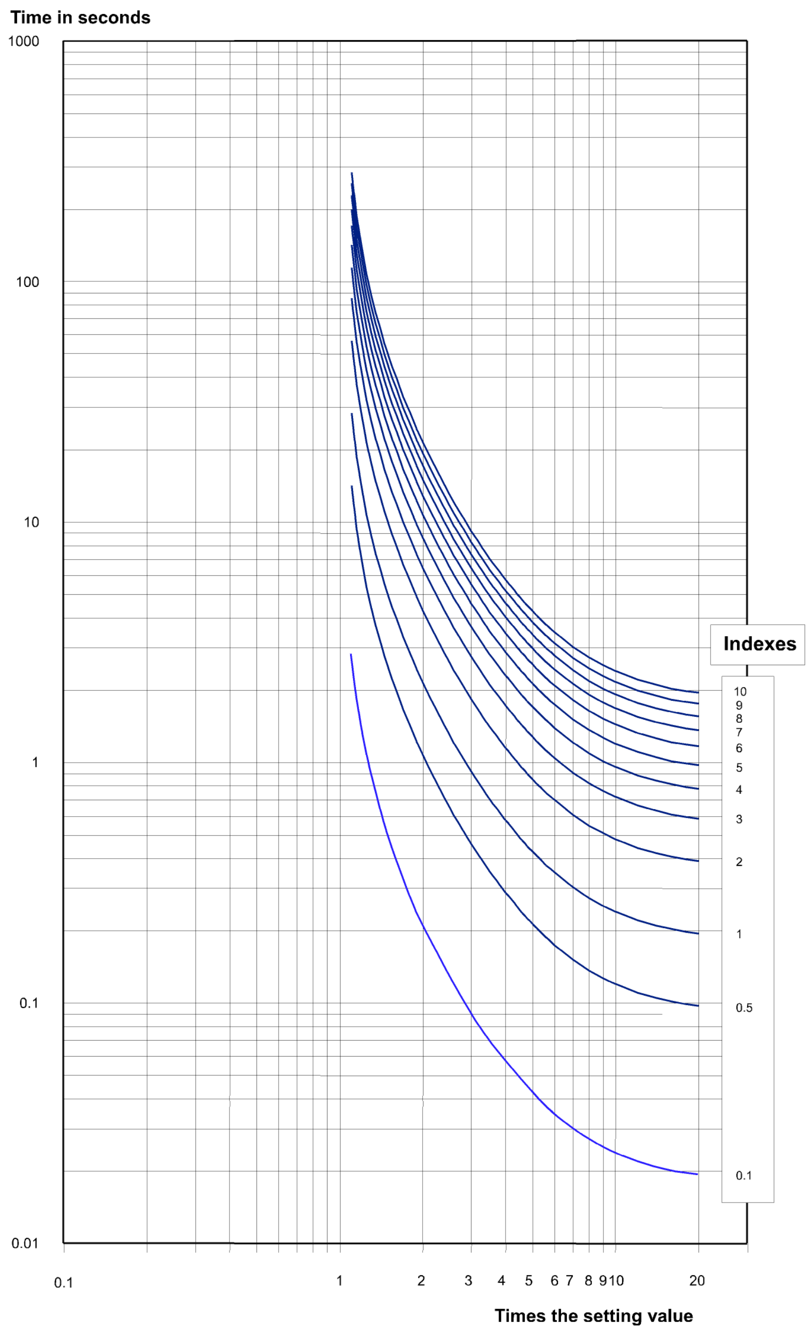


Figure 3.1.12 INVERSE Time Curve (U.S.).

$t = \left(0.180 + \dfrac{5.95}{I_S^{\,2} - 1}\right)$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

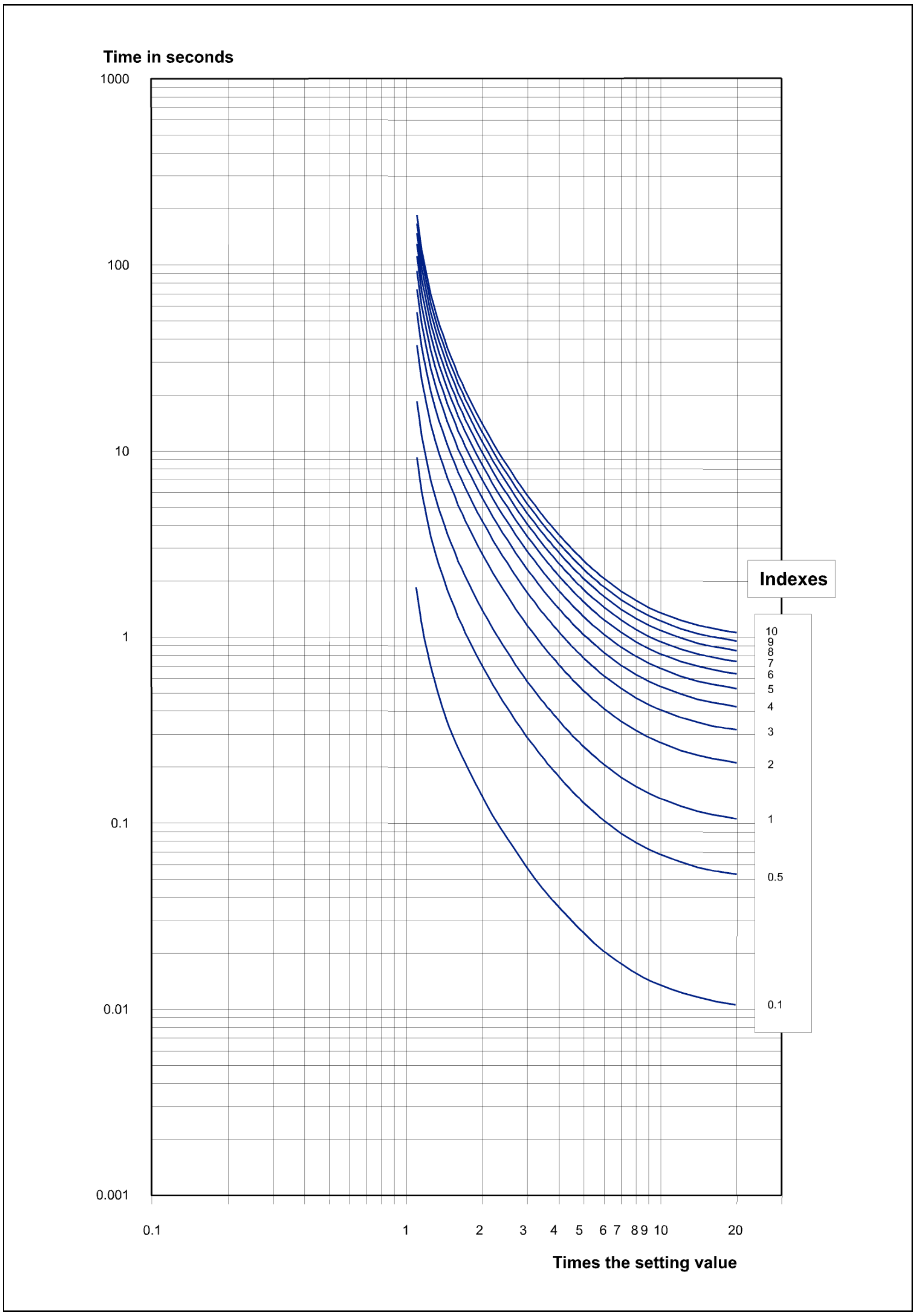


Figure 3.1.13 VERY INVERSE Time Curve (U.S.).

$t = \left(0.0963 + \frac{3.88}{I_S^2 - 1} \right)$ x Index	$I_S = \frac{I\ measured}{I\ pickup}$

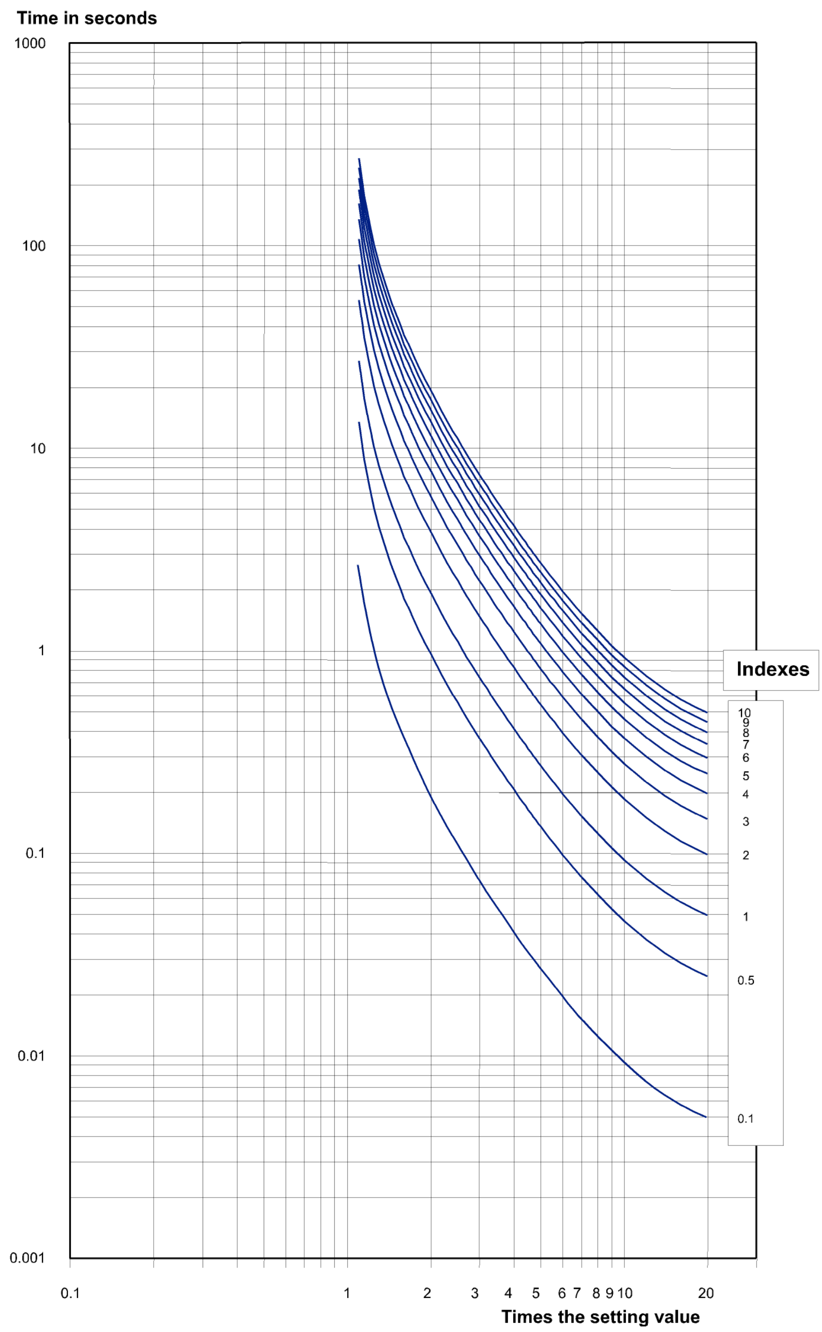


Figure 3.1.14 EXTREMELY INVERSE Time Curve (U.S.).

$t = \left(0.0352 + \frac{5.67}{I_S^{\,2} - 1} \right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

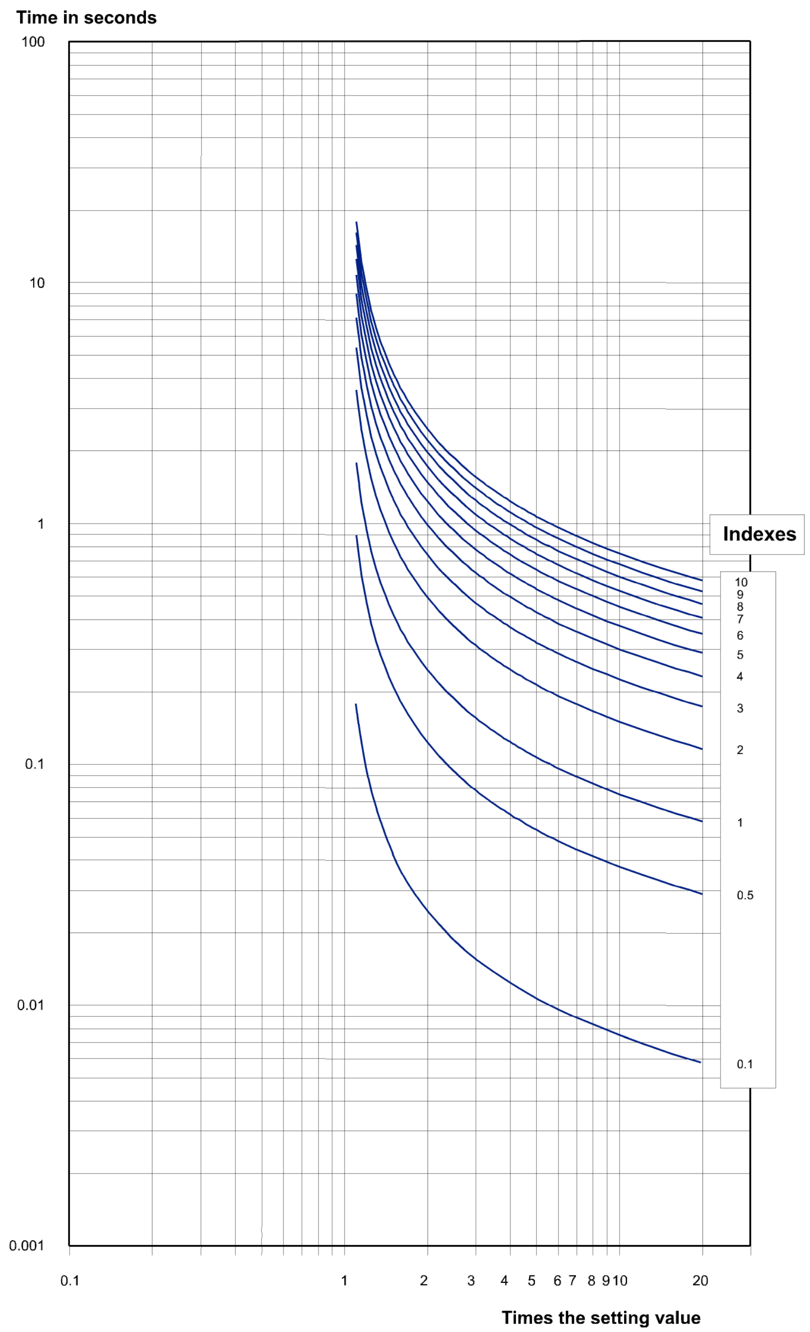


Figure 3.1.15 SHORT INVERSE Time Curve (U.S.).

$t = \left(0.00262 + \frac{0.00342}{I_S^{0.02} - 1} \right)$ x Index	$I_S = \frac{I\ measured}{I\ pickup}$

And figure 3.1.16 presents the RI inverse curve.

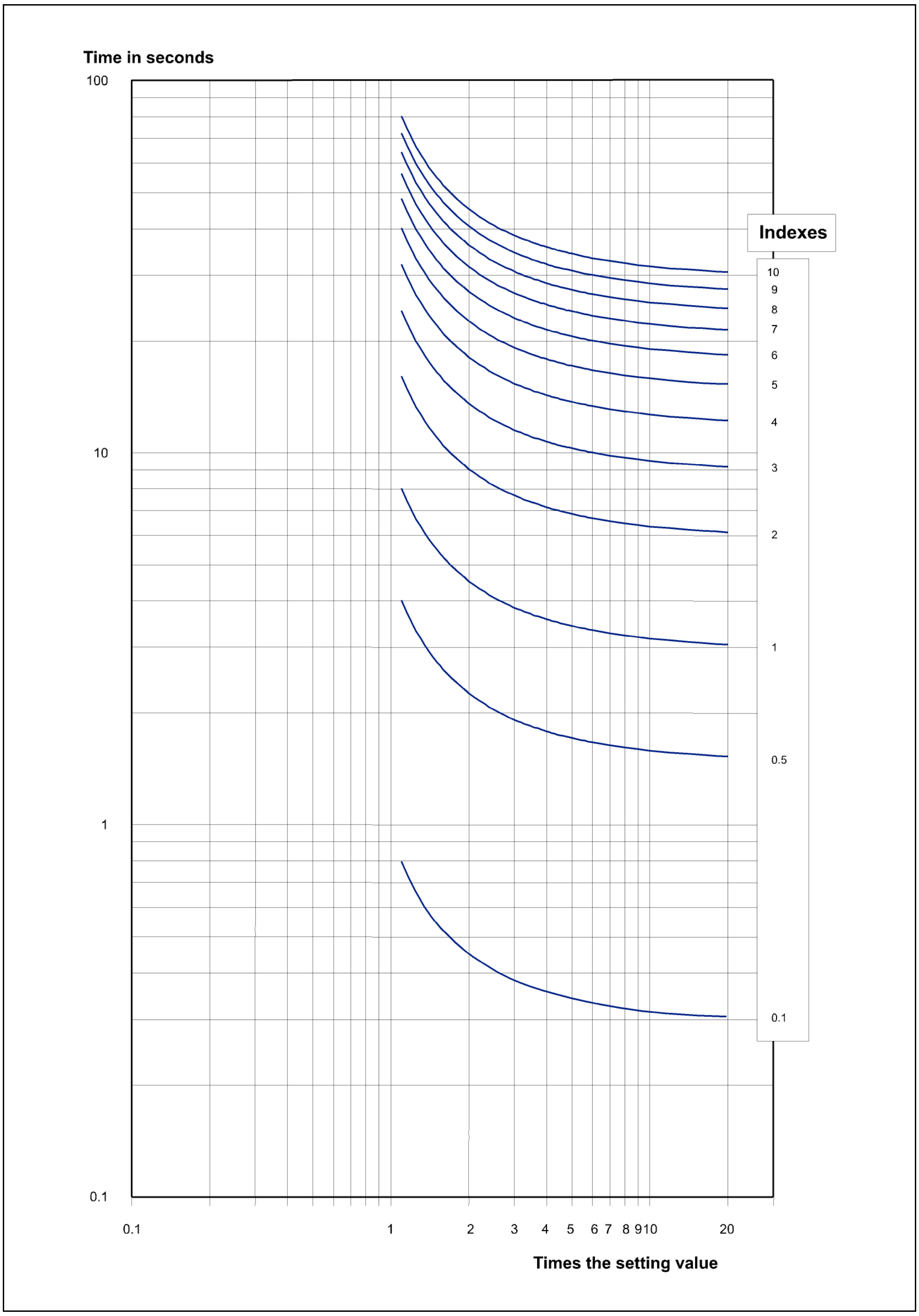


Figure 3.1.16 RI INVERSE Time Curve.

$t = \dfrac{1}{0.339 - 0.236 \cdot \left(\dfrac{1}{I_S}\right)}$ x Index	$I_S = \dfrac{I_{measured}}{I_{pickup}}$

3.1.4 Negative Sequence Time Overcurrent Element

Same as for instantaneous elements, the negative sequence time-overcurrent algorithm is the same as for phase, ground and sensitive ground.

Time delay functions and time characteristics are the same as stated in paragraph 3.1.3.

3.1.5 Overcurrent Element Block Diagrams

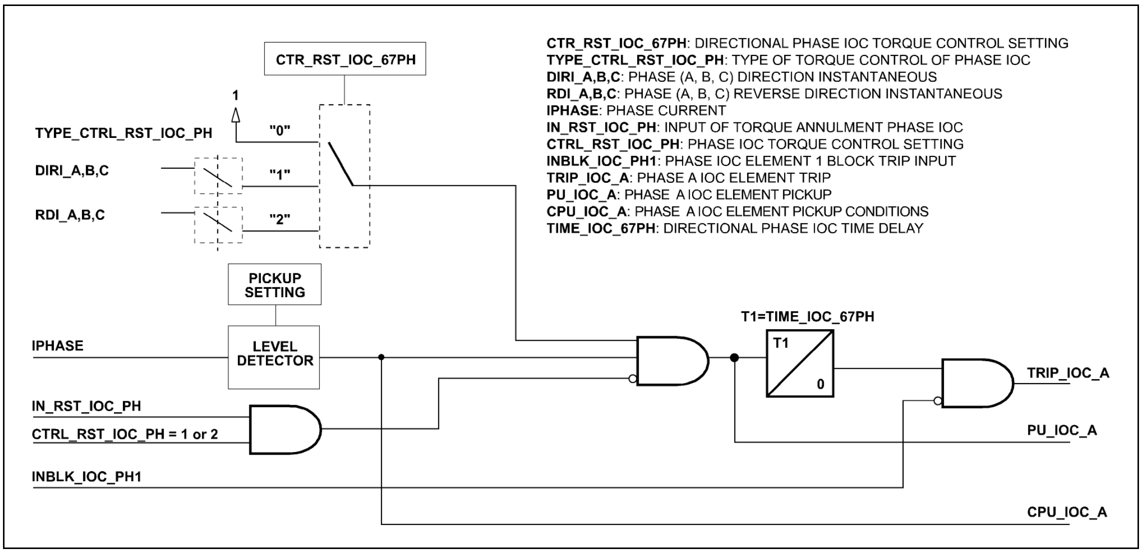


Figure 3.1.17 Block Diagram of a Phase Instantaneous Overcurrent Element.

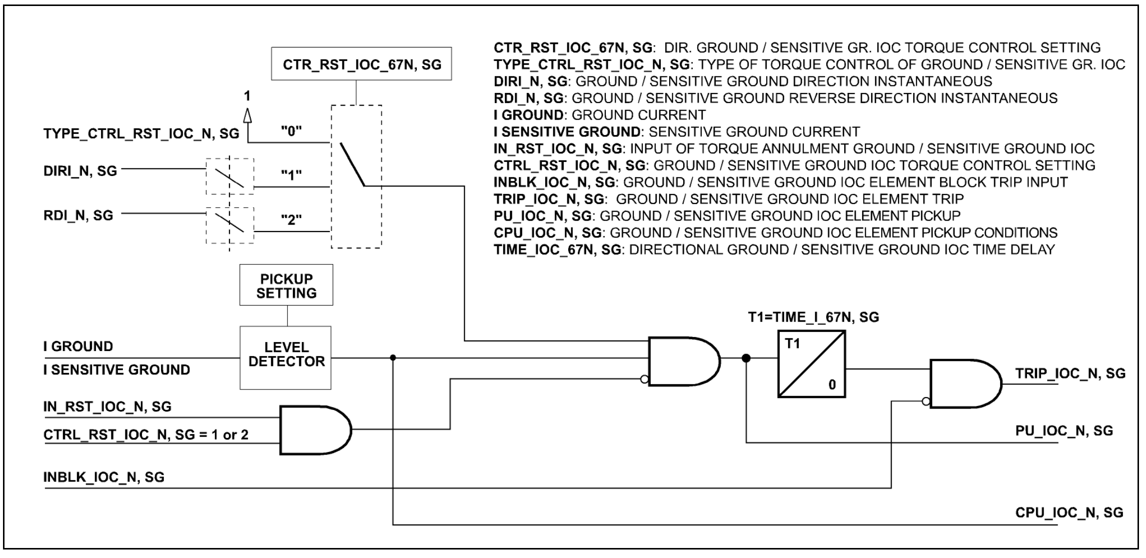


Figure 3.1.18 Block Diagram of a Ground and Sensitive Ground Instantaneous Overcurrent Element.

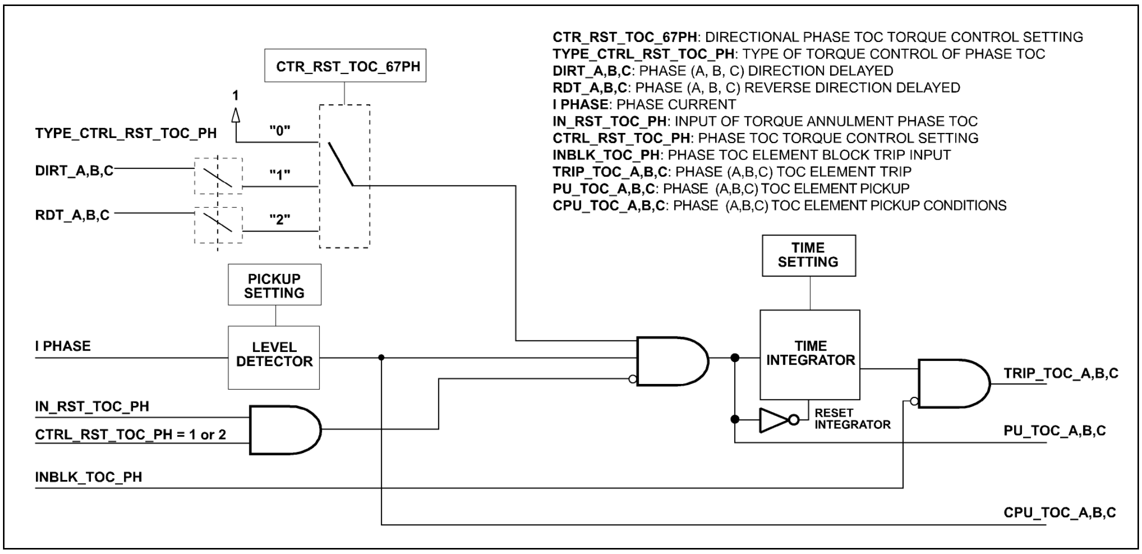


Figure 3.1.19 Block Diagram of a Phase Time Overcurrent Element.

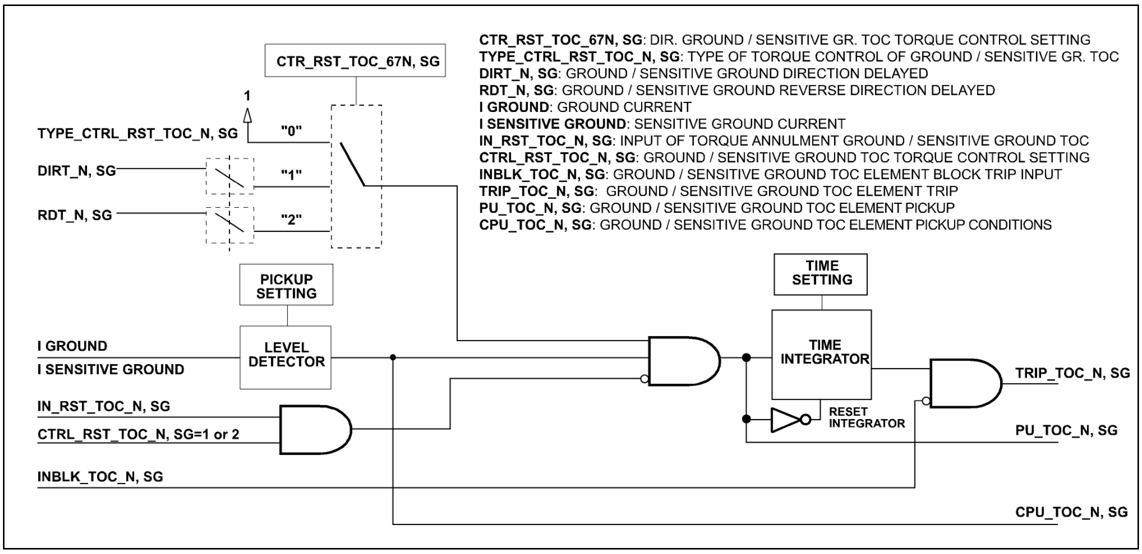


Figure 3.1.20 Block Diagram of a Ground and Sensitive Ground Time Overcurrent Element.

Direction (**DIR**) and **Reverse Direction** (**RD**) signals included in the above diagrams come from the directional elements. For more information see 3.2.

Block diagrams, both for **Negative Sequence Time Overcurrent** element and **Negative Sequence Instantaneous Overcurrent** element are similar to Ground and Sensitive Ground elements. They differ in that the digital signals are specific to these elements.

3.1.6 Voltage Dependent Time-Overcurrent Element

This element operates as a back up for generator differential element. It also operates for downstream faults not cleared by other failed relay or breaker, as a generator is a power source for any line fault until cleared.

Voltage dependent elements guarantee that no operation takes place on overcurrent conditions, providing the high sensitivity required by the limited capacity of the generator to supply sustained short-circuit current. Generator-fed fault current decays with time, decay rate varying as a function of generator voltage control system operation; at worse, the fault current will drop below maximum load current, so that single overcurrent protection will not be activated.

Coordination with downstream overcurrent relays is vital, allowing for quick operation but avoiding trips on load.

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**.

3.1.6.a Voltage Restraint Time Element

It consists of a definite time element with a variable pickup setting 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 3.1-1: Voltage Restraint Time Element

Phase Current	Control Voltage (Phase Sequence ABC)	Control Voltage (Phase Sequence ACB)
IA	UAB	UAC
IB	UBC	UBA
IC	UCA	UCB

This variable characteristic makes coordination with downstream devices more difficult. In any case, this mode is deemed the most appropriate mode when the generator is coupled with the line through a booster transformer; if a phase to phase fault occurs at busbar connection, only a partial phase to phase voltage drop would occur at generator terminals.

Pickup setting multiplier is a function of the measured voltage as shown in figure 3.1.21 and in following table.

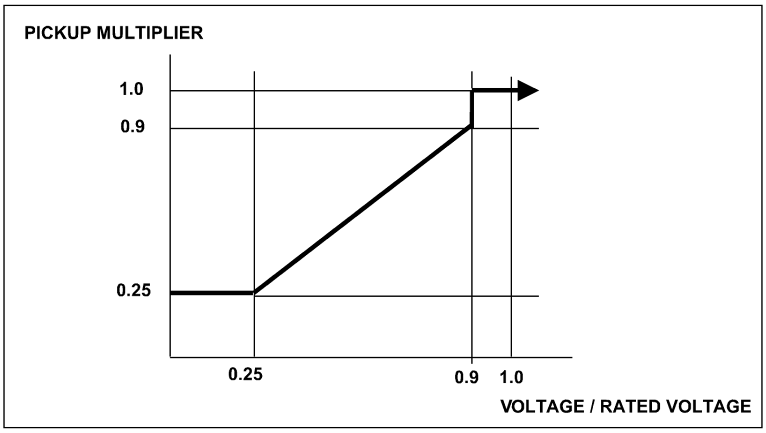


Figure 3.1.21 Voltage Restrained Time Overcurrent Element.

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

3.1.6.b Voltage Controlled Time 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.

3.1.6.c Setting and Tripping Criteria

Pickup current for these elements is typically defined as 125% of full load at normal voltage.

Trip time selection must take into account the coordination with downstream devices, as booster transformers.

The percentage of the nominal voltage is figured out based on Nominal Voltage (Vn) setting incorporated in **IRX** relay. As this element works using phase-to-phase voltages, full nominal voltage is deemed to have been reached when control voltage measured value is Vn.

Current elements pickup at 105 % of setting value and reset at 100%.

In **Voltage Controlled** mode, the operate voltage enables pickup at 100% of setting and resets at 105%.

3.1.7 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, models **IRX** are provided with **Torque Control Type** in Ground Overcurrent elements. This allows selecting the supervising directional element. Possible values for each type of overcurrent elements are as follows:

- **Phase Overcurrent** (instantaneous and time overcurrent). They are not provided with this setting as they are only monitored by the Phase Directional element (67PH).

- **Ground and Sensitive Ground Overcurrent** (instantaneous and time overcurrent).
  67G (ground directional element)
  67NS (negative sequence directional element). Option 67NS may be interesting compared with option 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 (67NS).

3.1.8 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. 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.

3.1.9 Blocking by Harmonics

The energising of a transformer causes transient saturation as a consequence of the dc component generated in the magnetic flux. This results in high magnetising currents (*inrush*), which can be several times the machine rated current.

Under over excitation conditions of the transformer, as a result of overvoltage and under frequency, important magnetising currents can also be produced.

In order to avoid the operation of overcurrent elements under the mentioned magnetising currents, **IRX-***-****F0**** models include the blocking by harmonics function. In order to differentiate between a fault current and an *inrush* current, both with high fundamental component, the 2nd and 5th harmonic components are analysed.

Energising 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 **Blocking by 2nd harmonic enable** and **Blocking by 5th harmonic 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 **Blocking by 2nd harmonic 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 **Residual ground blocking by 2nd harmonic** will activate, as a function of the type of current analysed. Likewise, when the ration between the 5th harmonic current and the fundamental current exceeds the setting **Blocking by 5th harmonic 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 **Residual ground blocking by 5th harmonic** activate. The signals **Phase A blocking by harmonics**, **Phase B blocking by harmonics**, **Phase C blocking by harmonics**, **Ground blocking by harmonics** and **Residual ground blocking by harmonics** are OR functions of the corresponding blocking signals by 2nd and 5th harmonic.

All overcurrent elements of **IRX-***-****F0**** models include the setting **Blocking by harmonics**. When this setting is set to **Yes**, the applicable overcurrent element will be blocked by the corresponding blocking by harmonics signal. The phase A overcurrent element 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 residual ground). This setting must equal the minimum pickup level setting of the applicable overcurrent element (phase, ground or residual ground).

For phase overcurrent 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 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 of 3** option has a better response than the **OR** option. When the energised transformer winding has the neutral connected to ground and another winding is delta connected, the logic **2 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 of 3** option will not be met either.

The **AND** option of the setting **Type of blocking by harmonics** disables the crossed-blocking logic.

The setting **Cross-blocking time** limits the duration of the cross-blocking logic. 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 energising 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 energised from the star side, the **2 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 of 3** is met. This signal will be used to block the negative sequence overcurrent elements, provided the setting **Blocking by harmonics** is enabled.

3.1.10 Overcurrent Elements Settings

Phase Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Phase TOC Enable	YES / NO		NO
Phase TOC Pickup	(0.02 - 25) In	0.01 A	2.00 A
Phase TOC Curve	See list of curves		Definite Time
Phase TOC 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
Phase TOC Definite Time	0.05 - 300 s	0.01 s	0.05 s
Phase TOC Direction	0: None 1: Direction 2: Reverse		0: None
Reset Type	0: Instantaneous 1: Disc Emulation		0: Instantaneous
Blocking by Harmonics (**IRX*******F0*****)	YES / NO		NO

Ground Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Ground TOC Enable	YES / NO		NO
Ground TOC Pickup	(0.02 - 25) In	0.01 A	1.00 A
Ground TOC Curve	See list of curves		Definite Time
Ground TOC 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
Ground TOC Definite Time	0.05 - 300 s	0.01 s	0.05 s
Ground TOC Direction	0: None 1: Direction 2: Reverse		0: None
Torque Control Type	0: Ground Directional Element 1: Negative Sequence Dir. Element		0: Ground Dir. Element
Reset Type	0: Instantaneous 1: Disc Emulation		0: Instantaneous
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Sensitive Ground Time Overcurrent			
Setting	**Range**	**Step**	**Default**
SG TOC Enable	YES / NO		NO
SG TOC Pickup	0.005 - 2.0 A	0.001A	0.1 A
SG TOC Curve	See list of curves		Definite Time
SG TOC 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
SG TOC Definite Time	0,05 - 1800 s	0.01 s	0.05 s
SG TOC Direction	0: None 1: Direction 2: Reverse		0: None
Torque Control Type	0: Ground Directional Element 1: Negative Sequence Dir. Element		0: Ground Dir. Element
Reset Type	0: Instantaneous 1: Disc Emulation		0: Instantaneous
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Negative Sequence Time Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
N.S. TOC Enable	YES / NO		NO
N.S. TOC Pickup	(0.1- 5.0) In	0.1A	2 A
N.S. TOC Curve	See list of curves		Definite Time
N.S. TOC 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
N.S. TOC Definite Time	0.05 - 300 s	0.01 s	0.05 s
N.S TOC Direction	0: None 1: Direction 2: Reverse		0: None
Reset Type	0: Instantaneous 1: Disc Emulation		0: Instantaneous
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Voltage Dependent Time Overcurrent Element			
Setting	**Range**	**Step**	**Default**
V Dependent Enable	YES / NO		NO
V Dependent Mode	0: V Restraint 1: V Controlled		0: V Restraint
V Dependent Pickup	(0.2- 20) In	0.1A	5.00 A
Operating Voltage (V Controlled Mode)	(10- 100) % de Un	1%	50 %
V Dependent Time	0.05 - 300 s	0.01 s	1 s

Phase Instantaneous Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Phase IOC Enable	YES / NO		NO
Phase IOC Pickup	(0.01 - 30) In	0.01 A	5.00 A
Phase IOC Delay	0 - 300 s	0.01 s	0 s
Phase IOC Direction	0: None 1: Direction 2: Reverse		0: None
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Ground Instantaneous Overcurrent (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Gnd IOC Enable	YES / NO		NO
Gnd IOC Pickup	(0.01 - 30) In	0.01 A	5.00 A
Gnd IOC Delay	0 - 300 s	0.01 s	0 s
Gnd IOC Direction (*)	0: None 1: Direction 2: Reverse		0: None
Torque Control Type	0: Ground Directional Element 1: Negative Sequence Dir. Element		0: Ground Dir. Element
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Sensitive Ground Instantaneous Overcurrent			
Setting	**Range**	**Step**	**Default**
SG IOC Enable	YES / NO		NO
SG IOC Pickup	0.005 - 3.00 A	0.001 A	0.1 A
SG IOC Delay	0 - 300 s	0.01 s	0 s
SG IOC Direction	0: None 1: Direction 2: Reverse		0: None
Torque Control Type	0: Ground Directional Element 1: Negative Sequence Dir. Element		0: Ground Dir. Element
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

Negative Sequence Instantaneous Overcurrent (Elements 1 and 2)			
Setting	**Range**	**Step**	**Default**
N.S. IOC Enable	YES / NO		NO
N.S. IOC Pickup	(0.05 – 30.00) In	0.001 A	10.00 A
N.S. IOC Delay	0 - 300 s	0.01 s	0 s
Gnd IOC Direction (*)	0: None 1: Direction 2: Reverse		0: None
Blocking by Harmonics (IRX*******F0***)	YES / NO		NO

(*) For models with Protection Schemes, when DIRECTIONAL COMPARISON BLOCKING is selected, Ground and Negative Sequence instantaneous elements 2 used will present REVERSE DIRECTION torque control, even if the setting shows otherwise.

Blocking by Harmonics (IRX*******F0***)			
Setting	**Range**	**Step**	**Default**
Blocking by 2nd Harmonic Enable	YES / NO		NO
Blocking by 2nd Harmonic Pickup	5% - 100%	0.01%	20%
Blocking by 5th Harmonic Enable	YES / NO		NO
Blocking by 5th Harmonic Pickup	5% - 100%	0.01%	20%
Type of blocking by harmonics	OR, AND, 2 DE 3		
Minimum phase current	0.01 – 120 A	0.01 A	0.2 A
Minimum ground current	0.01 – 90 A	0.01 A	0.2 A
Minimum residual ground current	0.005 – 3 A	0.001 A	0.1 A

- **Time Overcurrent Units: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - OVERCURRENT**
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - Activate Group	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	3 - BREAKER FAILURE
4 - INFORMATION	...	4 - RESID. CURRENT DET.
		...

0 - OVERCURRENT	0 - DIRECTIONAL	**0 - PHASE TOC**
1 - VOLTAGE	**1 - TIME OVERCURRENT**	**1 - NEGSEQ TOC**
2 - FREQUENCY	2 - INSTANTANEOUS	**2 - GROUND TOC**
3 - BREAKER FAILURE		**3 - S.GROUND TIME**
4 - RESID. CURRENT DET.		**4 - V DEPENDENT TIME**
...		

0 - PHASE TOC	**0 - UNIT 1**	**0 - PHASE TOC ENABLE**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - PHASE TOC PICKUP**
2 - GROUND TOC	**2 - UNIT 3**	**2 - PHASE TOC CURVE**
3 - S.GROUND TIME		**3 - PHASE TOC DIAL**
4 - V DEPENDENT TIME		**4 - PHASE TOC DELAY**
		5 - RESET TYPE
		6 - PH TOC DIRECTION

0 - PHASE TOC	**0 - UNIT 1**	**0 - N.S. TOC ENABLE**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - N.S. TOC PICKUP**
2 - GROUND TOC	**2 - UNIT 3**	**2 - N.S. TOC CURVE**
3 - S.GROUND TIME		**3 - N.S. TOC DIAL**
4 - V DEPENDENT TIME		**4 - N.S. TOC DELAY**
		5 - RESET TYPE

0 - PHASE TOC	**0 - UNIT 1**	**0 - GROUND TOC ENABLE**
1 - NEGSEQ TOC	**1 - UNIT 2**	**1 - GROUND TOC PICKUP**
2 - GROUND TOC	**2 - UNIT 3**	**2 - GROUND TOC CURVE**
3 - S.GROUND TIME		**3 - GROUND TOC DIAL**
4 - V DEPENDENT TIME		**4 - GROUND TOC DELAY**
		5 - RESET TYPE
		6 - GND TOC DIRECTION

0 - PHASE TOC	**0 - S.G.TIME ENABLE**
1 - NEGSEQ TOC	**1 - S.G. TIME PICKUP**
2 - GROUND TOC	**2 - S.G. CURVE**
3 - S.GROUND TIME	**3 - S.G.TIME DIAL**
4 - V DEPENDENT TIME	**4 - S.G. FIXED TIME**
	5 - RESET TYPE
	5 - S.G. TOC DIRECTION

0 - PHASE TOC	**0 - V DEPENDENT ENABLE**
1 - NEGSEQ TOC	**1 - V DEPENDENT MODE**
2 - GROUND TOC	**2 - V DEPENDENT PICKUP**
3 - S.GROUND TIME	**3 - OPERATING VOLTAGE**
4 - V DEPENDENT TIME	**4 - V DEPENDENT TIME**

- **Instantaneous Overcurrent Units: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - OVERCURRENT**
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - Activate Group	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	3 - BREAKER FAILURE
4 - INFORMATION	...	4 - RESID. CURRENT DET.
		...

0 - OVERCURRENT	0 - DIRECTIONAL	**0 - PHASE IOC**
1 - VOLTAGE	1 - TIME OVERCURRENT	**1 - NEGSEQ IOC**
2 - FREQUENCY	**2 - INSTANTANEOUS**	**2 - GROUND IOC**
3 - BREAKER FAILURE		**3 - S.GROUND INSTANT.**
4 - RESID. CURRENT DET.		
...		

0 - PHASE IOC	**0 - UNIT 1**	**0 - PHASE IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - PHASE IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - PHASE IOC DELAY**
3 - S.GROUND INSTANT.		**3 - PHASEIOC DIRECTION**

0 - PHASE IOC	**0 - UNIT 1**	**0 - N.S. IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - N.S. IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - N.S. IOC DELAY**
3 - S.GROUND INSTANT.		**3 - N.S. IOC DIRECTION**

0 - PHASE IOC	**0 - UNIT 1**	**0 - GND IOC ENABLE**
1 - NEGSEQ IOC	**1 - UNIT 2**	**1 - GND IOC PICKUP**
2 - GROUND IOC	**2 - UNIT 3**	**2 - GND IOC DELAY**
3 - S.GROUND INSTANT.		**3 - GND IOC DIRECTION**
		4 - GND IOC DIREC UNIT

0 - INSTA. FASES	**0 - S.G. IOC ENABLE**
1 - INSTA. SEC. INV.	**1 - S.G. IOC PICKUP**
2 - GROUND IOC	**2 - S.G. IOC DELAY**
3 - S.GROUND INSTANT.	**3 - S.G. IOC DIRECTION**

3.1.11 Digital Inputs of the Overcurrent Modules

Table 3.1-2: Digital Inputs of the Overcurrent Modules

Name	Description	Function
INBLK_IOC_PH1	Phase instantaneous element 1 block trip input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
INBLK_IOC_N1	Ground instantaneous element 1 block trip input	
INBLK_IOC_NS1	Negative sequence instantaneous element 1 block trip input	
INBLK_IOC_PH2	Phase instantaneous element 2 block trip input	
INBLK_IOC_N2	Ground instantaneous element 2 block trip input	
INBLK_IOC_NS2	Negative sequence instantaneous element 2 block trip input	
INBLK_IOC_N3	Ground instantaneous element 3 block trip input	
INBLK_IOC_SG	Sensitive ground instantaneous overcurrent element block trip input	
INBLK_TOC_PH1	Phase time element 1 block trip input	
INBLK_TOC_N1	Ground time element 1 block trip input	
INBLK_TOC_NS1	Negative sequence time element 1 block trip input	
INBLK_TOC_PH2	Phase time element 2 block trip input	
INBLK_TOC_N2	Ground time element 2 block trip input	
INBLK_TOC_NS2	Negative sequence time element 2 block trip input	
INBLK_TOC_PH3	Phase time element 3 block trip input	
INBLK_TOC_N3	Ground time element 3 block trip input	
INBLK_TOC_NS3	Negative sequence time element 3 block trip input	
INBLK_TOC_SG	Sensitive ground time element block trip input	
INBLK_VTOC	Voltage dependent time element block trip input	
IN_RST_IOC_PH1	Phase instantaneous element 1 torque annulment input	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	Phase instantaneous element 2 torque annulment input	
IN_RST_IOC_N1	Ground instantaneous element 1 torque annulment input	
IN_RST_IOC_N2	Ground instantaneous element 2 torque annulment input	
IN_RST_IOC_NS1	Negative sequence instantaneous element 1 torque annulment input	
IN_RST_IOC_NS2	Negative sequence instantaneous element 2 torque annulment input	
IN_RST_IOC_N3	Ground instantaneous element 3 torque annulment input	
IN_RST_IOC_SG	Sensitive ground instantaneous element torque annulment input	

Table 3.1-2: Digital Inputs of the Overcurrent Modules

Name	Description	Function
IN_RST_TOC_PH1	Phase time element 1 torque annulment input	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_TOC_PH2	Phase time element 2 torque annulment input	
IN_RST_TOC_PH3	Phase time element 3 torque annulment input	
IN_RST_TOC_N1	Ground time element 1 torque annulment input	
IN_RST_TOC_N2	Ground time element 2 torque annulment input	
IN_RST_TOC_N3	Ground time element 3 torque annulment input	
IN_RST_TOC_NS1	Negative sequence time element 1 torque annulment input	
IN_RST_TOC_NS2	Negative sequence time element 2 torque annulment input	
IN_RST_TOC_NS3	Negative sequence time element 3 torque annulment input	
IN_RST_TOC_SG	Sensitive ground time element torque annulment input	
IN_BPT_PH1	Phase time element 1 bypass time input	It converts the set timing sequence of a given element to instantaneous.
IN_BPT_PH2	Phase time element 2 bypass time input	
IN_BPT_PH3	Phase time element 3 bypass time input	
IN_BPT_N1	Ground time element 1 bypass time input	
IN_BPT_N2	Ground time element 2 bypass time input	
IN_BPT_N3	Ground time element 3 bypass time input	
IN_BPT_NS1	Negative sequence time element 1 bypass time input	
IN_BPT_NS2	Negative sequence time element 2 bypass time input	
IN_BPT_NS3	Negative sequence time element 3 bypass time input	
IN_BPT_SG	Sensitive ground time element bypass time input	

Table 3.1-2: Digital Inputs of the Overcurrent Modules		
Name	**Description**	**Function**
ENBL_IOC_PH1	Phase instantaneous element 1 enable input	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_N1	Ground instantaneous element 1 enable input	
ENBL_IOC_NS1	Negative sequence instantaneous element 1 enable input	
ENBL_IOC_PH2	Phase instantaneous element 2 enable input	
ENBL_IOC_N2	Ground instantaneous element 2 enable input	
ENBL_IOC_NS2	Negative sequence instantaneous element 2 enable input	
ENBL_IOC_N3	Ground instantaneous element 3 enable input	
ENBL_IOC_SG	Sensitive ground instantaneous element enable input	
ENBL_TOC_PH1	Phase time element 1 enable input	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_TOC_N1	Ground time element 1 enable input	
ENBL_TOC_NS1	Negative sequence time element 1 enable input	
ENBL_TOC_PH2	Phase time element 2 enable input	
ENBL_TOC_N2	Ground time element 2 enable input	
ENBL_TOC_NS2	Negative sequence time element 2 enable input	
ENBL_TOC_PH3	Phase time element 3 enable input	
ENBL_TOC_N3	Ground time element 3 enable input	
ENBL_TOC_NS3	Negative sequence time element 3 enable input	
ENBL_TOC_SG	Sensitive ground time element enable input	
ENBL_VTOC	Voltage dependent time element enable input	

3.1.12 Auxiliary Outputs and Events of the Overcurrent Modules

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules

Name	Description	Function
PU_IOC_A1	Phase A instantaneous element 1 pickup	AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_B1	Phase B instantaneous element 1 pickup	
PU_IOC_C1	Phase C instantaneous element 1 pickup	
PU_IOC_N1	Ground instantaneous element 1 pickup	
PU_IOC_NS1	Negative sequence instantaneous element 1 pickup	
PU_IOC_A2	Phase A instantaneous element 2 pickup	
PU_IOC_B2	Phase B instantaneous element 2 pickup	
PU_IOC_C2	Phase C instantaneous element 2 pickup	
PU_IOC_N2	Ground instantaneous element 2 pickup	
PU_IOC_NS2	Negative sequence instantaneous element 2 pickup	
PU_IOC_N3	Ground instantaneous element 3 pickup	
PU_IOC_SG	Sensitive ground instantaneous element pickup	
PU_TOC_A1	Phase A time element 1 pickup	
PU_TOC_B1	Phase B time element 1 pickup	
PU_TOC_C1	Phase C time element 1 pickup	
PU_TOC_N1	Ground time element 1 pickup	
PU_TOC_NS1	Negative sequence time element 1 pickup	
PU_TOC_A2	Phase A time element 2 pickup	
PU_TOC_B2	Phase B time element 2 pickup	
PU_TOC_C2	Phase C time element 2 pickup	
PU_TOC_N2	Ground time element 2 pickup	
PU_TOC_NS2	Negative sequence time element 2 pickup	
PU_TOC_A3	Phase A time element 3 pickup	
PU_TOC_B3	Phase B time element 3 pickup	
PU_TOC_C3	Phase C time element 3 pickup	
PU_TOC_N3	Ground time element 3 pickup	
PU_TOC_NS3	Negative sequence time element 3 pickup	
PU_TOC_SG	Sensitive ground time element pickup	
PU_VTOC_A	Phase A voltage dependent time overcurrent pickup	
PU_VTOC_B	Phase B voltage dependent time overcurrent pickup	
PU_VTOC_C	Phase C voltage dependent time overcurrent pickup	
PU_IOC	Instantaneous elements pickup (does not generate an event)	Pickup of the grouped current elements.
PU_TOC	Time elements pickup (does not generate an event)	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
CPU_IOC_A1	Phase A instantaneous element 1 pickup conditions	Pickup of the current elements, unaffected by the torque control.
CPU_IOC_B1	Phase B instantaneous element 1 pickup conditions	
CPU_IOC_C1	Phase C instantaneous element 1 pickup conditions	
CPU_IOC_N1	Ground instantaneous element 1 pickup conditions	
CPU_IOC_A2	Phase A instantaneous element 2 pickup conditions	
CPU_IOC_B2	Phase B instantaneous element 2 pickup conditions	
CPU_IOC_C2	Phase C instantaneous element 2 pickup conditions	
CPU_IOC_N2	Ground instantaneous element 2 pickup conditions	
CPU_IOC_N3	Ground instantaneous element 3 pickup conditions	
CPU_IOC_SG	Sensitive ground instantaneous element pickup conditions	
CPU_TOC_A1	Phase A time element 1 pickup conditions	
CPU_TOC_B1	Phase B time element 1 pickup conditions	
CPU_TOC_C1	Phase C time element 1 pickup conditions	
CPU_TOC_N1	Ground time element 1 pickup conditions	
CPU_TOC_A2	Phase A time element 2 pickup conditions	
CPU_TOC_B2	Phase B time element 2 pickup conditions	
CPU_TOC_C2	Phase C time element 2 pickup conditions	
CPU_TOC_N2	Ground time element 2 pickup conditions	
CPU_TOC_A3	Phase A time element 3 pickup conditions	
CPU_TOC_B3	Phase B time element 3 pickup conditions	
CPU_TOC_C3	Phase C time element 3 pickup conditions	
CPU_TOC_N3	Ground time element 3 pickup conditions	
CPU_TOC_SG	Sensitive ground time element pickup conditions	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
TRIP_IOC_A1	Phase A instantaneous element 1 trip	Trip of the current elements.
TRIP_IOC_B1	Phase B instantaneous element 1 trip	
TRIP_IOC_C1	Phase C instantaneous element 1 trip	
TRIP_IOC_N1	Ground instantaneous element 1 trip	
TRIP_IOC_NS1	Negative sequence instantaneous element 1 trip	
TRIP_IOC_A2	Phase A instantaneous element 2 trip	
TRIP_IOC_B2	Phase B instantaneous element 2 trip	
TRIP_IOC_C2	Phase C instantaneous element 2 trip	
TRIP_IOC_N2	Ground instantaneous element 2 trip	
TRIP_IOC_NS2	Negative sequence instantaneous element 2 trip	
TRIP_IOC_N3	Ground instantaneous element 3 trip	
TRIP_IOC_SG	Sensitive ground instantaneous element trip	
TRIP_TOC_A1	Phase A time element 1 trip	
TRIP_TOC_B1	Phase B time element 1 trip	
TRIP_TOC_C1	Phase C time element 1 trip	
TRIP_TOC_N1	Ground time element 1 trip	
TRIP_TOC_NS1	Negative sequence time element 1 trip	
TRIP_TOC_A2	Phase A time element 2 trip	
TRIP_TOC_B2	Phase B time element 2 trip	
TRIP_TOC_C2	Phase C time element 2 trip	
TRIP_TOC_N2	Ground time element 2 trip	
TRIP_TOC_NS2	Negative sequence time element 2 trip	
TRIP_TOC_A3	Phase A time element 3 trip	
TRIP_TOC_B3	Phase B time element 3 trip	
TRIP_TOC_C3	Phase C time element 3 trip	
TRIP_TOC_N3	Ground time element 3 trip	
TRIP_TOC_NS3	Negative sequence time element 3 trip	
TRIP_TOC_SG	Sensitive ground time element trip	
TRIP_VTOC_A	Phase A voltage dependent time overcurrent trip	
TRIP_VTOC_B	Phase B voltage dependent time overcurrent trip	
TRIP_VTOC_C	Phase C voltage dependent time overcurrent trip	
TRIP_IOC	Instantaneous elements trips (does not generate an event)	Trip of the grouped current elements.
TRIP_TOC	Time elements trips (does not generate an event)	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
TRIP_IOC_A1M	Phase A instantaneous element 1 masked trip	Trip of the elements affected by their corresponding trip mask.
TRIP_IOC_B1M	Phase B instantaneous element 1 masked trip	
TRIP_IOC_C1M	Phase C instantaneous element 1 masked trip	
TRIP_IOC_N1M	Ground instantaneous element 1 masked trip	
TRIP_IOC_NS1M	Negative sequence instantaneous element 1 masked trip	
TRIP_IOC_A2M	Phase A instantaneous element 2 masked trip	
TRIP_IOC_B2M	Phase B instantaneous element 2 masked trip	
TRIP_IOC_C2M	Phase C instantaneous element 2 masked trip	
TRIP_IOC_N2M	Ground instantaneous element 2 masked trip	
TRIP_IOC_NS2M	Negative sequence instantaneous element 2 masked trip	
TRIP_IOC_N3M	Ground instantaneous element 3 masked trip	
TRIP_IOC_SGM	Sensitive ground instantaneous element masked trip	
TRIP_TOC_A1M	Phase A time element 1 masked trip	
TRIP_TOC_B1M	Phase B time element 1 masked trip	
TRIP_TOC_C1M	Phase C time element 1 masked trip	
TRIP_TOC_N1M	Ground time element 1 masked trip	
TRIP_TOC_NS1M	Negative sequence time element 1 masked trip	
TRIP_TOC_A2M	Phase A time element 2 masked trip	
TRIP_TOC_B2M	Phase B time element 2 masked trip	
TRIP_TOC_C2M	Phase C time element 2 masked trip	
TRIP_TOC_N2M	Ground time element 2 masked trip	
TRIP_TOC_NS2M	Negative sequence time element 2 masked trip	
TRIP_TOC_A3M	Phase A time element 3 masked trip	
TRIP_TOC_B3M	Phase B time element 3 masked trip	
TRIP_TOC_C3M	Phase C time element 3 masked trip	
TRIP_TOC_N3M	Ground time element 3 masked trip	
TRIP_TOC_NS3M	Negative sequence time element 3 masked trip	
TRIP_TOC_SGM	Sensitive ground time element masked trip	
TRIP_VTOC_AM	Phase A voltage dependent time overcurrent masked trip	
TRIP_VTOC_BM	Phase B voltage dependent time overcurrent masked trip	
TRIP_VTOC_CM	Phase C voltage dependent time overcurrent masked trip	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
INBLK_IOC_PH1	Phase instantaneous element 1 block trip input	The same as for the digital inputs.
INBLK_IOC_N1	Ground instantaneous element 1 block trip input	
INBLK_IOC_NS1	Negative sequence instantaneous element 1 block trip input	
INBLK_IOC_PH2	Phase instantaneous element 2 block trip input	
INBLK_IOC_N2	Ground instantaneous element 2 block trip input	
INBLK_IOC_NS2	Negative sequence instantaneous element 2 block trip input	
INBLK_IOC_N3	Ground instantaneous element 3 block trip input	
INBLK_IOC_SG	Sensitive ground instantaneous element block trip input	
INBLK_TOC_PH1	Phase time element 1 block trip input	
INBLK_TOC_N1	Ground time element 1 block trip input	
INBLK_TOC_NS1	Negative sequence time element 1 block trip input	
INBLK_TOC_PH2	Phase time element 2 block trip input	
INBLK_TOC_N2	Ground time element 2 block trip input	
INBLK_TOC_NS2	Negative sequence time element 2 block trip input	
INBLK_TOC_PH3	Phase time element 3 block trip input	
INBLK_TOC_N3	Ground time element 3 block trip input	
INBLK_TOC_NS3	Negative sequence time element 3 block trip input	
INBLK_TOC_SG	Sensitive ground time element block trip input	
INBLK_VTOC	Voltage dependent time element block trip input	
IN_RST_IOC_PH1	Phase instantaneous element 1 torque annulment input	The same as for the digital inputs.
IN_RST_IOC_PH2	Phase instantaneous element 2 torque annulment input	
IN_RST_IOC_N1	Ground instantaneous element 1 torque annulment input	
IN_RST_IOC_N2	Ground instantaneous element 2 torque annulment input	
IN_RST_IOC_N3	Ground instantaneous element 3 torque annulment input	
IN_RST_IOC_NS1	Negative sequence instantaneous element 1 torque annulment input	
IN_RST_IOC_NS2	Negative sequence instantaneous element 2 torque annulment input	
IN_RST_IOC_SG	Sensitive ground instantaneous element torque annulment input	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
HAR_2_BLK_A	Phase A blocking by 2nd harmonic	Blocking by Phase, Ground and residual ground harmonics.
HAR_2_BLK_B	Phase B blocking by 2nd harmonic	
HAR_2_BLK_C	Phase C blocking by 2nd harmonic	
HAR_2_BLK_N	Ground blocking by 2nd harmonic	
HAR_2_BLK_SN	Residual ground blocking by 2nd harmonic	
HAR_5_BLK_A	Phase A blocking by 5th harmonic	
HAR_5_BLK_B	Phase B blocking by 5th harmonic	
HAR_5_BLK_C	Phase C blocking by 5th harmonic	
HAR_5_BLK_N	Ground blocking by 5th harmonic	
HAR_5_BLK_SN	Residual ground blocking by 5th harmoni	
HAR_BLK_A	Phase A blocking by harmonics	
HAR_BLK_B	Phase B blocking by harmonics	
HAR_BLK_C	Phase C blocking by harmonics	
HAR_BLK_N	Ground blocking by harmonics	
HAR_BLK_SN	Residual ground blocking by harmonics	
HAR_BLK_CROSS	Cross-blocking by harmon**ics**	
IN_RST_TOC_PH1	Phase time element 1 torque annulment input	The same as for the digital inputs.
IN_RST_TOC_PH2	Phase time element 2 torque annulment input	
IN_RST_TOC_PH3	Phase time element 3 torque annulment input	
IN_RST_TOC_N1	Ground time element 1 torque annulment input	
IN_RST_TOC_N2	Ground time element 2 torque annulment input	
IN_RST_TOC_N3	Ground time element 3 torque annulment input	
IN_RST_TOC_NS1	Negative sequence time element 1 torque annulment input	
IN_RST_TOC_NS2	Negative sequence time element 2 torque annulment input	
IN_RST_TOC_NS3	Negative sequence time element 3 torque annulment input	
IN_RST_TOC_SG	Sensitive ground time element torque annulment input	
IN_BPT_PH1	Phase time element 1 bypass time input	The same as for the digital inputs.
IN_BPT_PH2	Phase time element 2 bypass time input	
IN_BPT_PH3	Phase time element 3 bypass time input	
IN_BPT_N1	Ground time element 1 bypass time input	
IN_BPT_N2	Ground time element 2 bypass time input	
IN_BPT_N3	Ground time element 3 bypass time input	
IN_BPT_NS1	Negative sequence time element 1 bypass time input	
IN_BPT_NS2	Negative sequence time element 2 bypass time input	
IN_BPT_NS3	Negative sequence time element 3 bypass time input	
IN_BPT_SG	Sensitive ground time element bypass time input	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
ENBL_IOC_PH1	Phase instantaneous element 1 enable input	The same as for the digital inputs.
ENBL_IOC_N1	Ground instantaneous element 1 enable input	
ENBL_IOC_NS1	Negative sequence instantaneous element 1 enable input	
ENBL_IOC_PH2	Phase instantaneous element 2 enable input	
ENBL_IOC_N2	Ground instantaneous element 2 enable input	
ENBL_IOC_NS2	Negative sequence instantaneous element 2 enable input	
ENBL_IOC_N3	Ground instantaneous element 3 enable input	
ENBL_IOC_SG	Sensitive ground instantaneous element enable input	
ENBL_TOC_PH1	Phase time element 1 enable input	The same as for the digital inputs.
ENBL_TOC_N1	Ground time element 1 enable input	
ENBL_TOC_NS1	Negative sequence time element 1 enable input	
ENBL_TOC_PH2	Phase time element 2 enable input	
ENBL_TOC_N2	Ground time element 2 enable input	
ENBL_TOC_NS2	Negative sequence time element 2 enable input	
ENBL_TOC_PH3	Phase time element 3 enable input	
ENBL_TOC_N3	Ground time element 3 enable input	
ENBL_TOC_NS3	Negative sequence time element 3 enable input	
ENBL_TOC_SG	Sensitive ground time element enable input	
ENBL_VTOC	Voltage dependent time element enable input	

Table 3.1-3: Auxiliary Outputs and Events of the Overcurrent Modules		
Name	**Description**	**Function**
IOC_PH1_ENBLD	Phase instantaneous element 1 enabled	Indication of enabled or disabled status of the current elements.
IOC_N1_ENBLD	Ground instantaneous element 1 enabled	
IOC_NS1_ENBLD	Negative sequence instantaneous element 1 enabled	
IOC_PH2_ENBLD	Phase instantaneous element 2 enabled	
IOC_N2_ENBLD	Ground instantaneous element 2 enabled	
IOC_NS2_ENBLD	Negative sequence instantaneous element 2 enabled	
IOC_N3_ENBLD	Ground instantaneous element 3 enabled	
IOC_SG_ENBLD	Sensitive ground instantaneous element enabled	
TOC_PH1_ENBLD	Phase time element 1 enabled	
TOC_N1_ENBLD	Ground time element 1 enabled	
TOC_NS1_ENBLD	Negative sequence time element 1 enabled	
TOC_PH2_ENBLD	Phase time element 2 enabled	
TOC_N2_ENBLD	Ground time element 2 enabled	
TOC_NS2_ENBLD	Negative sequence time element 2 enabled	
TOC_PH3_ENBLD	Phase time element 3 enabled	
TOC_N3_ENBLD	Ground time element 3 enabled	
TOC_NS3_ENBLD	Negative sequence time element 3 enabled	
TOC_SG_ENBLD	Sensitive ground time element enabled	
VTOC_ENBLD	Voltage dependent time element enabled	

3.1.13 Overcurrent Elements Tests

One–by-one element testing is recommended and all elements not being tested at that moment must be disabled. To carry out this test, we recommend that you cancel the directionality of the equipment, in order not to depend on the voltages (**TOC Direction** set to None) and select **Instantaneous** reset type.Otherwise they must be applied, 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. Likewise, it may also be checked that the trip flag in said menu activates when element trips.

Table 3.1-4: Overcurrent Elements Pickup and Reset

Element Setting	Pickup		Reset	
	Maximum	Minimum		maximum
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**

This is checked through trip terminals C1-C2.

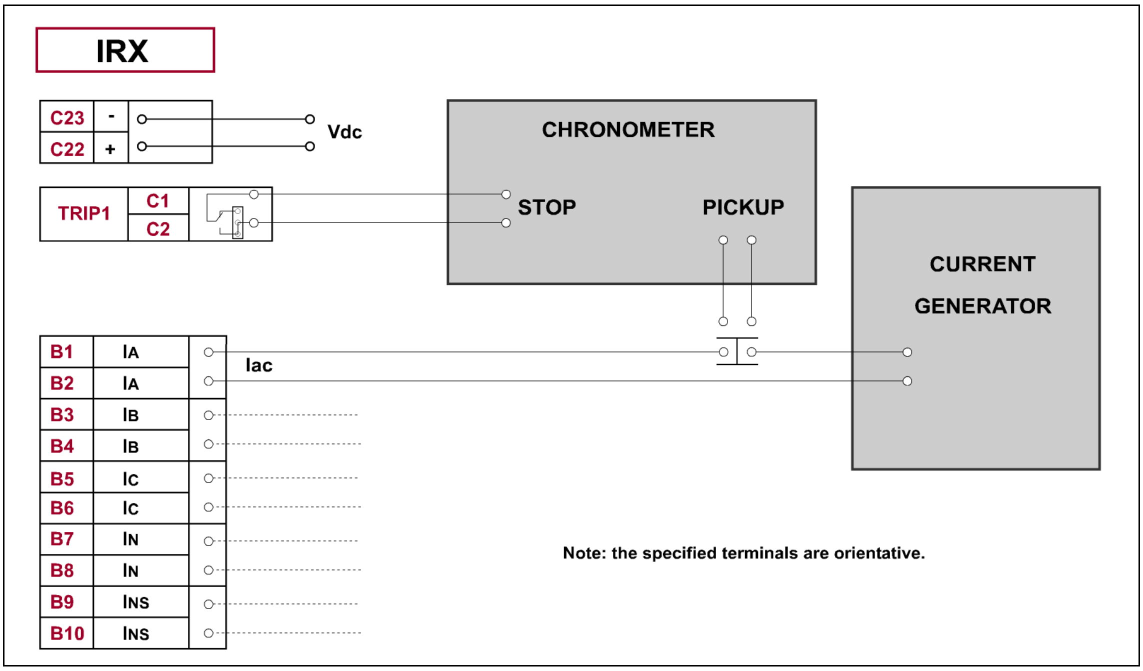


Figure 3.1.22 Operating Time Test Setup (Overcurrent Elements).

Definite or Instantaneous Time

A current 20% above the selected pickup setting value shall be applied. Time delay must be ±1% or ±25ms (whichever is greater) of the selected time delay setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 25 ms.

Inverse Time

For a given curve, time delay 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 for model **IRX** can be checked for curves shown in paragraph 3.1.3 according to IEC and IEEE/ANSI standards. RI Inverse Curve characteristic is added to these curves, mainly used in combination with electromechanical relays.

3.1.13.b Voltage Restraint Time 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 22Vac 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 * 0.25A) ± 3%, and resets at 0.25A ± 3%.

Disconnect phase A voltage and apply 55Vac 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 * 0.5A) ± 3%, and resets at 0.5A ± 3%.

Finally, disconnect phase B voltage and apply 104.5Vac 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 * 1A) ± 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 ±25ms (whichever is greater) of the selected time setting value. Bear in mind that time delay for 0 ms setting will be between 20 and 25 ms.

3.2 Directional Elements

3.2.1 Introduction

IRX relay with voltage measurement feature, as a function of model, the following directional elements: one Phase Directional Element (67), one Ground Directional Element (67G), one Sensitive Ground Directional Element (67SG), one Negative Sequence Directional Element (67NS) and one Ungrounded Directional Element (67UNG).

The task of directional elements is to determine the operate current flow direction to control the associated overcurrent elements. Direction is figured out by comparing its phase with that of a reference magnitude, the phase of which remains regardless the operate current flow direction.

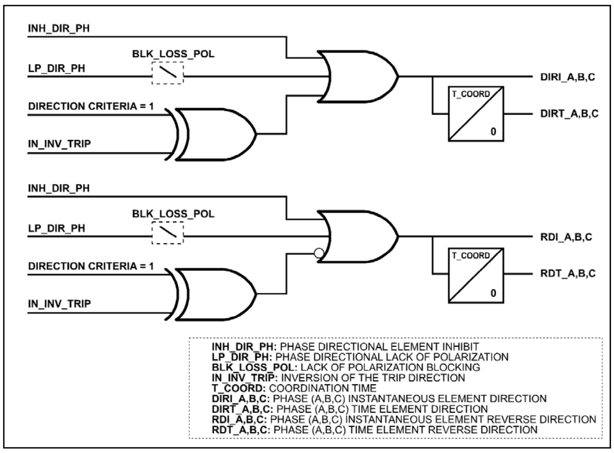


Figure 3.2.1 Phase Directional Element Block Diagram.

Each directional element has control over the corresponding overcurrent elements provided the **Torque Control** setting is different from zero. If it should be zero, directional control is inhibited enabling trip in both directions. Instantaneous overcurrent element trips are enabled and time overcurrent elements are enabled after the coordination timer times out.

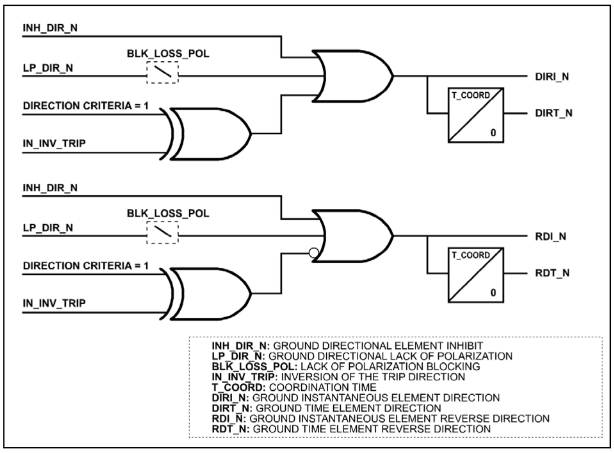


Figure 3.2.2 Ground Directional Element Block Diagram.

If direction forward is asserted, reverse direction instantaneous and time overcurrent are blocked and direction forward instantaneous is enabled. Direction forward time overcurrent is also enabled after the coordination timer times out.

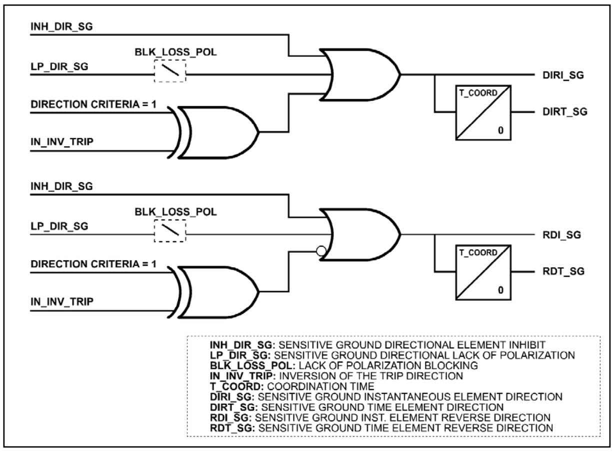


Figure 3.2.3 Sensitive Ground Directional Element Block Diagram.

If reverse direction is asserted, direction forward instantaneous and time overcurrent are blocked and reverse direction instantaneous is enabled. Reverse direction time overcurrent is enabled after the coordination timer times out.

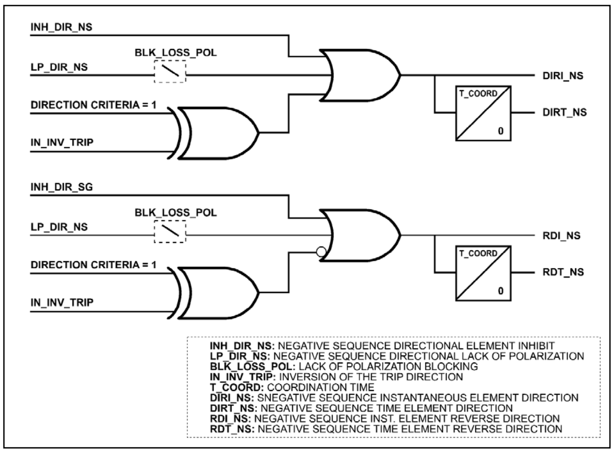


Figure 3.2.4 Negative Sequence Directional Element Block Diagram.

For overcurrent elements to operate, directional elements must pickup and then a current level higher than the overcurrent element setting value must be detected. If the directional element disables overcurrent element operation, the time delay function will not initiate. If the operation is disabled after timer pickup, this will be reset so that if element operation should be enabled timer will start again from zero.

In any case, for a trip to take place, the time function must run uninterrupted.

In all cases, directional elements can enable or block in both directions (direction and reverse direction) as a function of the **Torque Control** setting (**1** for direction trips and **2** for reverse direction trips). If **Torque Disable** input is activated, pickup of the corresponding directional element is blocked.

Directional element settings corresponding to ground are common for the three types of ground. In case there only exists **Ground**, this uses the corresponding settings. If there are **Ground** and **Sensitive Ground** at the same time, settings are common for both. And if there is **Directional Ungrounded**, it shares settings with above grounds, bearing in mind that in this case phase characteristic angle is capacitive.

3.2.2 Phase Directional Element

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 memorized 2 cycles before pickup.

Table 3.2-1 shows operation and polarization magnitudes applied to each of three phases.

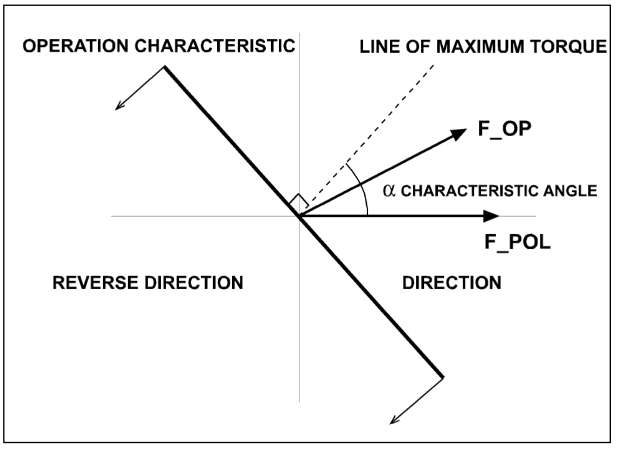


Figure 3.2.5 Vector Diagram of the Directional Phase Element.

The aim of directional phase elements is to check whether phase currents and voltages exceed a given value. This value is settable for voltage 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, trips in both directions are blocked.

Table 3.2-1: Phase Sequence		
ABC Phase Sequence		
Phase	**Operate magnitude (F_OP)**	**Polarization magnitude (F_POL)**
A	I_A	$U_{BC} = V_B - V_C$
B	I_B	$U_{CA} = V_C - V_A$
C	I_C	$U_{AB} = V_A - V_B$
ACB Phase Sequence		
Phase	**Operate magnitude (F_OP)**	**Polarization magnitude (F_POL)**
A	IA	$U_{CB} = V_C – V_B$
B	IB	$U_{AC} = V_A – V_C$
C	IC	$U_{BA} = V_B – V_A$

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 application example in paragraph 3.2.2.a).

When the directional element is set **Direction**, the overcurrent element is enabled when the operate magnitude phasor is within the operate zone, ±90° with respect to maximum torque line, and is disabled when within the opposite half plane. When set **Reverse Direction**, the overcurrent element is enabled when phasor is within the opposite half plane.

As mentioned above, directional control is made phase after phase.

3.2.2.a Application Example

An analysis of the phase **Characteristic Angle**, with respect to the **Polarization Magnitude**, used by the relay to establish **Maximum Torque Line** dividing the plane into enable and disable zones of phase differential elements set **Direction** and with **ABC Phase Sequence** is made in this paragraph.

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 $\mathbf{Z_{l\alpha}}$ is line impedance, fault current $\mathbf{I_A}$ will be produced by voltage $\mathbf{V_A}$ with phase lag angle α.

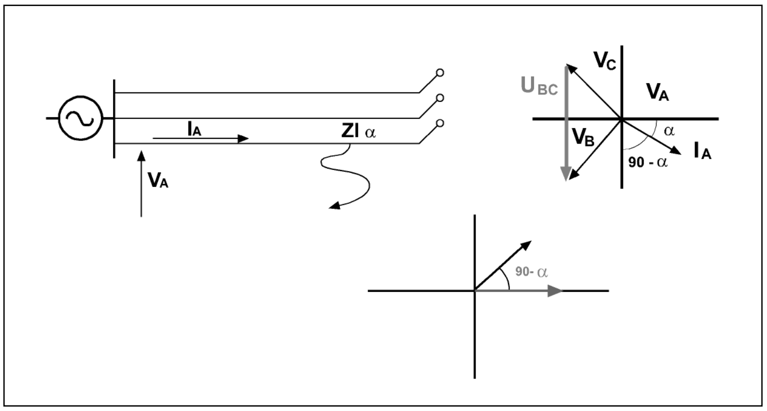


Figure 3.2.6 Graphics for the Application Example.

IRX relay 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 3.2-1).

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** (α) set at the relay is the angle between **Operate Magnitude** and **Polarization Magnitude** (see figure 3.2.4), 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.

Summarizing, if $\mathbf{Z_{l\theta}}$ is line impedance, phase characteristic angle (α) setting is:

$$\alpha = 90 - \theta$$

3.2.3 Ground and Sensitive Ground Directional Elements

Ground and Sensitive Ground Directional element operation is based on zero-sequence and ground magnitudes. Zero-sequence current is taken as operate magnitude (measured through ground and sensitive ground channel).

Polarization magnitudes to be considered will depend on the units enabled:

- **Directional Earth Fault Unit**: This can be polarised by the zero-sequence voltage (VN) or by the earthing current. In this situation, there will be two different operation characteristics corresponding to each polarization mode. Such characteristics on the R-X diagram are straight lines that divide the diagram in two halfs. The location of the "operation magnitude" will directly determine the activation of the directional unit and the corresponding effect on the overcurrent unit.

- **Sensitive Earth Fault Protection**: This unit can only be polarised by the zero-sequence voltage (VN).

The reason for both polarization magnitudes is next:

- **Zero-sequence voltage**

  Zero-sequence voltage (VN) is calculated from phase voltages as follows:

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

- **Current flow by ground fault** (this current input is only available in some models)

In this case two operate characteristics exist, corresponding to each of the two modes, which drawn on a polar diagram result into straight lines, each dividing the plane into two half planes. Directional element output and action on the overcurrent element is determined by the position of the operate magnitude.

If the directional element is inhibited, trip in both directions is enabled. In this case instantaneous trips are enabled and when the coordination timer times out time-overcurrent trips will be enabled.

- **Voltage Polarization**

Figure 3.2.7 shows the elements used to explain voltage polarization principles.

In this case Ground Directional Element operating principle rests on finding the angle difference between the zero-sequence current and zero-sequence voltage. The figure has been drawn following the same criteria as for phase element operating principles, so that the concepts used are entirely equivalent.

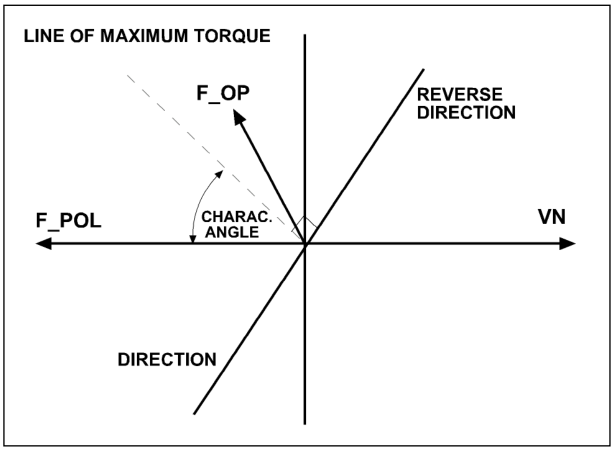


Figure 3.2.7 Vector Diagram of the Ground and Sensitive Ground Directional Element (Polarization by Voltage).

It must be made clear that, in order to handle characteristic angles smaller than 90º, the phasor opposite to the zero-sequence voltage (F_POL) has been drawn as polarization magnitude, which is rotated clockwise the neutral characteristic angle to obtain the straight line dividing both zones.

Ground and Sensitive Ground Directional elements check that ground current and voltage exceed a given value. This value is settable for voltage and is set to **60mA** and **2.7mA** for ground and sensitive ground currents respectively. 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, trips in both directions are blocked.

The same as for phase elements, when the directional element is set **Direction**, the characteristic angle must be such that on fault condition the operate magnitude is within ±90° with respect to maximum torque line. When set **Reverse Direction**, the overcurrent element is enabled when phasor is within the opposite half plane.

- **Voltage Polarization (2IRX-B**-****D0** Models)**

Models **2IRX-B**-****D0**** use the compensated zero sequence voltage as directional element polarisation phasor through setting **Zero Sequence Voltage Compensation Factor** (K_{COMP_67N}): $-V0+I0\cdot K_{COMP\_67N}\angle ANG\_67N$. Figure diagrams the elements used to explain how polarization by voltage works.

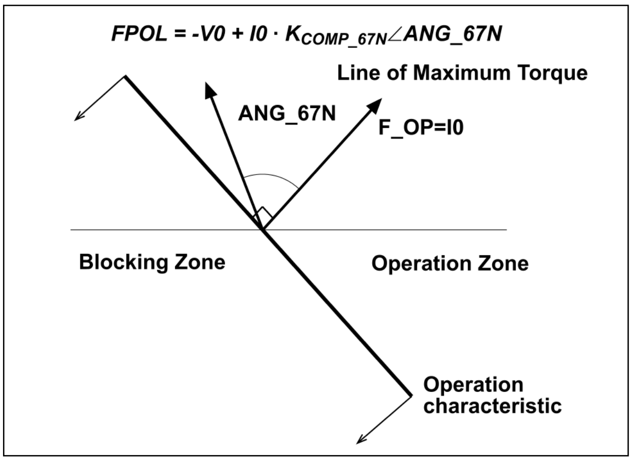


Figure 3.2.8 Vector Diagram of the Ground Directional Element (Polarization by Voltage). Models 2IRX-B-****D0**.**

The following table shows the operation and polarization phasors which intervene in the ground directional element, as well as the operation criteria applied.

Table 3.2-2: Directional Ground Element (polarization by voltage). 2IRX-B**-****D0** Models		
F_OP	**F_POL**	**Criteria**
I0	$-V0+I0\cdot K_{COMP\_67N}\angle ANG\_67N$	$-\left(90^{o}+ANG\_67N\right)\leq\left[\arg\left(Fop\right)-\arg\left(Fpol\right)\right]\leq\left(90^{o}-ANG\_67N\right)$

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 Zero Sequence Voltage**:

  When the zero sequence impedance of the local source is small, in case of forward fault, the $V0$ voltage which measures the relay may present values under the **Minimum Zero Sequence Voltage** setting [it was previously deduced that $V0 = ZA0\cdot(-I0)$]. In order to have sufficient voltage to polarize the ground directional element, a new voltage with the same phase is added to the $-V0$ phasor, which will correspond to the voltage drop in an impedance with **ANG_67N** 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}.

The K_{COMP_67N} 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 $V0 = (ZL0 + ZB0) \cdot I0$, as was deduced previously. If we assume that the $ZL0 + ZB0$ angle is similar to the **ANG_67N** setting (assumption equal to $ZA0$ angle), $-V0$ and $I0 \cdot K_{COMP\_67N}$ will be in anti-phase, for which the sum of $I0 \cdot K_{COMP\_67N}$ 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.

- **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, $V0$ 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 $-V0$ 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. Notwithstanding, and 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).

- **Current Polarization**

This polarization is available only for the earth fault units (but not for the sensitive ones). It is based on the principle of finding out the phase angle difference between the residual current and the fault current. Analysis is simple as the phase difference between both magnitudes may not be other than 0º and 180º or, in other words, the characteristic angle must always be 0º.

When set **Direction**, the operate zone corresponds to the zone where fault or operate current **In** is rotated 180º with respect to ground fault, as in figure F_POL is equal to IPT rotated 180º, thus, F_POL and In must be in phase to be within the operate zone. When set **Reverse Direction**, the overcurrent element is enabled in the opposite half plane.

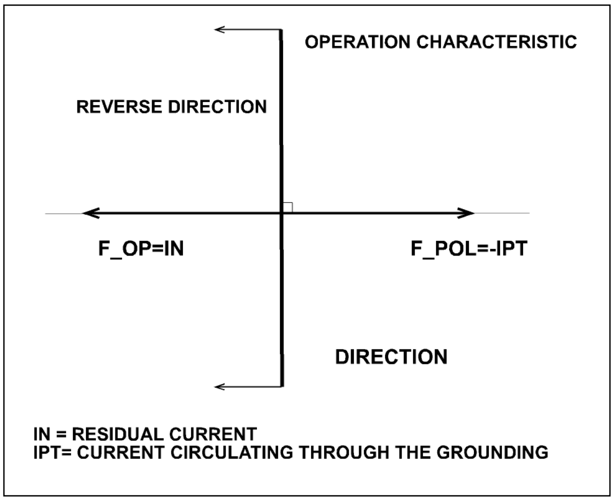


Figure 3.2.9 Vector Diagram of the Ground Directional Element (Polarization by Current).

Ground and Sensitive Ground Directional elements check that polarization current exceeds a given value; this value is **60mA**. If polarization current does not exceed the threshold value 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, trips in both directions are blocked.

- **Voltage and Current Polarization**

This polarization is available only for the earth fault units (but not for the sensitive ones). In case both polarizations are present the following criterion is used:

If the Ground or Sensitive Ground Directional element is inhibited check the current exceeds a minimum value. If it does not exceed this value, the **Lack of Voltage Polarization Blocking** setting is checked. If set to NO proceed as for the case of directional inhibition, but if set to YES, trips in both directions are blocked.

If it exceeds said value, check the polarization current exceeds a given value. If it exceeds this value proceed to determine if there is trip direction. If **Direction Reversal** input is active, the calculated direction is reversed.

If current polarization solves the directional control (trip enable), voltage polarization is not checked.

If current polarization does not solve the directional control check the polarization voltage exceeds a given settable value. If it does not, the **Lack of Voltage Polarization Blocking** setting is checked. If set to NO proceed as for the case of directional inhibition, but if set to YES, trips in both directions are blocked.

If voltage level is correct, polarization voltage is moved according to set characteristic angle checking for trip direction. If **Direction Reversal** input is active, the calculated direction is reversed.

If **Direction** is asserted, instantaneous and time-overcurrent **Reverse Direction** are blocked and instantaneous **Direction** is enabled. When the coordination timer times out the time-overcurrent **Direction** will be enabled.

If **Reverse Direction** is asserted, instantaneous and time-overcurrent **Direction** are disabled and instantaneous **Reverse Direction** is enabled. When coordination timer times out, time-overcurrent **Reverse Direction** will be enabled.

3.2.4 Negative-Sequence Directional Element

IRX models include a Negative Sequence Directional element. The operating principle is based on calculating the phase angle difference between the Negative Sequence current (I2) and the polarization magnitude, which is the Negative Sequence voltage (V2) 180º out-of-phase.

Figure shows the phasor diagram associated to a Negative Sequence Directional element.

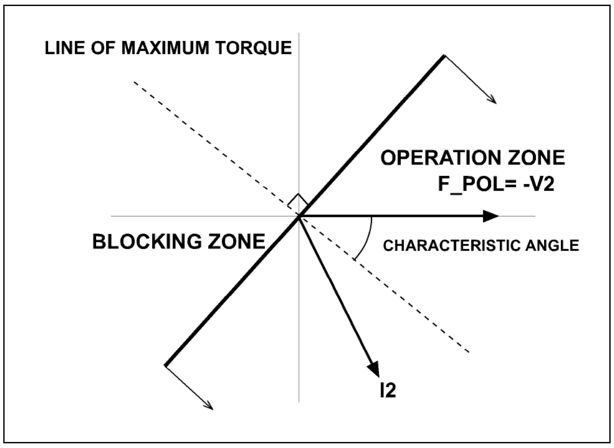


Figure 3.2.10 Vector Diagram of the Negative Sequence Directional Element.

Negative Sequence Directional elements check if negative sequence currents and voltages exceed a given value. This value is settable for voltage (**Minimum Negative Sequence Voltage** setting) and **0.02 In** for the operate phasor, **In** being rated current.

If current or voltage do not exceed their 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, trips in both directions are blocked.

The operate characteristic, drawn on a polar diagram, is a straight line, the perpendicular of which (maximum torque line) is rotated a given angle (known as characteristic angle) clockwise with respect to polarization magnitude. Said straight line divides the plane into two half planes.

When the directional element is set **Direction**, the overcurrent element is enabled when the operate magnitude phasor is within the operate zone, ±90° with respect to maximum torque line, and is disabled when within the opposite half plane. When set **Reverse Direction**, the overcurrent element is enabled when phasor is within the opposite half plane.

3.2.5 Positive Sequence Directional Element

2IRX-B-****D0**** models include a Positive Sequence directional element. The operation is based on determining the phase difference between positive sequence current and positive sequence voltage memorised two cycles in advance of fault detector activation (see 3.5). Figure shows the phasor diagram associated to the positive sequence directional element.

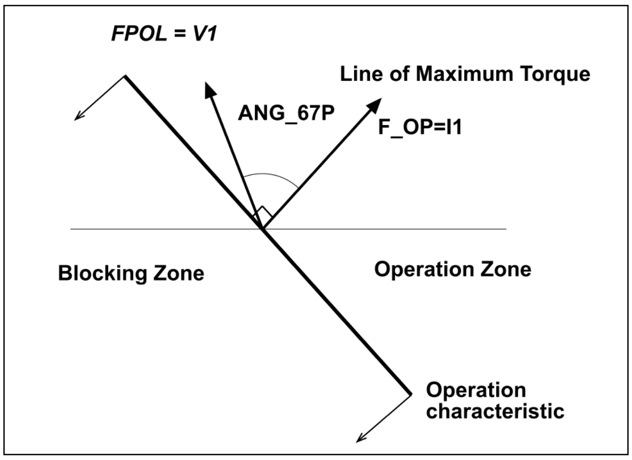


Figure 3.2.11 Vector Diagram of the Positive Sequence Directional Element.

The negative sequence directional element checks that operation and polarisation phasors exceed given values. This value is adjustable for the polarization phasor (**Minimum Zero 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 this setting indicates that there is NO blocking, the procedure is the same as for inhibiting the directional element. If, however, it indicates blocking due to lack of polarization, 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 3.2-3: Directional Negative Sequence Element		
Fop	**Fpol**	**Criteria**
I1	V1	$-\left(90^{\circ}+ANG\_67P\right)\leq\left[\arg\left(Fop\right)-\arg\left(Fpol\right)\right]\leq\left(90^{\circ}-ANG\_67P\right)$

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 polarisation used (positive sequence voltage memory), the positive sequence directional element operates correctly on voltage reversals produced in series compensated lines.

The logic diagram of operation of the directional positive sequence element is shown in this Figure.

If the **Direction Inversion Input** (**IN_INV_TRIP**) is active, the calculated direction is changed.

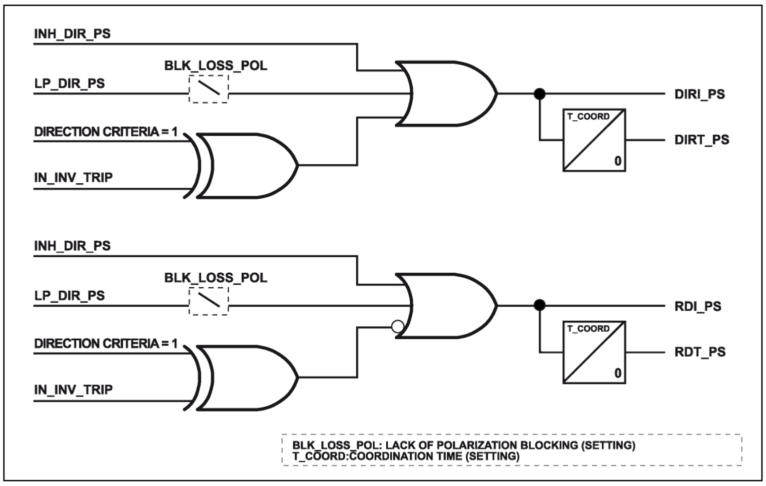


Figure 3.2.12 Block Diagram of a Directional Positive Sequence Element.

The activation of the **Inhibit of the Directional Negative Sequence** (**INH_DIR_NS**) input converts the element to non-directional.

3.2.6 Ungrounded Directional Element

2IRX-B-****F1**** relays include an Ungrounded Directional element. Ungrounded Directional Elements consist of a measuring element that operates according to voltage / current characteristic, as represented in Figure. It differs from the above in that it does not include **Coordination Time** setting and the **Characteristic Angle** setting is capacitive.

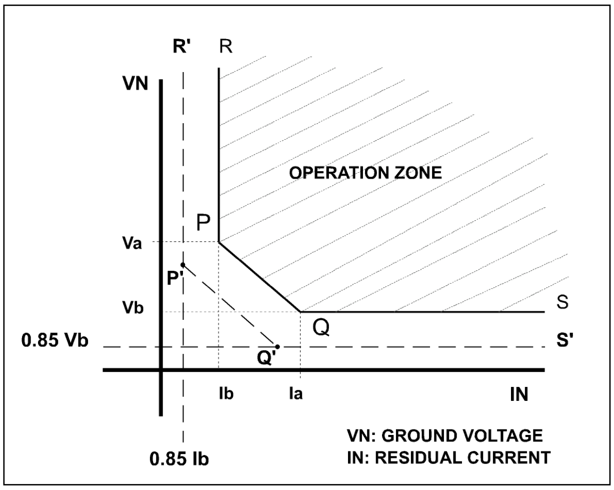


Figure 3.2.13 Diagram of the Characteristic of Ungrounded Directional Element.

The shaded zone is delimited by the operate characteristic and defines the set of zero-sequence voltage and residual current RMS values for which the characteristics generator activates element **Pickup** (**ADD_IN**) output.

The element picks up at 100% of the operate zone limit value, marked as R-P-Q-S (±5%) in figure 3.2.10, and resets at V and I values below line R'-P'-Q'-S' (±5%), where P' and Q' are:

$$P' \left[0.85\, I_b ;\ 0.85\, V_a \right]$$

$$Q' \left[0.85\, I_a ;\ 0.85\, V_b \right]$$

For a given applied voltage, pickup and reset currents are calculated as follows:

Pickup: $I = \dfrac{V_b + mI_a - Vapplied}{m}$ Reset: $I = \dfrac{\left(V_b + mI_a\right)0.85 - Vapplied}{m}$

Where **m** is the slope of line PQ: $m = \dfrac{V_a - V_b}{I_a - I_b}$

The zero sequence voltage (**VN**) is measured through a dedicated analog input (In **2IRX-B**-****F1**** relays, **VN** can be selected through the **Ground Voltage Source** setting; refer to Chapter 3.22, General Settings), as the residual current (IN) for ungrounded systems is another extremely precise analog input for very low current values.

This unit is monitored by the Ungrounded Directional element, which blocks the function if current flows in reverse to the selected direction. This directional element is polarized by voltage VN, and in order to operate, measures the phase shift between current IN and polarization voltage VN. Voltage lags the characteristic angle (α) resulting into the maximum torque line; then the phase shift between IN and said maximum torque line is measured. If this phase shift is less than 90º, IN and VN lagging by α degrees are on the same side of the characteristic and the trip is enabled. If, on the contrary, the phase shift is more than 90º, they are on opposite sides of the characteristic, and the trip is disabled (see next figure).

The operate characteristic drawn in a polar diagram results into a straight line. The position of the operate magnitude defines directional element output and the action on the overcurrent element.

In ungrounded lines, fault currents are mainly capacitive so that the characteristic angle (α) for these type of lines is normally 90º capacitive. In figure, the characteristic angle takes a fixed value of 90º capacitive with respect to polarization magnitude F_POL.

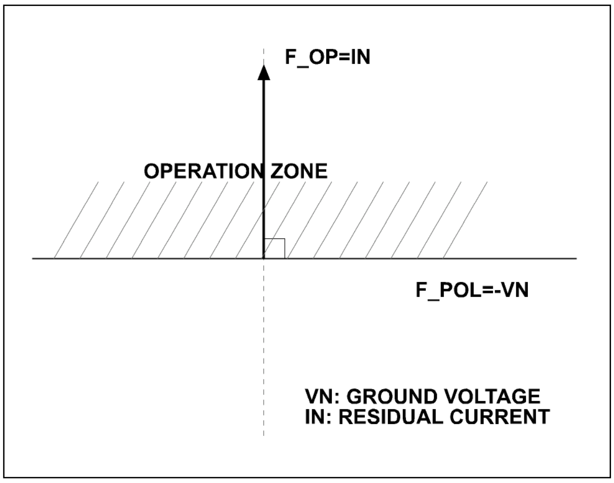


Figure 3.2.14 Vector Diagram of the Characteristic of the Directional Ungrounded Element.

If the point defined by the voltage and neutral current pair appears inside the operate zone, the element picks up and a timer starts timing. If directional blocking so enables, the element trips when the timer times out.

After the first trip the instantaneous enable timer starts timing. All trips within this time occur without counting the delay time. When delay time times out the element returns to normal operating mode.

3.2.6.a Ungrounded Protection Element Logic

Next Figure shows the overcurrent protection element block diagram. Mention is made of two elements:

- Voltage / current characteristic generator.
- Directional element.

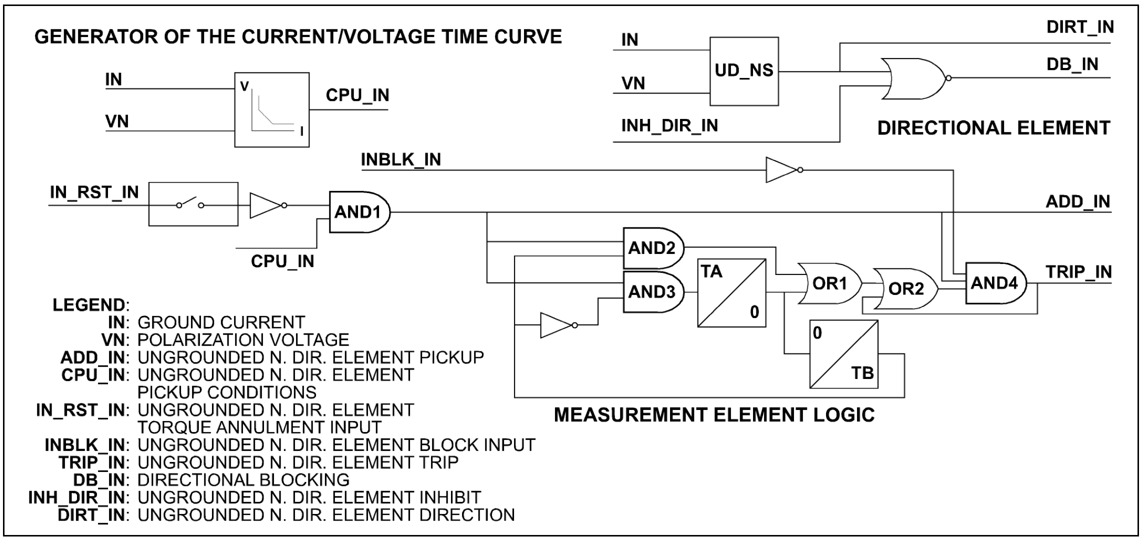


Figure 3.2.15 Ungrounded Protection Element Logic.

3.2.6.b Compensated Ground Protection (Petersen Coil)

The element is provided with a setting that allows including a special directional compensated ground characteristic (Petersen Coil). This new criterion allows for ground fault protection in Petersen coil- compensated lines.

Directional Ungrounded elements and Compensated Ground elements are operated simultaneously and share the same voltage / current characteristic. Nevertheless they are provided with separate timers (ungrounded time and compensated ground time) and separate directional characteristics.

Selection between both directional characteristics is made as shown in the following chart:

Table 3.2-4: Directional Characteristic Selection

Petersen Coil Supervision	Connected Coil	Disconnected Coil
YES	Compensated Ground	Ungrounded
NO	Compensated Ground + Ungrounded	Compensated Ground + Ungrounded

Supervision of Connected Petersen Coil input digital signal is made through **Petersen Coil Supervision** setting. If setting is YES, the state of said signal tells which of the two directional elements (ungrounded or compensated ground) will be used.

If **Petersen Coil Supervision** is set to NO, both directional characteristics are always combined. In case a fault is detected in the common zone, the characteristic with the least operating time will trip. This case has an application in a situation where if the connected Petersen coil is not well tuned, the ungrounded characteristic which setting would be much smaller than the compensated ground (Petersen coil) could operate.

Next Figure shows directional characteristics of both of them based on the fact that polarization magnitudes (-VN) and operate magnitudes (IN) are the same for ungrounded than for neutral connected to ground through the Petersen coil.

The grey zone represents the directional isolated neutral characteristic, with the maximum slope line rotated 90º counter clockwise with respect –VN. The reason for this characteristic angle is that ground fault currents are basically capacitive.

The blue zone represents the directional compensated ground (Petersen Coil) characteristic, with the maximum slope line in phase with polarization phasor (-VN). Characteristic angle is 0º as for a perfectly tuned system ground fault currents are purely resistive.

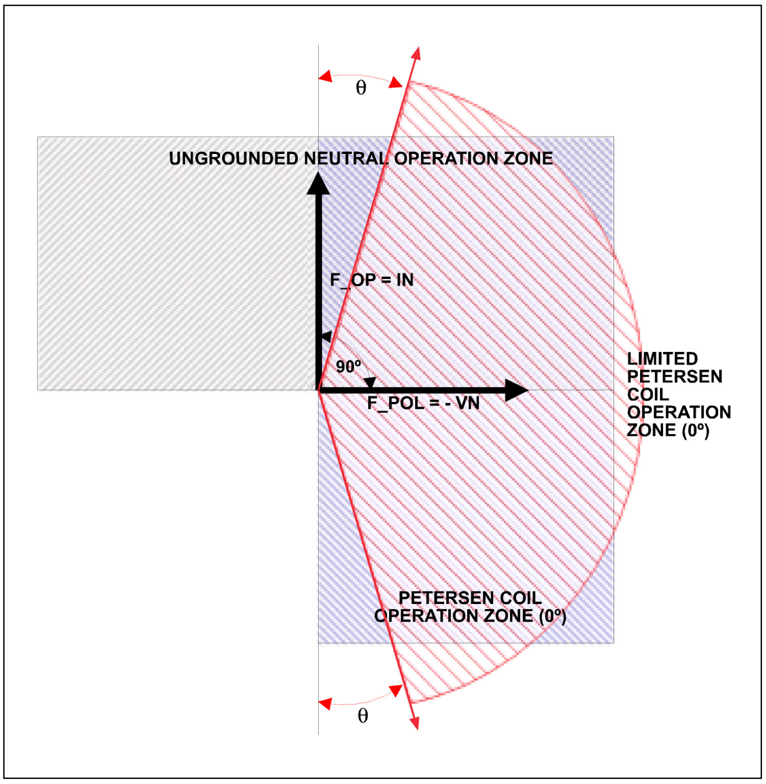


Figure 3.2.16 Vector Diagram of the Characteristic of Directional Ungrounded and Compensated Ground (Petersen Coil) Element.

The red zone represents the compensated ground (Petersen Coil) characteristic as defined above but with an operate half plane limited through angle θ setting.

Regarding recloser settings (trip and reclose permissive signals) and oscillography start permissive signal, the new directional compensated ground (Petersen Coil) characteristic shares the same settings than the directional ungrounded element.

3.2.7 Change in Trip Direction

Directional elements are provided with a logic input that can be connected to some of the digital inputs using the programming capability of the same, the function of which is to change trip direction. When this input is deactivated the trip direction is that of the previous schemes. If said input is activated, trip direction changes to the opposite direction.

3.2.8 Coordination Time

IRX type protection terminals can be used in permissive underreach schemes, connecting time overcurrent element auxiliary pickup contact to carrier relay activation input, at one end and the received carrier contact to the time overcurrent element timer disable input, at the remote end.

In case of two parallel lines; fault detection and later sequential trip in one of the lines can cause current reversal at one terminal of the parallel line, picking up as a result of the same fault. In this case, the directional element state changes from trip block to trip enable. If as a result of the permissive underreach scheme the timer is disabled, an instantaneous trip occurs as the carrier signal reset time is different from zero. In order to avoid this possibility, a coordination timer has been provided, which delays the directional trip until carrier signal disappears. This delay only affects time overcurrent elements, provided they are configured as directional.

Selected range is 0 to 30ms.

3.2.9 Directional Elements Settings

Directional Elements			
Setting	**Range**	**Step**	**Default**
Phase Characteristic Angle	0º - 90º	1º	45º
Gnd Characteristic Angle	0º - 90º	1º	45º
Negative Sequence Characteristic Angle	0º - 90º	1º	45º
Positive Sequence Characteristic Angle (2IRX-B**-***F0***)	0 - 90º	1º	45º
Lack of direction blocking	YES / NO		NO
Min. Phase Voltage	0.05 - 10 V	0.01 V	0.2 V
Min. Gnd Voltage	0.05 - 10 V	0.01 V	0.2 V
Min. Negative Sequence Voltage	0.05 - 10 V	0.01 V	
Coordinating Time	0 - 30 ms	1 ms	0 ms
Petersen Coil Angle Limit	0º - 60º	1º	0º

Neutral (Ungrounded / Petersen Coil)			
Setting	**Range**	**Step**	**Default**
Neutral Enable	YES / NO		NO
Low Current	0.005 - 0.5 A	0.001 A	0.005 A
High Current	1.0 - 3.0 x Ib	0.01	2 x Ib
Low Voltage	0.5 - 30 V	0.01 V	0.5 V
High Voltage	0.5 - 70 V	0.01 V	1 V
Ungrounded Neutral Time	0.05 - 300.00 s	0.01 s	0.1 s
Time to Instantaneous	0.05 - 300.00 s	0.01 s	3 s
Neutral Direction	0: None 1: Direction 2: Reverse		0: None
Petersen Coil Supervision	YES / NO		NO
Petersen Coil Time	0.05 - 300 s	0.01 s	0.1 s

- **Directional Overcurrent Protection: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - OVERCURRENT**
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 – ACTIVATE GROUP	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	3 - BREAKER FAILURE
4 - INFORMATION	...	4 - RESID. CURRENT DET.
		...

0 - OVERCURRENT	**0 - DIRECTIONAL**	**0 - PHASE CHARAC ANGLE**
1 - VOLTAGE	1 - TIME OVERCURRENT	**1 - GND. CHARACT. ANGLE**
2 - FREQUENCY	2 - INSTANTANEOUS	**2 - NEGSEQ CHARACT ANGLE**
3 - BREAKER FAILURE		**3 - LACK POLARIZ BLOCK**
4 - RESID. CURRENT DET.		**4 - COORD. TIME**
...		**5 - MIN. PHASE VOLTAGE**
		6 - MIN. GND VOLTAGE
		7 - MIN. NEG SEQ VOLTAGE

3.2.10 Digital Inputs of the Directional Modules

Table 3.2-5: Digital Inputs of the Directional Modules

Name	Description	Function
INBLK_IN	Ungrounded neutral directional element block input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
INBLK_PC	Petersen coil directional element block input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_RST_INPC	Ungrounded neutral / Petersen coil directional element torque annulment input	It resets the timing function included in the element and keeps it at 0 while it is active. With the unit configured in directional mode, if the corresponding monitoring setting and the input are active, trip is blocked for lack of determining the direction.
ENBL_INPC	Ungrounded neutral / Petersen coil directional element enable input	Activation of this input puts the unit into service. 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 of this logic input signal is a “1.”

Table3.2-5: Digital Inputs of the Directional Modules		
Name	**Description**	**Function**
INH_DIR_PH	Phase directional element inhibit	The activation of these inputs converts the directional elements into non-directional..
INH_DIR_N	Ground directional element inhibit	
INH_DIR_SG	Sensitive ground directional element inhibit	
INH_DIR_NS	Negative sequence directional element inhibit	
INH_DIR_INPC	Ungrounded neutral / Petersen coil directional element inhibit	
IN_INV_TRIP	Inversion of the trip direction	When the input is quiescent, the operation zones are those indicated in this section 3.2. If it is activated, the operation zone of all the directional elements is inverted.
CON_PC	Connected Petersen coil input	This input is used to select ungrounded or compensated ground elements.

3.2.11 Auxiliary Outputs and Events of the Directional Modules

Table 3.2-6: Auxiliary Outputs and Events of the Directional Modules		
Name	**Description**	**Function**
ADD_INPC	Ungrounded neutral / Petersen coil directional element pickup	AND logic of the pickup of the current element with the corresponding torque-control input.
CPU_INPC	Ungrounded neutral / Petersen coil directional element pickup conditions	Element pickup unaffected by torque control.
TRIP_INPC	Ungrounded neutral / Petersen coil directional element trip	Trip of the insulated ground / compensated ground element.
CT_IN	Ungrounded neutral directional element trip conditions	Trip of the insulated ground element.
CT_PC	Petersen coil directional element trip conditions	Trip of the compensated ground element.
TRIP_INPCM	Ungrounded neutral / Petersen coil directional element masked trip	Trip of the insulated ground / compensated ground current element affected by its corresponding trip mask.
INBLK_IN	Ungrounded neutral directional element block input	The same as for the digital input.
INBLK_PC	Petersen coil directional element block input	The same as for the digital input.
IN_RST_INPC	Ungrounded neutral / Petersen coil directional element torque annulment input	The same as for the digital input.
ENBL_INPC	Ungrounded neutral / Petersen coil directional element enable input	The same as for the digital input.
INPC_ENBLD	Ungrounded neutral / Petersen coil directional element enabled	Indication of enabled or disabled status of the unit.

Table 3.2-6: Auxiliary Outputs and Events of the Directional Modules

Name	Description	Function
RDI_A	Phase A instantaneous element reverse direction	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	Phase B instantaneous element reverse direction	
RDI_B	Phase C instantaneous element reverse direction	
RDI_B	Ground instantaneous element reverse direction	
RDI_SG	Sensitive ground instantaneous element reverse direction	
RDI_NS	Negative sequence instantaneous element reverse direction	
RDT_A	Phase A time element reverse direction	
RDT_B	Phase B time element reverse direction	
RDT_B	Phase C time element reverse direction	
RDT_B	Ground time element reverse direction	
RDT_SG	Sensitive ground time element reverse direction	
RDT_NS	Negative sequence time element reverse direction	
RDT_IN	Ungrounded neutral element reverse direction	
RDT_PC	Petersen coil element reverse direction	
DIRI_A	Phase A instantaneous element direction	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	Phase B instantaneous element direction	
DIRI_B	Phase C instantaneous element direction	
DIRI_B	Ground instantaneous element direction	
DIRI_SG	Sensitive ground instantaneous element direction	
DIRI_NS	Negative sequence instantaneous element direction	
DIRT_A	Phase A time element direction	
DIRT_B	Phase B time element direction	
DIRT_B	Phase C time element direction	
DIRT_B	Ground time element direction	
DIRT_SG	Sensitive ground time element direction	
DIRT_NS	Negative sequence time element direction	
DIRT_IN	Ungrounded neutral element direction	
DIRT_PC	Petersen coil element direction	
INHD_PH	Phase directional element inhibit	The same as for the digital inputs.
INHD_N	Ground directional element inhibit	
INHD_SG	Sensitive ground directional element inhibit	
INHD_NS	Negative sequence directional element inhibit	
INH_DIR_INPC	Ungrounded neutral / Petersen coil directional element inhibit	
INV_TRIP	Inversion of the trip direction	The same as for the digital input.
CON_PC	Connected Petersen coil input	This input is used to select ungrounded or compensated ground elements.

3.2.12 Directional Elements 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, Ic with Va, In with Va and Ins with Va. Next Tables show 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 3.2-7: Phase Directional Control	
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

Table 3.2-8: Ground Directional Control			
Ground Directional and Sensitive Ground Directional by Vpol		**Ground Directional by Ipol**	
V APPLIED	I APPLIED	I APPLIED	
Va = 64V⌊0º	In = 1A⌊ (90º - α charact to 270º - α charact) ± 2º	Ip = 1A⌊180º	In = 1A⌊-90º to 90º

Table 3.2-9: Negative Sequence Directional Control	
V APPLIED	I APPLIED
Va = 64V⌊180º	Ia = 1A⌊(270º - α charact to 90º - α charact) ± 2º

3.2.12.a Ungrounded / Compensated Ground (Petersen Coil) Element Test

Prior to testing, Phase Instantaneous and Time Overcurrent elements must be disabled and Ground element must be enabled with following settings:

Low current (Ib)	0.05 A
High current (Ia)	3 x Ib
Low voltage (Ub)	3 V
High voltage (Ua)	50 V
Time first trip	0.1 s
Time to instantaneous	3 s
Ground characteristic angle	90º
Petersen coil supervision	NO
Compensated ground time	0.1 s

- **Pickup**

Apply current to ground current input and voltage leading the current by 135º to ground voltage input; check, for currents shown in table 3.2-10, that Ground element pickup state indicator sets to steady “1” when voltage is between Arr_MIN and Arr_MAX. Eventually the Ground element output will also activate and, simultaneously, trip contacts will close.

Check that the pickup indicator resets when current is between Rep_MIN and Rep_MAX. When the pickup indicator resets the output indicator also resets.

Table 3.2-10: Ungrounded / Compensated Ground Element Test (Pickup)

Voltage (V)	Arr_MAX	Arr_MIN	Rep_MAX	Rep_MIN
55	0.053	0.048	0.050	0.045
45.3	0.063	0.057	0.055	0.047
26.5	0.105	0.095	0.097	0.087
7.7	0.147	0.133	0.139	0.125
2	No pickup			

For these settings, pickup and reset values are given by:

	Arr_MAX	Arr_MIN
Vap	$\frac{V_b + mI_a - V_{ap} \cdot 0.99}{m} \bullet 1.01$	$\frac{V_b + mI_a - V_{ap} \cdot 1.01}{m} \bullet 0.99$

Rep_MAX	Rep_MIN
$\frac{(V_b + mI_a) \cdot 0.85 - V_{ap} \cdot 0.99}{m} \bullet 1.01$	$\frac{(V_b + mI_a) \cdot 0.85 - V_{ap} \cdot 1.01}{m} \bullet 0.99$

Where: $m = \frac{V_a - V_b}{I_a - I_b}$

- **Trip Times**

Apply a voltage of 15 Vac leading the current by 135º. Check that when applying a current of 2 Aac, for the settings stated in next Table, trip times are within the stated margins.

Table 3.2-11: Ungrounded / Compensated Ground Element Test (Trip Times)			
Ungrounded Neutral Time Setting (s)	Compensated Ground Time Setting (s)	TMIN (s)	TMAX (s)
0.1	1	0.075	0.125
1	2	0.98	1.02
10	15	9.8	10.2
1	0.1	0.075	0.125
2	1	0.98	1.02
3	2	1.96	2.04

It is worth mentioning that after the first trip, trips occurring within the next three seconds will be instantaneous.

After testing one of the time delayed trips and before a 3 s time lapse, current will be applied again checking that the instantaneous trip time is, in all cases, within a 25 ms margin. Then, wait at least for three seconds before checking the next delayed trip.

- **Directional Element Test**

Set the **Petersen Coil Angle Limit** to 15º and apply 2 Aac ground current and 15 Vac ground voltage, leading the current by 135º.

Set **Petersen Coil Supervision** to NO, and check that the Ground element operates as a Petersen Coil and Ungrounded Neutral.

Set **Petersen Coil Supervision** to YES, and check that the Ground element operates as Ungrounded Neutral.

Set **Petersen Coil Supervision** to YES and activate through a DI the digital signal **Connected Petersen Coil** input. Check that the Ground element operates as a **Petersen Coil**.

Direction and reverse direction areas for each of the cases are shown in next Table with an error of ±1º:

Table 3.2-12: Directional Element Test			
Ungrounded Neutral		**Compensated Ground**	
Direction	Reverse Direction	Direction	Reverse Direction
315º to 135º	135º to 315º	240º to 30º	60º to 210º

3.3 Protection Schemes for Overcurrent Elements

3.3.1 Description

2IRX-B and **2IRX-C** relays Ground and Negative Sequence Directional Instantaneous Overcurrent elements (with the possibility of time overcurrent operation) can be provided with Protection Schemes.

All schemes use two elements, one underreach and the other overreach, which will coincide with Ground and Negative Sequence Overcurrent elements 1 and 2 as a function of **Teleprotection Elements** setting. Both elements must monitor direction forward. 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 (**2IRX-B**-****D0**** Models).
3. Direct Transfer Trip.
4. Permissive Overreach Trip.
5. Directional Comparison Unblocking (**2IRX-B**-****D0**** Models).
6. Directional Comparison Blocking.

2IRX-B-****D0**** models comprises **Weak Infeed** logic and **Reverse Current Blocking** logic, which, if enabled, 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. Said element will pickup, in **2IRX-B**-****D0**** models, on the activation of the **Reverse Direction Element Pickup** logic input. In the remaining models, the reverse direction element will be the ground instantaneous overcurrent or negative sequence element 2 as a function of the **Protection through Communications Element** setting.

3.3.2 Permissive Underreach (2IRX-B**-****D0** Models)

Permissive Underreach is activated when selected in the **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, **Overcurrent Weak Infeed Output** (**WI_OCM**) 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.

3.3.2.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 **Open Breaker Transmission** is set to **YES**.

3.3.2.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 **Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo + Trip**.

3.3.2.c Operation

Channel activation and trip command generation are shown in the block diagram.

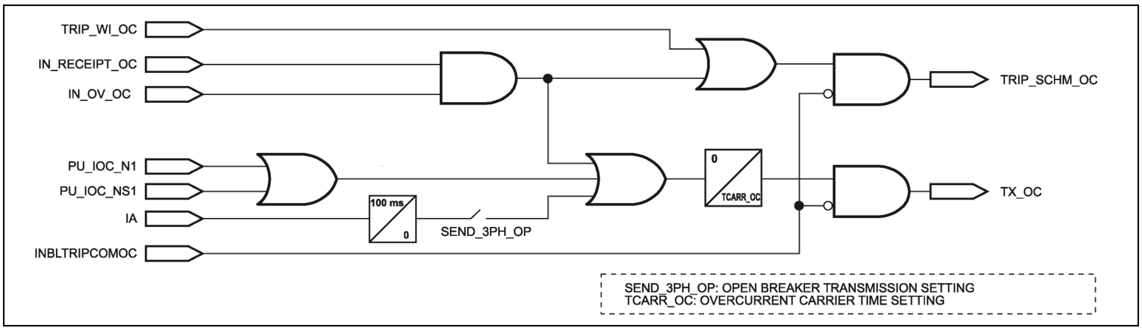


Figure 3.3.1 Permissive Underreach Scheme Block Diagram (2IRX-B-****D0**).**

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) setting on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

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 **Overcurrent Channel Trip Blocking** (**INBLTRIPCOMOC**).

3.3.3 Direct Transfer Trip

The Direct Transfer Trip scheme activates when **Overcurrent Protection Scheme** is set to **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.

3.3.3.a Channel Activation Conditions (“Overcurrent Channel Transmission”)

Communications channel activates on any of the following conditions:

1. Underreach element pickup
2. Open breaker if **Open Breaker Transmission** is set to YES.

3.3.3.b Trip Condition (“Overcurrent Protection Scheme Trip”)

Transfer trip occurs whenever channel is received.

3.3.3.c Operation

Channel activation and trip conditions are depicted in block diagram of next Figure.

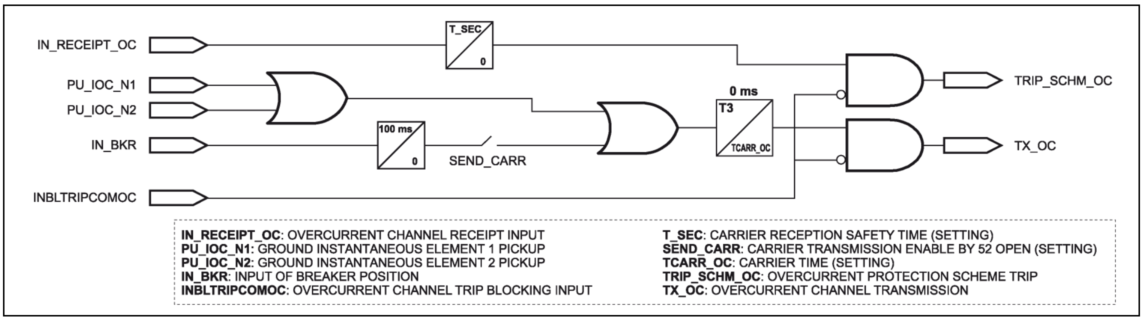


Figure 3.3.2 Direct Transfer Trip Scheme Block Diagram (Overcurrent).

Overcurrent Carrier Time setting (**TCARR_OC**) shown in diagram guarantees a minimum time requirement for channel activation (**TX_OC**).

Open Breaker Transmission setting allows channel activation with open breaker. The 100 ms delay is to delay carrier transmission caused by open breaker.

Safety Time setting (**T_SEC**) 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 (**INBLTRIPCOMOC**).

3.3.4 Permissive Overreach Trip

The Permissive Overreach Trip scheme activates when **Overcurrent Protection Scheme** sets to **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.

In **2IRX-B**-****D0**** models, **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, in **2IRX-B**-****D0**** models, 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 (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option for tripping the "weak" end (**Overcurrent Weak Infeed Output** (**WI_OCM**) must set to **Echo + Trip**).

3.3.4.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 **Open Breaker Transmission** is set to YES.
3. **Overcurrent Echo** (**ECHO_OC**) activated, output of **Weak Infeed Logic**, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) setting of said logic must be set to **Echo** or **Echo + Trip** (**2IRX-B**-****D0**** models).

3.3.4.b Trip Condition ("Overcurrent Protection Scheme Trip")

Channel trip will take place upon channel reception and pickup of the overreach unit or, in **IRV-D/G/H******Y0** models, if **Overcurrent Weak Infeed Trip** (**TRIP_WI_OC**) is activated, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) of the **Weak Infeed Logic** (for overcurrent elements) must be set to **Echo + Trip**.

3.3.4.c Operation

Channel and trip activation conditions are depicted in block diagram of figure 3.3.2.

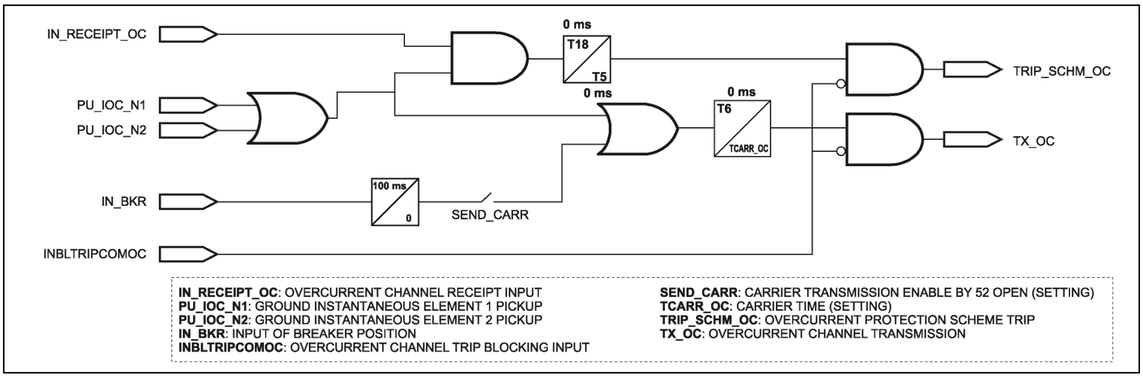


Figure 3.3.3 Permissive Overreach Scheme Block Diagram (Overcurrent).

Overcurrent Carrier Time setting (**TCARR_OC**) on diagram guarantees a minimum time requirement for channel activation (**TX_OC**).

Open Breaker Transmission setting allows channel activation with open breaker. The 100 ms delay is to delay carrier transmission caused by open breaker.

Transfer trip and channel activation may be blocked activating **Overcurrent Channel Trip Blocking** digital input (**INBLTRIPCOMOC**).

3.3.5 Directional Comparison Unblocking (2IRX-B**-****D0** Models)

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 (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo** or **Echo + Trip**), apart from giving the option to trip the “weak” end (**Overcurrent Weak Infeed Output** (**WI_OCM**) must be set to **Echo + Trip**).

3.3.5.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 **Open Breaker Transmission** is set to **YES**.
3. Activation of **Overcurrent Echo** (**ECHO_OC**) signal, **Weak Infeed Logic** output, for which **Overcurrent Weak Infeed Output** (**WI_OCM**) of said logic must be set to **Echo** or **Echo + Trip**.

3.3.5.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 **Overcurrent Weak Infeed Output** (**WI_OCM**) of **Weak Infeed Logic** (for Overcurrent elements) must be set to **Echo + Trip**.

3.3.5.c Operation

Activation of a channel and generation of a trip command are shown in the following block diagram.

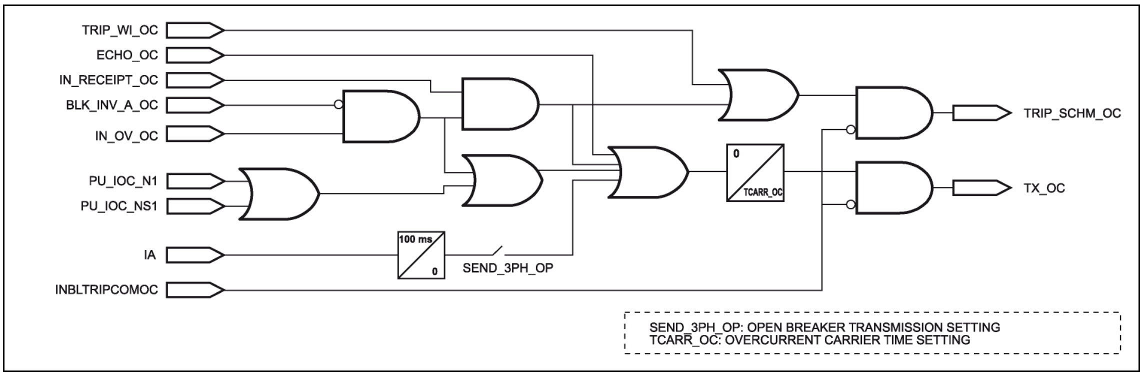


Figure 3.3.4 Directional Comparison Unblocking Scheme Block Diagram (2IRX-B-****D0**).**

The purpose of **Overcurrent Carrier Time** (**TCARR_OC**) on the diagram is guaranteeing a minimum time for channel activation (**TX_OC**).

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 **8ZLV Overcurrent Guard Loss** input - **INLOSSGUAR_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 (**IRV** IED output) must be wired to the wave carrier equipment input, which will give the command for frequency switching.

When both **INLOSSGUAR_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 **INLOSSGUAR_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_CWE**, the signal **FAIL_CWE**=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** (**INBLTRIPCOMOC**).

3.3.6 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 Ground or Negative Sequence Overcurrent element set reverse direction is necessary, which is used for channel activation. Said element will be the Ground or Negative Sequence Instantaneous Overcurrent element 2 (OR both). In **2IRX-B**-****D0**** relays, the reverse looking element pickup will coincide with the activation of the logic input **Reverse Looking Element Pickup**, to which the pickup signal of any overcurrent element could be allocated.

Note: when this protection scheme is selected, the element 2 will show reverse direction torque control, even if the setting shows otherwise.

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 **Blocking Scheme Time Delay** setting.

3.3.6.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. **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.

3.3.6.b Channel Disable Conditions (“Overcurrent Channel Disable”)

Deactivating or blocking a terminal communications channel (end of block signal transmission) takes place under any of the following conditions:

1. Channel disable 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.

3.3.6.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.

3.3.6.d Operation

Channel activation and trip conditions are depicted in block diagram of figure 3.3.3.

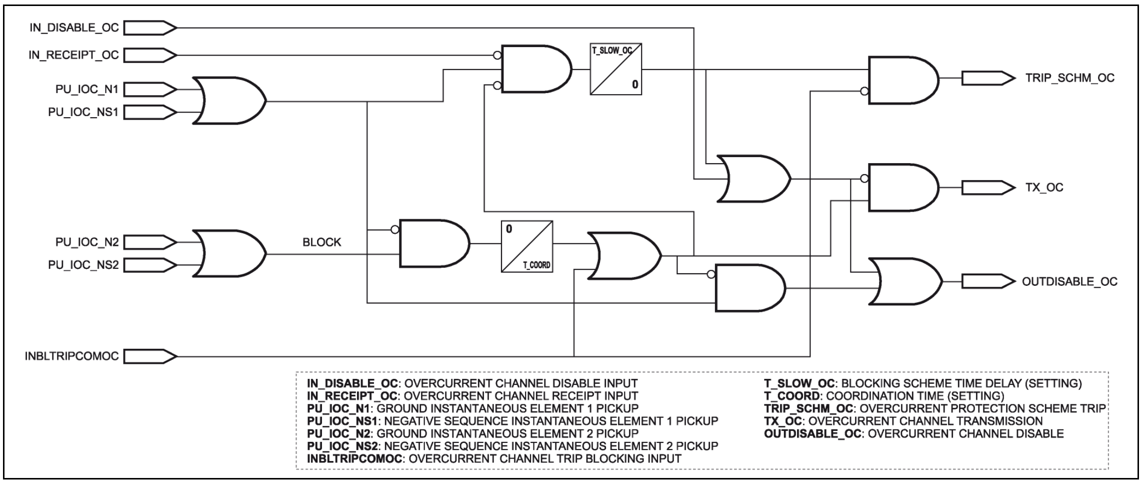


Figure 3.3.5 Directional Comparison Blocking Scheme Block Diagram (Overcurrent).

Blocking Scheme Time Delay setting (**T_SLOW_OC**), allows, as mentioned above, for external faults, time for reception of the blocking signal from the remote terminal.

Overcurrent **Coordination Time** setting (**T_COORD**) 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.

IRX channel stop output must be hard wired to communications equipment **Overcurrent Channel Disable** (**IN_DISABLE_OC**) input to disable the channel. Nevertheless said output also cancels channel activation output in order to prevent against the fact that **IN_DISABLE_OC** input is not configured in the communications channel 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** (**INBLTRIPCOMOC**) digital input.

3.3.7 Weak Infeed Logic (2IRX-B**-****D0** Models)

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**.

3.3.7.a Echo Logic

This function is enabled by setting **Overcurrent Weak Infeed Output** (**WI_OCM**) 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.

3.3.7.b Weak Infeed Tripping

This function is enabled by setting **Overcurrent Weak Infeed Output** (**WI_OCM**) 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.

3.3.7.c Operation

Next Figure shows the logic operating diagram.

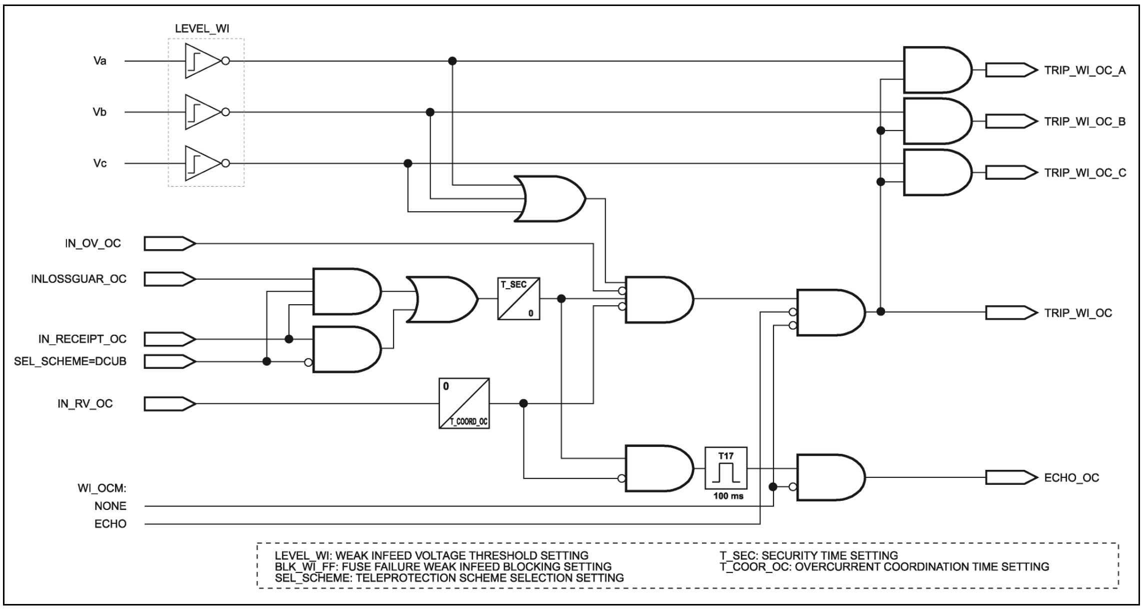


Figure 3.3.6 Weak Infeed Logic Block Diagram (2IRX-B-****D0**).**

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 **Safety Time** (**T_SEC**) 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** (**INLOSSGUAR_OC**) input activation.

The setting **Overcurrent Coordination Time** (**T_COORD_OC**) is used to prevent weak infeed trips upon current reversal in double circuits.

3.3.8 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).

3.3.9 Overcurrent Elements Protection Schemes Settings

Protection Scheme			
Setting	**Range**	**Step**	**Default**
Carrier transmission enable by 52 open	YES / NO		YES
Carrier reception safety time	0 - 50 ms	1 ms	0 ms
Protection scheme	0: None. 1: Direct transfer trip. 2: Permissive overreach. 3: Directional comparison blocking.		0: None
Teleprotection elements	0 - Ground 1 - Negative Sequence 2 - Ground or Negative Sequence		
Carrier time	0 - 200 ms	10 ms	50 ms
Blocking scheme time delay	0 - 200 ms	10 ms	50 ms

Protection Scheme (2IRX-B**-****D0**)			
Setting	**Range**	**Step**	**Default**
Carrier transmission enable by 52 open	YES / NO		YES
Carrier reception safety time	0 - 50 ms	1 ms	0 ms
Weak Infeed voltage level	15.00 - 70.00 V	0,01 V	45 V
Protection scheme	0: None. 1: Permissive underreach. 2: Direct transfer trip. 3: Permissive overreach. 4: Directional comparison unblocking. 5: Directional comparison blocking.		Ninguno
Teleprotection Elements	0 - Ground 1 - Negative Sequence 2 - Ground or Negative Sequence		
Carrier time	0 - 200 ms	10 ms	50 ms
Coordination time (Reverse Current Blocking Logic)	0 - 50 ms	1 ms	25 ms
Blocking scheme time delay	0 - 200 ms	10 ms	50 ms
Weak Infeed logic output	NONE ECHO ECHO + TRIP	NONE	

3.3.10 Digital Inputs of the Overcurrent Protection Schemes Module

Table 3.3-1: Digital Inputs of the Overcurrent Protection Schemes Module

Name	Description	Function
IN_RECEIPT_OC	Overcurrent channel receipt input	The activation of this input means a signal receipt (trip permissive or blocking, as a function of the selected scheme) from the other end.
INBLTRIPCOMOC	Overcurrent channel trip blocking input	The activation of this input blocks the trip of any overcurrent protection scheme.
INLOSSGUAR_OC	Overcurrent guard signal loss input	The activation of this input means that the guard signal receipt has ceased. It is used in the Directional Comparison Unblocking scheme.
IN_DISABLE_OC	Overcurrent channel disable input	The activation of this input generates Channel Disable output. It is used in the Directional Comparison Blocking scheme.
IN_OV_OC	Overreach element pickup input	Overreach overcurrent element pickup.
IN_RV_OC	Reverse looking element pickup input	Reverse looking overcurrent element pickup.

3.3.11 Auxiliary Outputs of the Overcurrent Protection Schemes Module

Table 3.3-2: Auxiliary Outputs of the Overcurrent Protection Schemes Module		
Name	**Description**	**Function**
TRIP_SCHM_OC	Overcurrent protection scheme trip	Selected overcurrent protection scheme trip.
TX_OC	Overcurrent channel transmission	Channel activation by the selected overcurrent protection scheme.
FAIL_CWE	Carrier wave equipment failure	Carrier wave equipment failure.
OUTDISABLE_OC	Overcurrent channel disable	Output for channel disabling used in Directional Comparison Blocking scheme.
TRIP_WI_OC	Overcurrent weak infeed trip	Weak infeed condition trip in overcurrent protection scheme.
TRIP_WI_OC_A	Phase A overcurrent weak infeed trip	Trip by weak infeed condition in phase A in overcurrent protection scheme.
TRIP_WI_OC_B	Phase B overcurrent weak infeed trip	Trip by weak infeed condition in phase B in overcurrent protection scheme.
TRIP_WI_OC_C	Phase C overcurrent weak infeed trip	Trip by weak infeed condition in phase C in overcurrent protection scheme.
ECHO_OC	Overcurrent echo transmission	Echo transmission in overcurrent protection scheme.
BLK_INV_A_OC	Overcurrent reverse current blocking	Overreaching unit blocking in overcurrent protection scheme by current reversal detection.
IN_RECEIPT_OC	Overcurrent channel receipt input	The same as for the digital input.
INBLTRIPCOMOC	Overcurrent channel trip blocking input	The same as for the digital input.
INLOSSGUAR_OC	Overcurrent guard signal loss input	The same as for the digital input.
IN_DISABLE_OC	Overcurrent channel disable input	The same as for the digital input.
IN_OV_OC	Overreach element pickup input	The same as for the Digital Input.
IN_RV_OC	Reverse looking element pickup input	The same as for the Digital Input.

3.4 Voltage Elements

3.4.1 Undervoltage Elements

IRX IEDs have the following undervoltage elements:

- Three phase undervoltage elements (27F1, 27F2 and 27F3).

Each element is associated with the three voltage analog inputs and has a setting to select between working with **Phase-Ground** or **Phase-Phase** voltages. They operate when the RMS values of the voltages measured reach a given value. This value is set simultaneously for the three voltages in each IED. It is set as either **phase-ground** or **phase-phase** voltage.

The undervoltage elements have an associated logic which can be controlled with a setting in which you select between the following two possible types of operation (3.4.2):

- **AND**: the (27F) element trips when the three associated undervoltage elements (V1, V2 and V3) comply with the trip condition.
- **OR**: the (27F) element trips when one or more of the three associated undervoltage elements (V1, V2 or V3) comply with the trip condition.

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** timing sequence.

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.

An analog input can be assigned to the logic signal that blocks the trip signaling of the undervoltage phase elements, thus disabling the output if this signal is activated.

The operation of these elements is conditioned to the position of the breaker. An open breaker disables the element.

3.4.2 Overvoltage Elements

IRX IEDs have the following overvoltage elements:

- Phase overvoltage elements (59F1, 59F2 and 59F3).
- Two ground overvoltage elements (59N1 and 59N2 or 64_1 and 64_2).
- One negative sequence overvoltage unit (47)

3.4.2.a Phase Overvoltage Elements

The phase overvoltage elements are associated with the three voltage analog inputs and have a setting to select between working with **Phase-Ground** or **Phase-Phase** voltages. They operate when the RMS values of the voltages measured reach a given value. This value is set simultaneously for the three voltages in each IED. It is set as either **Phase-Ground** or **Phase-Phase** voltage.

The overvoltage 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 3.4.2):

- **AND**: the (59F) element trips when the three associated overvoltage elements (V1, V2 and V3) comply with the trip condition.
- **OR**: the (59F) element trips when one or more of the three associated overvoltage elements (V1, V2 or V3) comply with the trip condition.

Pickup occurs for a given overvoltage element when the value measured is greater than one times the set value, and resets at a selectable percentage (less) of 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** timing sequence.

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.

You can assign an analog input to the logic signal that blocks the trip signaling of the overvoltage phase elements, thus disabling the output if this signal is activated.

The algorithm below exemplifies a typical application:

- 59F1A, 59F1B and 59F1C associated with an **AND** algorithm, with pickup level 1.2Vn and instantaneous operation,
- 59P2A, 59P2B and 59P2C associated with an **OR** algorithm, with pickup level 1.1Vn and delayed operation.

3.4.2.b Ground Overvoltage Elements

- **Elements 59N1 and 59N2**

Ground overvoltage elements 59N1 and 59N2 are made up of an instantaneous overvoltage element with an additional independent adjustable timer.

The ground voltage is calculated using data from the three phase voltages. The RMS value of this ground voltage, which is the operating magnitude of the level detector, is calculated with the phase voltages as follows:

$$\overline{V_N} = \overline{V_A} + \overline{V_B} + \overline{V_C}$$

The adjustable output of this detector is the pickup signal of elements 59N1 and 59N2. It initializes an adjustable timer, whose output, combined with the blocking signal of the unit, in the AND gate is taken as the element's output. See figure 3.4.1.

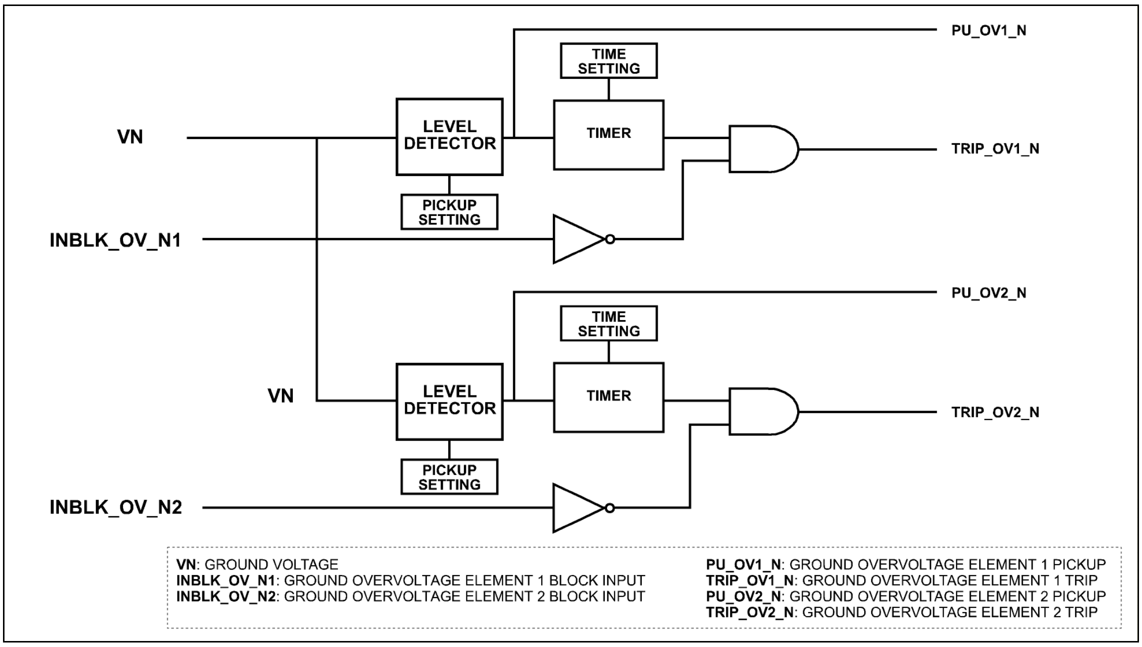


Figure 3.4.1 Block Diagram of Ground Overvoltage Elements 59N1 and 59N2.

Each element picks up when the RMS value of the zero sequence voltage exceeds 1 times the set pickup value and resets with a selectable value percentage (lower) of the setting.

Elements 59N1 and 59N2 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. To be able to use these logic input signals, it is necessary to program the status contact inputs defined as **Block Trip**.

- **Elements 64_1 and 64_2**

The characteristics of these elements are identical to those of elements 59N1 and 59N2, except that the neutral voltage is obtained directly through a TT connection in open delta. This is why the IED has a specific voltage analog input.

3.4.2.c Negative Sequence Overvoltage Element

IRX models have an negative sequence overvoltage element. It operates when the value of the negative sequence voltage exceeds the set value. The element picks up when the negative sequence voltage surpasses 1 times the pickup setting and resets with a selectable percentage value (lower) of the setting.

This element has an adjustable timer that allows an optional delay of the output.

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.

The negative sequence overvoltage element can be blocked with the **Negative Sequence Overvoltage Blocking Input**. This requires assigning this blocking logic input signal to one of the status contact inputs.

- **Blocking Logic**

It is relatively common to use an algorithm to block the neutral time overcurrent elements when the undervoltage element (27) and the negative sequence overvoltage element (47) are both picked up. This type of blocking acts before the timer of the overcurrent elements is initiated.

To have this type of blocking, it must first be configured in the programmable logic.

3.4.3 Block Diagram of the Voltage Elements

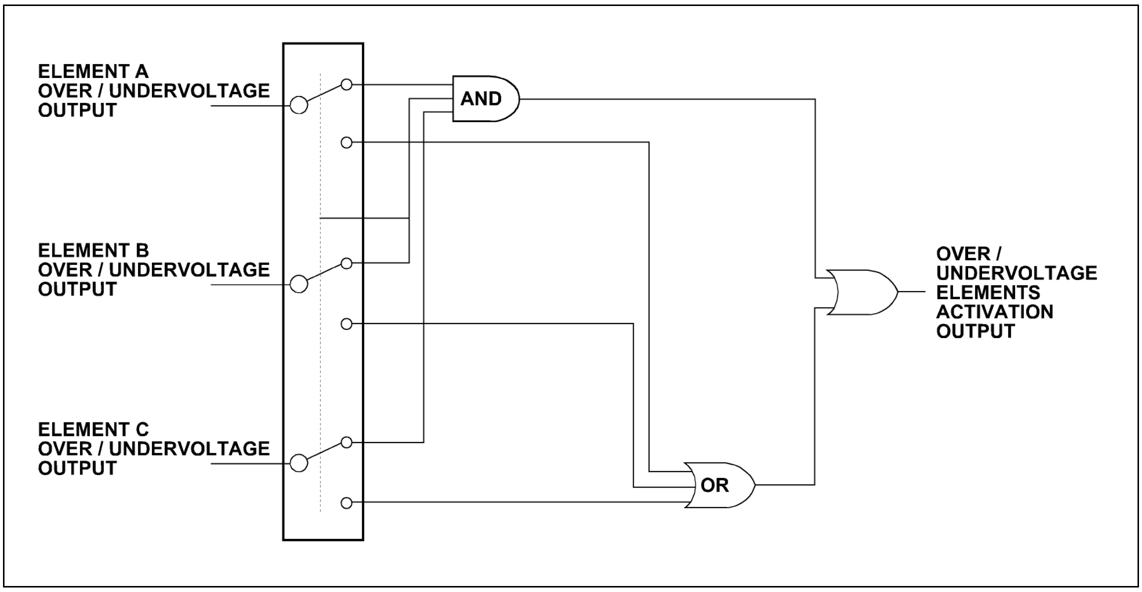


Figure 3.4.2 Block Diagram of the AND/OR Operation for the Voltage Elements.

The output that enables overvoltage/undervoltage elements in the diagram of figure 3.4.2 corresponds to the outputs of **three-phase masked trip of undervoltage and overvoltage elements 1, 2 and 3**. This means that their corresponding trip masks affect these signals, which are directional to the protection trip. The masked trips of each of the phases generate events and activate signals that can be used in the programmable logic, but by themselves they do not give rise to a trip.

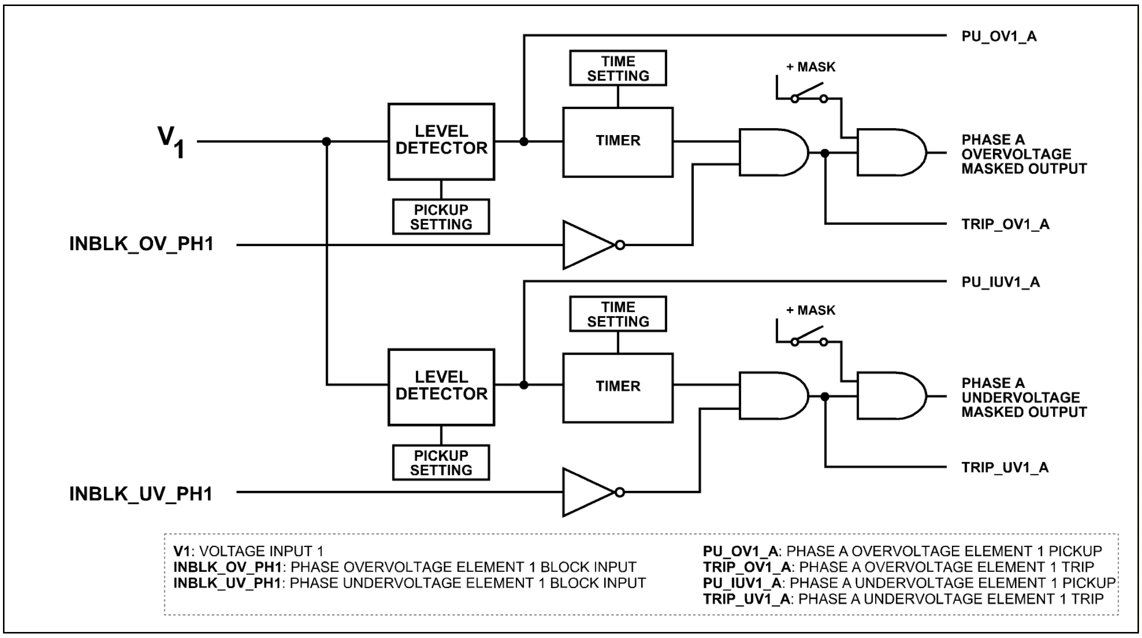


Figure 3.4.3 Block Diagram of an Overvoltage / Undervoltage Element.

3.4.4 Voltage Elements Settings

Voltage Dropout			
Setting	**Range**	**Step**	**Default**
Phase overvoltage elements dropout	50 - 99% of setting	1	95 %
Ground overvoltage elements dropout	50 - 99% of setting	1	95 %
Neg. sequence overvoltage elements dropout	50 - 99% of setting	1	95 %
Phase undervoltage elements dropout	101 - 150% of setting	1	105 %

Phase Overvoltage (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Voltage Type	Line Voltage Phase Voltage		Line Voltage
Pickup	20 - 300 V	0.01 V	70 V
Time Delay	0 - 300 s	0.01 s	0 s
Tripping Logic	OR / AND		OR

Phase Undervoltage (Elements 1, 2 and 3)			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Voltage Type	Line Voltage Phase Voltage		Line Voltage
Pickup	10 - 300 V	0.01 V	40 V
Time Delay	0 - 300 s	0.01 s	0 s
Tripping Logic	OR / AND		OR

Ground Overvoltage (Elements 1 and 2)			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	2 - 150 V	0.01 V	10 V
Time Delay	0 - 300 s	0.01 s	0 s

Negative Sequence Overvoltage Element			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	2 - 100 V	0.01 V	10 V
Time Delay	0 - 300 s	0.01 s	0 s

- **Voltage Protection: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	**1 - VOLTAGE**
2 – ACTIVATE GROUP	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	3 - BREAKER FAILURE
4 - INFORMATION	...	...

0 - OVERCURRENT	**0 - VOLTAGE RESET**
1 - VOLTAGE	**1 - PHASE OVERVOLTAGE**
2 - FREQUENCY	**2 - NEG. SEQ. OVERVOLT.**
3 - BREAKER FAILURE	**3 - GROUND OVERVOLTAGE**
...	**4 - PHASE UNDERVOLTAGE**

Voltage Reset

0 - VOLTAGE RESET	**0 - PH. UV RESET**
1 - PHASE OVERVOLTAGE	**1 - PH OV RESET**
2 - NEG. SEQ. OVERVOLT.	**2 - GND OV RESET**
3 - GROUND OVERVOLTAGE	**0 - NEGSEQ OV RESET**
4 - PHASE UNDERVOLTAGE	

Phase Overvoltage

0 - VOLTAGE RESET	**0 - UNIT 1**	**0 - PH. OV ENABLE**
1 - PHASE OVERVOLTAGE	**1 - UNIT 2**	**1 - VOLTAGE TYPE**
2 - NEG. SEQ. OVERVOLT.	**2 - UNIT 3**	**2 - PH. OV PICKUP**
3 - GROUND OVERVOLTAGE		**3 - PH. OV DELAY**
4 - PHASE UNDERVOLTAGE		**4 - OUTPUT LOGIC PH OV**

Negative Sequence Overvoltage

0 - VOLTAGE RESET	**0 - NEGSEQ OV ENBL**
1 - PHASE OVERVOLTAGE	**1 - NEGSEQ OV PICKUP**
2 - NEG. SEQ. OVERVOLT.	**2 - NEGSEQ OV TIMER**
3 - GROUND OVERVOLTAGE	
4 - PHASE UNDERVOLTAGE	

Ground Overvoltage

0 - VOLTAGE RESET	**0 - UNIT 1**	**0 - GND OV ENABLE**
1 - PHASE OVERVOLTAGE	**1 - UNIT 2**	**1 - GND OV PICKUP**
2 - NEG. SEQ. OVERVOLT.		**2 - GND OV DELAY**
3 - GROUND OVERVOLTAGE		
4 - PHASE UNDERVOLTAGE		

Phase Undervoltage

0 - VOLTAGE RESET	0 - UNIT 1	0 - PH. UV ENABLE
1 - PHASE OVERVOLTAGE	1 - UNIT 2	1 - VOLTAGE TYPE
2 - NEG. SEQ. OVERVOLT.	2 - UNIT 3	2 - PH. UV PICKUP
3 - GROUND OVERVOLTAGE		3 - PH. UV DELAY
4 - PHASE UNDERVOLTAGE		4 - OUTPUT LOGIC PH UV

3.4.5 Digital Inputs of the Voltage Modules

Table 3.4-1: Digital Inputs of the Voltage Modules

Name	Description	Function
INBLK_UV1_PH	Phase undervoltage element 1 block input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
INBLK_UV2_PH	Phase undervoltage element 2 block input	
INBLK_UV3_PH	Phase undervoltage element 3 block input	
INBLK_OV_PH1	Phase overvoltage element 1 block input	
INBLK_OV_PH2	Phase overvoltage element 2 block input	
INBLK_OV_PH3	Phase overvoltage element 3 block input	
INBLK_OV_N1	Ground overvoltage element 1 block input	
INBLK_OV_N2	Ground overvoltage element 2 block input	
INBLK_OV_NS	Neg. sequence overvoltage element block input	
ENBL_UV_PH1	Phase undervoltage element 1 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.”
ENBL_UV_PH2	Phase undervoltage element 2 enable input	
ENBL_UV_PH3	Phase undervoltage element 3 enable input	
ENBL_OV_PH1	Phase overvoltage element 1 enable input	
ENBL_OV_PH2	Phase overvoltage element 2 enable input	
ENBL_OV_PH3	Phase overvoltage element 3 enable input	
ENBL_OV_N1	Ground overvoltage element 1 enable input	
ENBL_OV_N2	Ground overvoltage element 2 enable input	
ENBL_OV_NS	Neg. sequence overvoltage element enable input	

3.4.6 Auxiliary Outputs and Events of the Voltage Modules

Table 3.4-2: Auxiliary Outputs and Events of the Voltage Modules

Name	Description	Function
PU_IUV1_A	Phase A undervoltage element 1 pickup	Pickup of the undervoltage and overvoltage elements and start of the time count. Three-phase pickups are those that are generated after the chosen AND or OR algorithm.
PU_IUV2_A	Phase A undervoltage element 2 pickup	
PU_IUV3_A	Phase A undervoltage element 3 pickup	
PU_IUV1_B	Phase B undervoltage element 1 pickup	
PU_IUV2_B	Phase B undervoltage element 2 pickup	
PU_IUV3_B	Phase B undervoltage element 3 pickup	
PU_IUV1_C	Phase C undervoltage element 1 pickup	
PU_IUV2_C	Phase C undervoltage element 2 pickup	
PU_IUV3_C	Phase C undervoltage element 3 pickup	
PU_IUV1_3PH	Three-phase undervoltage element 1 pickup	
PU_IUV2_3PH	Three-phase undervoltage element 2 pickup	
PU_IUV3_3PH	Three-phase undervoltage element 3 pickup	
PU_OV1_A	Phase A overvoltage element 1 pickup	
PU_OV2_A	Phase A overvoltage element 2 pickup	
PU_OV3_A	Phase A overvoltage element 3 pickup	
PU_OV1_B	Phase B overvoltage element 1 pickup	
PU_OV2_B	Phase B overvoltage element 2 pickup	
PU_OV3_B	Phase B overvoltage element 3 pickup	
PU_OV1_C	Phase C overvoltage element 1 pickup	
PU_OV2_C	Phase C overvoltage element 2 pickup	
PU_OV3_C	Phase C overvoltage element 3 pickup	
PU_OV1_N	Ground overvoltage element 1 pickup	
PU_OV2_N	Ground overvoltage element 2 pickup	
PU_OV_NS	Negative sequence overvoltage element pickup	
PU_OV1_3PH	Three-phase overvoltage element 1 pickup	
PU_OV2_3PH	Three-phase overvoltage element 2 pickup	
PU_OV3_3PH	Three-phase overvoltage element 3 pickup	
TRIP_UV1_A	Phase A undervoltage element 1 trip	Trip of the undervoltage and overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_UV2_A	Phase A undervoltage element 2 trip	
TRIP_UV3_A	Phase A undervoltage element 3 trip	
TRIP_UV1_B	Phase B undervoltage element 1 trip	
TRIP_UV2_B	Phase B undervoltage element 2 trip	
TRIP_UV3_B	Phase B undervoltage element 3 trip	
TRIP_UV1_C	Phase C undervoltage element 1 trip	
TRIP_UV2_C	Phase C undervoltage element 2 trip	
TRIP_UV3_C	Phase C undervoltage element 3 trip	
TRIP_UV1_3PH	Three-phase undervoltage element 1 trip	
TRIP_UV2_3PH	Three-phase undervoltage element 2 trip	
TRIP_UV3_3PH	Three-phase undervoltage element 3 trip	
TRIP_OV1_A	Phase A overvoltage element 1 trip	
TRIP_OV2_A	Phase A overvoltage element 2 trip	
TRIP_OV3_A	Phase A overvoltage element 3 trip	

Table 3.4-2: Auxiliary Outputs and Events of the Voltage Modules		
Name	**Description**	**Function**
TRIP_OV1_B	Phase B overvoltage element 1 trip	Trip of the undervoltage and overvoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_OV2_B	Phase B overvoltage element 2 trip	
TRIP_OV3_B	Phase B overvoltage element 3 trip	
TRIP_OV1_C	Phase C overvoltage element 1 trip	
TRIP_OV2_C	Phase C overvoltage element 2 trip	
TRIP_OV3_C	Phase C overvoltage element 3 trip	
TRIP_OV1_N	Ground overvoltage element 1 trip	
TRIP_OV2_N	Ground overvoltage element 2 trip	
TRIP_OV_S2	Negative sequence overvoltage element trip	
TRIP_OV1_3PH	Three-phase overvoltage element 1 trip	
TRIP_OV2_3PH	Three-phase overvoltage element 2 trip	
TRIP_OV3_3PH	Three-phase overvoltage element 3 trip	
TRIP_UV1_3PHM	Three-phase undervoltage element 1 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.
TRIP_UV2_3PHM	Three-phase undervoltage element 2 masked trip	
TRIP_UV3_3PHM	Three-phase undervoltage element 3 masked trip	
TRIP_OV1_NM	Ground overvoltage element 1 masked trip	
TRIP_OV2_NM	Ground overvoltage element 2 masked trip	
TRIP_OV_S2M	Negative sequence overvoltage element masked trip	
TRIP_OV1_3PHM	Three-phase overvoltage element 1 masked trip	
TRIP_OV2_3PHM	Three-phase overvoltage element 2 masked trip	
TRIP_OV3_3PHM	Three-phase overvoltage element 3 masked trip	

Table 3.4-2: Auxiliary Outputs and Events of the Voltage Modules		
Name	**Description**	**Function**
INBLK_UV1_PH	Phase undervoltage element 1 block input	The same as for the digital inputs.
INBLK_UV2_PH	Phase undervoltage element 2 block input	
INBLK_UV3_PH	Phase undervoltage element 3 block input	
INBLK_OV_PH1	Phase overvoltage element 1 block input	
INBLK_OV_PH2	Phase overvoltage element 2 block input	
INBLK_OV_PH3	Phase overvoltage element 3 block input	
INBLK_OV_N1	Ground overvoltage element 1 block input	
INBLK_OV_N2	Ground overvoltage element 2 block input	
INBLK_OV_NS	Neg. sequence overvoltage element block input	
ENBL_UV_PH1	Phase undervoltage element 1 enable input	The same as for the digital inputs.
ENBL_UV_PH2	Phase undervoltage element 2 enable input	
ENBL_UV_PH3	Phase undervoltage element 3 enable input	
ENBL_OV_PH1	Phase overvoltage element 1 enable input	
ENBL_OV_PH2	Phase overvoltage element 2 enable input	
ENBL_OV_PH3	Phase overvoltage element 3 enable input	
ENBL_OV_N1	Ground overvoltage element 1 enable input	
ENBL_OV_N2	Ground overvoltage element 2 enable input	
ENBL_OV_NS	Neg. sequence overvoltage element enable input	
UV_PH1_ENBLD	Phase undervoltage element 1 enabled	The same as for the digital inputs.
UV_PH2_ENBLD	Phase undervoltage element 2 enabled	
UV_PH3_ENBLD	Phase undervoltage element 3 enabled	
OV_PH1_ENBLD	Phase overvoltage element 1 enabled	
OV_PH2_ENBLD	Phase overvoltage element 2 enabled	
OV_PH3_ENBLD	Phase overvoltage element 3 enabled	
OV_N1_ENBLD	Ground overvoltage element 1 enabled	
OV_N2_ENBLD	Ground overvoltage element 2 enabled	
OV_NS_ENBLD	Neg. sequence overvoltage element enabled	

3.4.7 Voltage Elements Test

3.4.7.a Overvoltage Elements Test

#IRX models have three phase overvoltage units (59F1, 59F2 and 59F3), two ground units (59N1 and 59N2 or 64_1 and 64_2) and a negative sequence unit (47). It is possible to select between **phase-ground** or **phase-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 3.4-3: ·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**

Outputs C4-C5 and C6-C7are used to verify them. [See figure 3.4.4].

Fixed Time or Instantaneous

The pickup setting is increased 20%. Operating time should be the selected time setting ±1% or ±25 ms (whichever is greater). A setting of 0 ms will have an operating time between 20 and 25 ms.

3.4.7.b Undervoltage Elements Test

IRX models have three phase undervoltage units (27F1, 27F2 and 27F3) and it is possible to select between **phase-ground** or **phase-phase** 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 3.4-4: Pickup and Reset of the Undervoltage Elements				
Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	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**

Outputs C4-C5 and C6-C7are used to verify them. [See figure 3.4.4].

Fixed Time or Instantaneous

The pickup setting is decreased 20%. Operating time should be the selected time setting ±1% or ± 25 ms (whichever is greater). A setting of 0 ms will have an operating time between 20 and 25 ms.

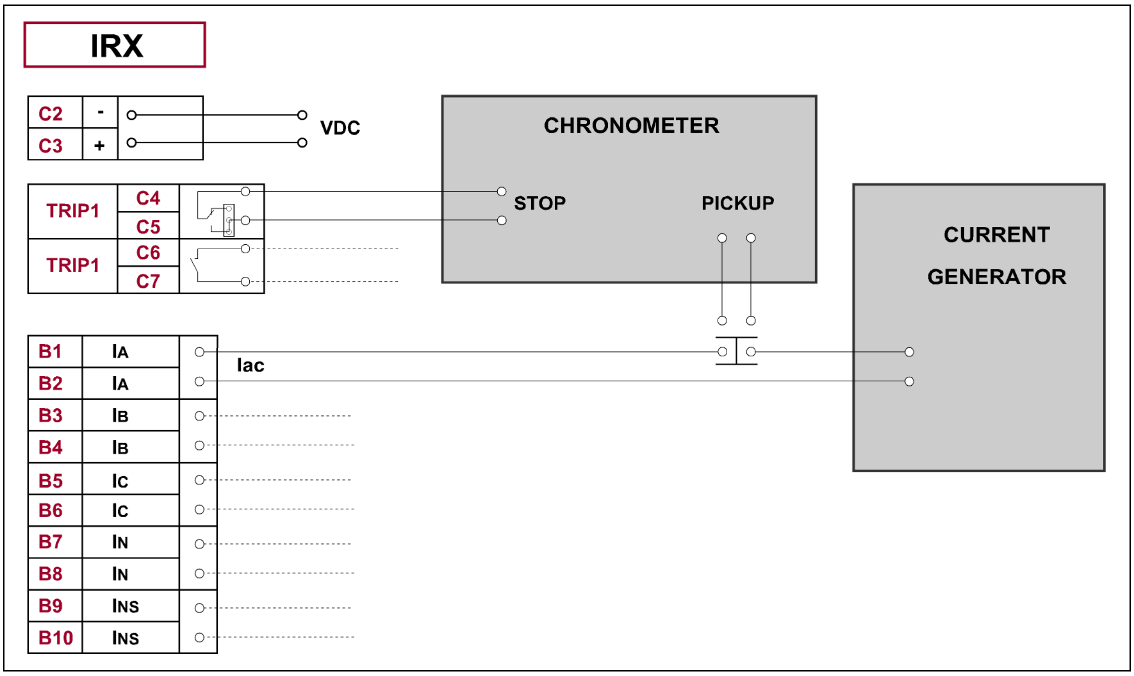


Figure 3.4.4 Operating Time Test Setup.

3.5 Fault Detector

3.5.1 Operating Principles

2IRX-B-****D0**** terminal units are provided with a Fault Detector to supervise element operation. Operation of the Fault Detector is based on:

3.5.1.a Detection of Increases in the Sequence Currents

The conditions which activate the Fault Detector are the following:

- An increase in the effective value of the **zero sequence current** with respect to the value of two cycles previously higher than **0.04*In A** (ground fault indicative).
- An increase in the effective value of the **negative sequence current** with respect to the two cycle value previously higher than **0.04*In A** (phase fault indicative).
- 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 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 of 30 ms is included.

3.5.1.b Detection of Levels Exceeded in the Sequence Current

The following are the conditions which activate the Fault Detector:

- **Ground fault output** activation originating from the phase selector.
- **Two-phase fault output** activation originating from the phase selector.

An open pole condition 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.

The above algorithms further need at least one of the following conditions to be met:

- Positive sequence current above 0.02*In A.
- Zero sequence current above 0.05*In A.

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 generated by either of the two previously-mentioned algorithms is kept sealed with the activation of any of the **Overcurrent Units** (**PU_IOC_PHn**, **PU_TOC_PHn**, **PU_IOC_Nn**, **PU_TOC_Nn**, **PU_IOC_NSn**, **PU_TOC_NSn**, see overcurrent units).

The operation diagram of the fault detector unit is shown in Figures 3.5.1, 3.5.2 and 3.5.3.

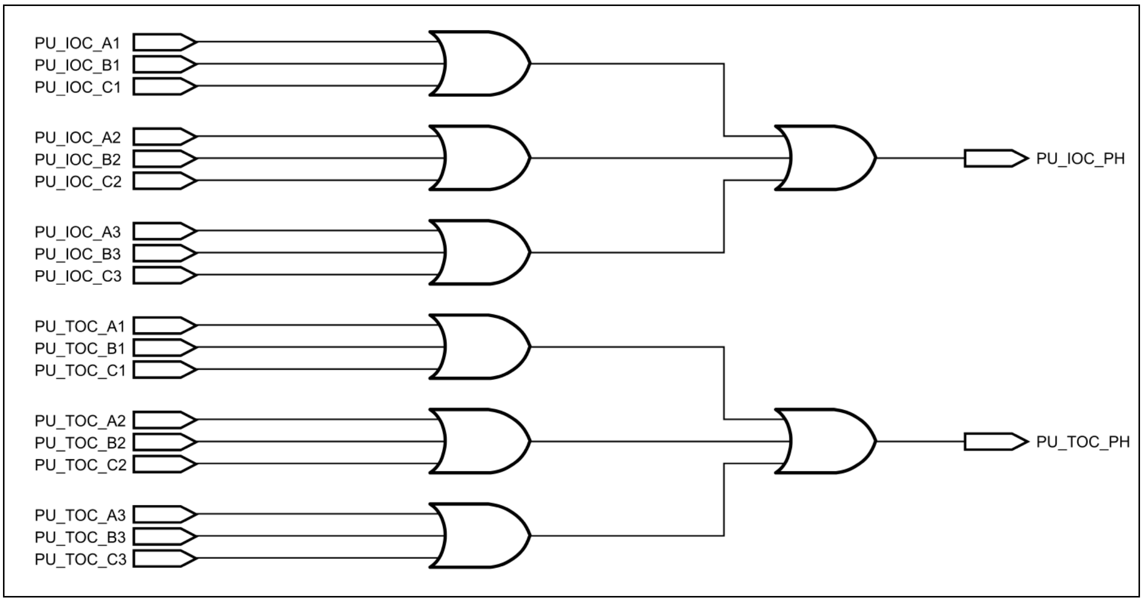


Figure 3.5.1 Activation Logic of Phase Overcurrent Elements Used by the Fault Detector.

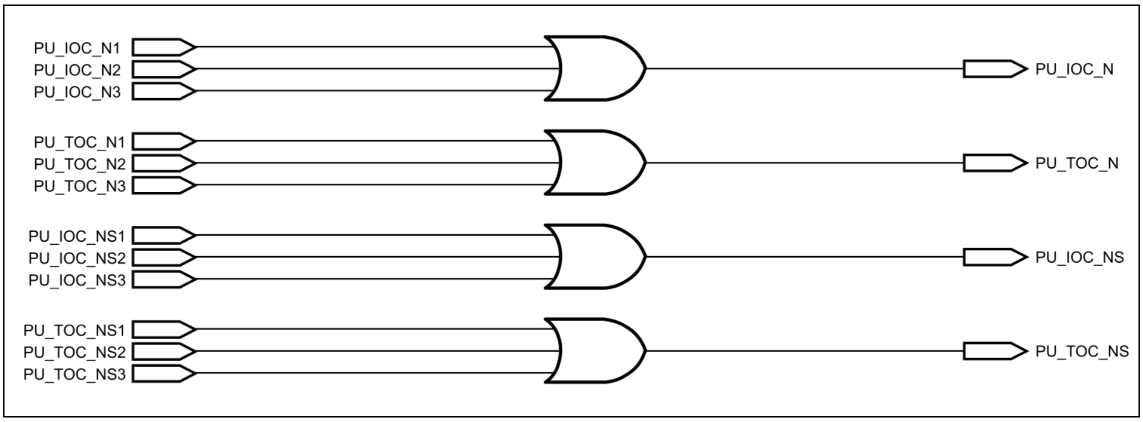


Figure 3.5.2 Activation Logic of Ground and Negative Sequence Overcurrent Elements Used by the Fault Detector.

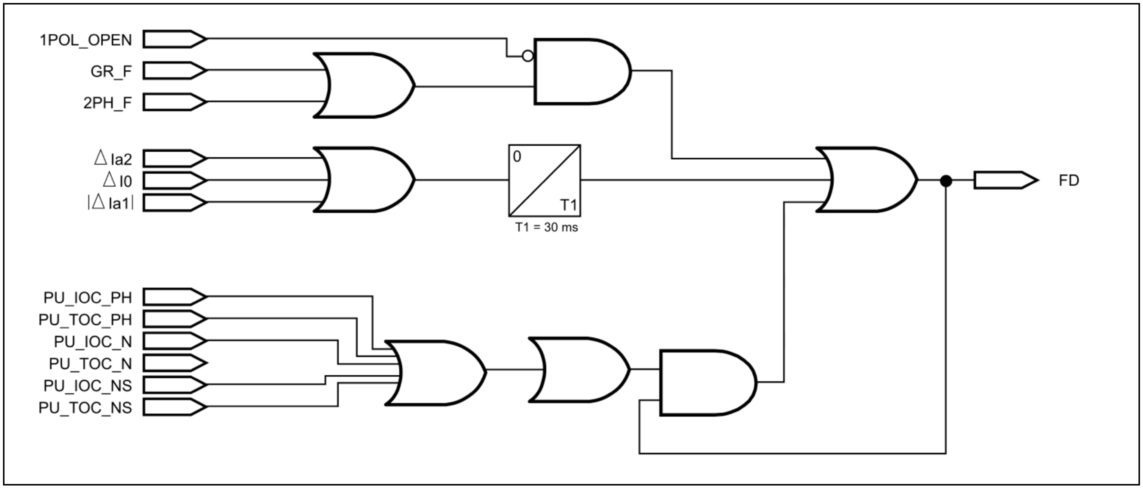


Figure 3.5.3 Fault Detector Block Diagram.

3.5.2 Digital Inputs and Events of the Fault Detector

The fault detector does not present any digital input, not even enable, remaining always in operation.

3.5.3 Digital Outputs and Events of the Fault Detector

Table 3-5-1: Digital Outputs and Events of the Fault Detector		
Name	**Description**	**Function**
FD	Fault detector activated	Detection of the existence of a fault.

3.6 Frequency Elements

3.6.1 Introduction

IRX IEDs have the following frequency elements:

- Four Overfrequency elements (81M1, 81M2, 81M3 and 81M43).
- Four Underfrequency elements (81m1, 81m2, 81m3 and 81m4).
- Four Rate of Change elements (81D1, 81D2, 81D3 and 81D4).

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.
- **Activation half-waves**. This is the number of half-waves that must meet the pick-up conditions to activate such pick-up of the frequency units. This setting is used to filter those transient frequency variations (duration of several half-waves) that can appear when the frequency of the system changes and could accidentally activate the unit trip
- **Reset cycles**. This is the number of cycles during which there may not exist pick-up conditions so that the frequency elements already picked up will reset (pick-up deactivation). When the frequency elements have been picked up and have not yet operated, the pick-up conditions may disappear during a brief instant (due to transient frequency variations). 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 pick-up of the protection function reset if the time the pick-up condition disappears is very short.
- **Load shedding algorithm**. 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.

All the elements have a disabling counter. This counter, of approximately 50 milliseconds, operates when, while the element is tripped, the function is deactivated either by the inhibition voltage, by setting or because the breaker opens.

All the elements have a time module that can be set to instantaneous. It has the following settings:

- Pickup.
- Time.

Figure 3.6.1 is the block diagram of one of the frequency elements.

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.

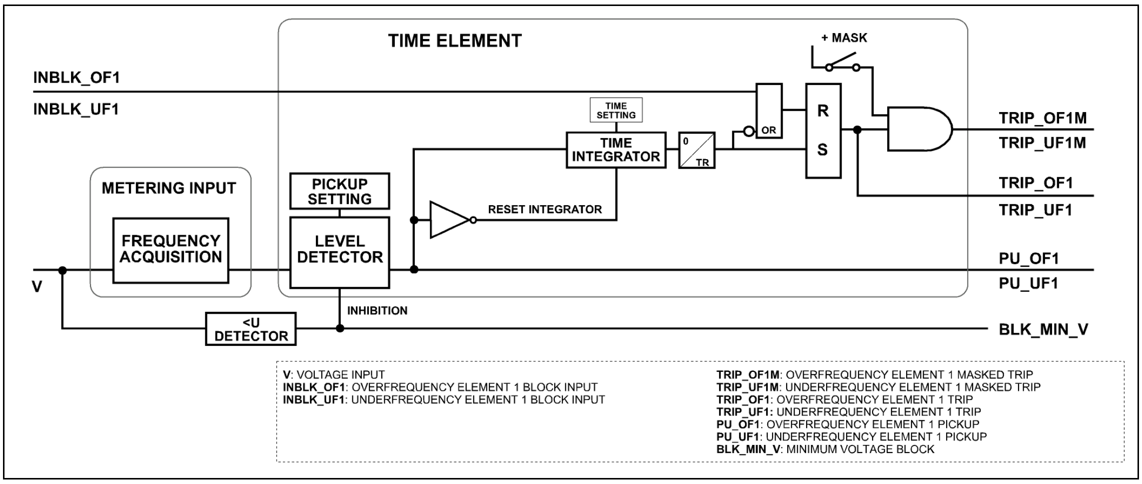


Figure 3.6.1 Block Diagram of a Frequency Element.

3.6.2 Overfrequency Elements

Overfrequency elements operate on the measured frequency value of input voltage V_A or V_{AB}.

Pickup occurs when the value measured coincides with or surpasses the pickup value (100% of the setting) during a number of half-waves equal to or greater than the **Activation Half-Waves** 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.

3.6.3 Underfrequency Elements

Underfrequency elements operate on the measured frequency value of input voltage V_A or V_{AB}.

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 of **Activation Half-Waves**, 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.

3.6.4 Rate of Change Elements

Rate of Change elements operate on the measured frequency value of input voltage V_A or V_{AB}.

Apart from the rest of settings common to all frequency units (see “Introduction”), the algorithm of these elements uses the following specific settings for the Rate of Change function (in addition to the enabling permission of each of them):

- **Frequency 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.
- **Timing**. Time during which the pick-up must remain for the element to activate.
- **Reset Time**. Time during which the unit pickup must keep deactivated to reset the unit trip.

dF/dT value is calculated every time that the voltage analog input Va makes itself zero by obtaining the variation of the frequency between the current value and the one available 5 half-waves before.

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 equal to the “**Activation half-waves**” setting value minus 7 half-waves. In detail, taking into account that the relay requires 2 half-waves to calculate the frequency value accurately and 5 half-waves to calculate the dF/dT value, the time period from the frequency variation to the pickup of the unit is that called as **“Activation half-waves**”. If the value of the **Activation Half-Waves** setting is less than 10 half-waves, then the Frequency Rate of Change unit will always consider a value equal to 10. Refer to the example regarding the operation of the unit pick-up.

In the algorithm, the Rate of Change must be equal to or less than a given adjustable value (frequency unit pickup) for a time equal to or greater than the **Activation Half-Waves** setting before the rate of change is taken into account. This algorithm checks the frequency and the rate of change of the frequency separately. For the element to operate, the pick-up conditions must exist for both. See figure 3.6.2.

The figure below depicts the operation mode for the Rate of Change function:

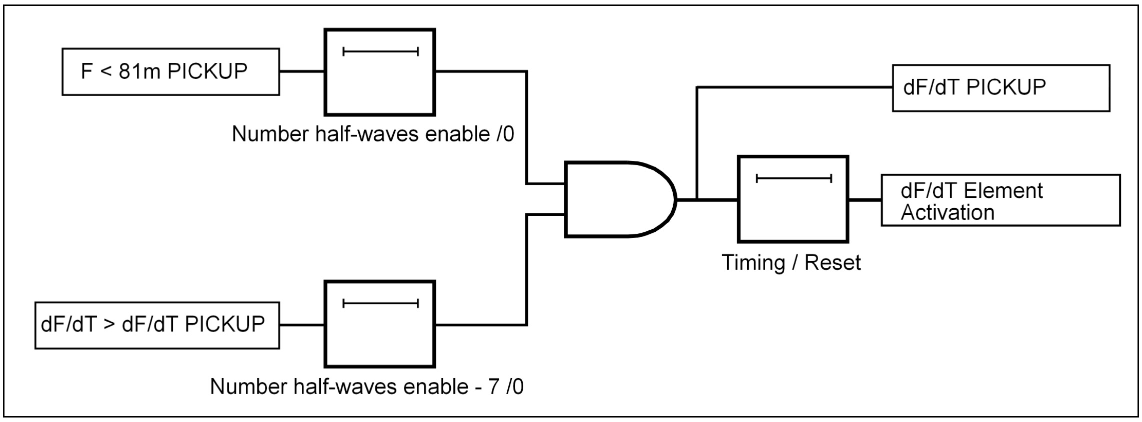


Figure 3.6.2 Logic Diagram of a Rate of Change Element.

Example regarding the operation of the unit pickup:

Activation half-waves = 3
Frequency unit pickup = 49.8 Hz
dF/dT unit pickup = -1 Hz/s
Time delay = 0.1 s

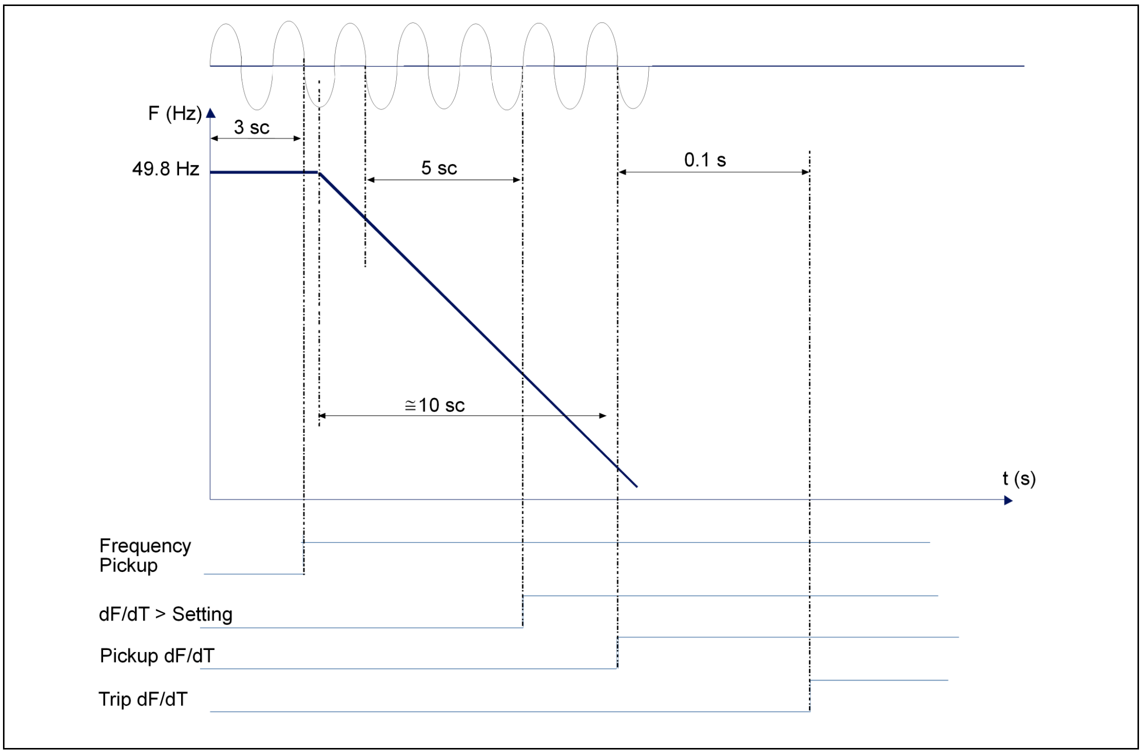


Figure 3.6.3 Example Regarding the Operation of the unit Pickup.

3.6.5 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 3.6.1.

These logic input signals can be associated to the relay's status contact inputs by configuring the input settings.

3.6.6 Undervoltage Element for Blocking

This element supervises the functioning of the Frequency elements, impeding their operation for measured voltage below the set value.

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 10 consecutive cycles. These 10 verification cycles provide assurance that the voltage is stable.

In any case, the relay cannot measure frequency for voltage less than 2 volts. Therefore, in these conditions, the Frequency and Phase Angle Measuring (Out-of-Step) elements do not work.

3.6.7 Load Shedding Algorithm

As described in previous units, the frequency measurement is obtained from the input voltage Va or Vab. 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. 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 3.6.4.

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 Closure 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.

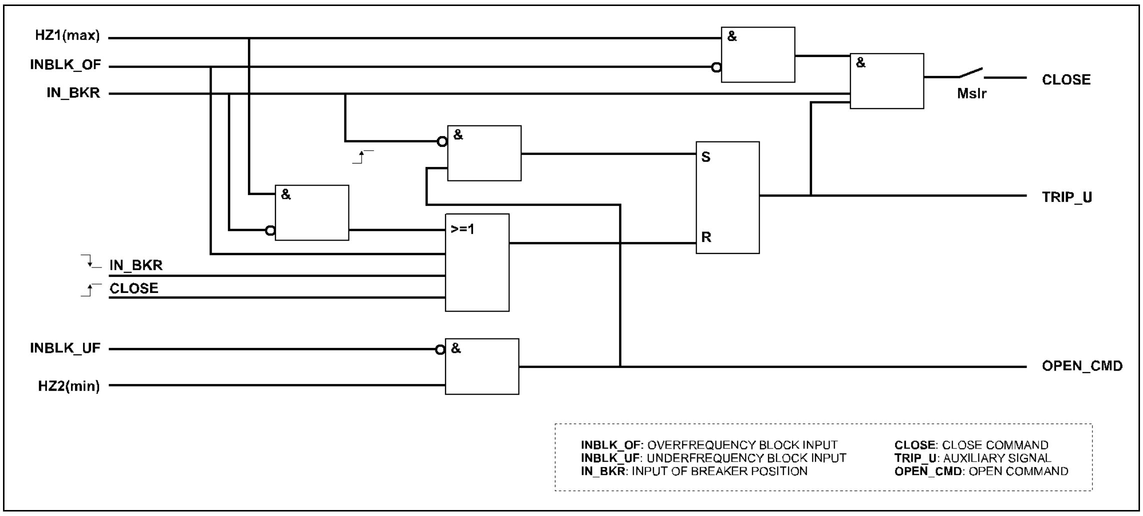


Figure 3.6.4 Under/Overfrequency Load Shedding Algorithm Logic Diagram.

Note 1: Beginning with software version 2.65.0, both startup and activation of the maximum frequency unit are conditioned by the previous action of the minimum frequency unit or derived from frequency (TRIP_U) and by the status of the open breaker (IN_BKR), as indicated in the logic diagram of figure 3.6.4. The maximum frequency unit resets when the frequency level complies with the reset conditions of the unit (point 3.6.2), or when the TRIP_U signal is reset.

3.6.8 Application of the Frequency Elements

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 3.6.5], 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 3.6.5], 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.

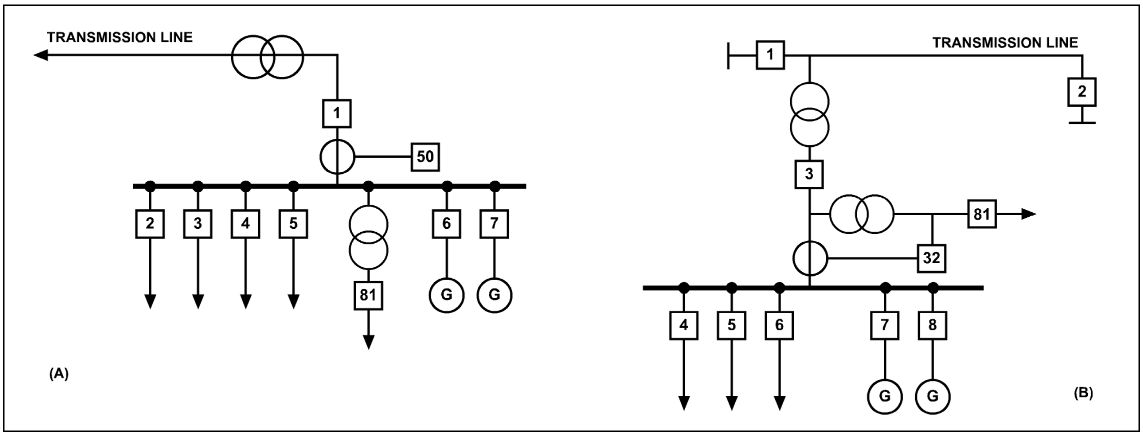


Figure 3.6.5 Load Shedding System in an Industrial Plant.

3.6.9 Frequency Elements Settings

Common Settings			
Setting	**Range**	**Step**	**Default**
Inhibit Voltage	2 - 150 V	1 V	2 V
Pickup Activation Timer	3 - 30 half_cycls 6 - 30 half_cycls (2IRX-B******J***)	1 half cycles	6 half cycles
Reset Time	0 - 10 cycls	1 cycle	0 cycle
Load Shedding Enable	YES / NO		NO
Load Shedding Type	0 - Underfrequency 1 - Rate of Change		0-Underfreq.

Overfrequency Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	40 - 70 Hz	0.01 Hz	70 Hz
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

Underfrequency Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	40 - 70 Hz	0.01 Hz	40 Hz
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

Frequency Rate of Change Elements 1, 2, 3 and 4			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Underfrequency Pickup	40 - 70 Hz	0.01 Hz	40 Hz
ROC Frequency Pickup	(-0.1) - (-10.00) Hz/s	0.01 Hz/s	-1 Hz/s
Time Delay	0.00 - 300 s	0.01 s	0 s
Reset Time	0.00 - 300 s	0.01 s	2 s

- **Frequency Protection: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - FREQUENCY**
3 - CHANGE SETTINGS	3 - LOGIC	3 - BREAKER FAILURE
4 - INFORMATION	...	...

0 - OVERCURRENT	**0 - INHIBIT VOLTAGE**
1 - VOLTAGE	**1 - PICK UP TIME**
2 - FREQUENCY	**2 - DROPOUT TIME**
3 - BREAKER FAILURE	**3 - LOAD SHEDD 1 ENBL**
...	**4 - LOAD SHEDDNG TYPE**
	5 - OVERFREQUENCY
	6 - UNDERFREQUENCY
	7 - FREQ RATEOFCHANGE

Overfrequency

0 - INHIBIT VOLTAGE	**0 - UNIT 1**	**0 - OVERFREQ. ENABLE**
1 - PICK UP TIME	**1 - UNIT 2**	**1 - OVERFREQ. PICKUP**
2 - DROPOUT TIME	**2 - UNIT 3**	**2 - OVERFREQ. DELAY**
3 - LOAD SHEDD 1 ENBL	**3 - UNIT 4**	**3 - DROPOUT TIME**
4 - LOAD SHEDDNG TYPE		
5 - OVERFREQUENCY		
6 - UNDERFREQUENCY		
7 - FREQ RATEOFCHANGE		

Underfrequency

0 - INHIBIT VOLTAGE	**0 - UNIT 1**	**0 - UNDERFREQ. ENABLE**
1 - PICK UP TIME	**1 - UNIT 2**	**1 - UNDERFREQ. PICKUP**
2 - DROPOUT TIME	**2 - UNIT 3**	**2 - UNDERFREQ. DELAY**
3 - LOAD SHEDD 1 ENBL	**3 - UNIT 4**	**3 - DROPOUT TIME**
4 - LOAD SHEDDNG TYPE		
5 - OVERFREQUENCY		
6 - UNDERFREQUENCY		
7 - FREQ RATEOFCHANGE		

Frequency Rate of Change

0 - INHIBIT VOLTAGE	**0 - UNIT 1**	**0 - ROC FREQ. ENABLE**
1 - PICK UP TIME	**1 - UNIT 2**	**1 - UNDERFREC PICKUP**
2 - DROPOUT TIME	**2 - UNIT 3**	**2 - ROC FREQ. PICKUP**
3 - LOAD SHEDD 1 ENBL	**3 - UNIT 4**	**3 - ROC FREQ. DELAY**
4 - LOAD SHEDDNG TYPE		**4 - DROPOUT TIME**
5 - OVERFREQUENCY		
6 - UNDERFREQUENCY		
7 - FREQ RATEOFCHANGE		

3.6.10 Digital Inputs of the Frequency Modules

Table 3.6-1: Digital Inputs of the Frequency Modules

Name	Description	Function
IN_BLK_OF1	Overfrequency element 1 block input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_OF2	Overfrequency element 2 block input	
IN_BLK_OF3	Overfrequency element 3 block input	
IN_BLK_OF4	Overfrequency element 4 block input	
IN_BLK_UF1	Underfrequency element 1 block input	
IN_BLK_UF2	Underfrequency element 2 block input	
IN_BLK_UF3	Underfrequency element 3 block input	
IN_BLK_UF4	Underfrequency element 4 block input	
IN_BLK_ROC1	Rate of Change element 1 block input	
IN_BLK_ROC2	Rate of Change element 2 block input	
IN_BLK_ROC3	Rate of Change element 3 block input	
IN_BLK_ROC4	Rate of Change element 4 block input	
ENBL_OF1	Overfrequency element 1 enable input	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_OF2	Overfrequency element 2 enable input	
ENBL_OF3	Overfrequency element 3 enable input	
ENBL_OF4	Overfrequency element 4 enable input	
ENBL_UF1	Underfrequency element 1 enable input	
ENBL_UF2	Underfrequency element 2 enable input	
ENBL_UF3	Underfrequency element 3 enable input	
ENBL_UF4	Underfrequency element 4 enable input	
ENBL_ROC1	Rate of Change element 1 enable input	
ENBL_ROC2	Rate of Change element 2 enable input	
ENBL_ROC3	Rate of Change element 3 enable input	
ENBL_ROC4	Rate of Change element 4 enable input	

3.6.11 Auxiliary Outputs and Events of the Frequency Modules

Table 3.6-2: Auxiliary Outputs and Events of the Frequency Modules		
Name	**Description**	**Function**
PU_OF1	Overfrequency element 1 pickup	Pickup of the Frequency Elements and start of the time count.
PU_OF2	Overfrequency element 2 pickup	
PU_OF3	Overfrequency element 3 pickup	
PU_OF4	Overfrequency element 4 pickup	
PU_UF1	Underfrequency element 1 pickup	
PU_UF2	Underfrequency element 2 pickup	
PU_UF3	Underfrequency element 3 pickup	
PU_UF4	Underfrequency element 4 pickup	
PU_ROC1	Rate of Change element 1 pickup	
PU_ROC2	Rate of Change element 2 pickup	
PU_ROC3	Rate of Change element 3 pickup	
PU_ROC4	Rate of Change element 4 pickup	
TRIP_OF1	Overfrequency element 1 trip	Trip of the Frequency Elements.
TRIP_OF2	Overfrequency element 2 trip	
TRIP_OF3	Overfrequency element 3 trip	
TRIP_OF4	Overfrequency element 4 trip	
TRIP_UF1	Underfrequency element 1 trip	
TRIP_UF2	Underfrequency element 2 trip	
TRIP_UF3	Underfrequency element 3 trip	
TRIP_UF4	Underfrequency element 4 trip	
TRIP_ROC1	Rate of Change element 1 trip	
TRIP_ROC2	Rate of Change element 2 trip	
TRIP_ROC3	Rate of Change element 3 trip	
TRIP_ROC4	Rate of Change element 4 trip	
CLS_LS1	Close of Load Shedding element 1	Close of the overfrequency element 1 when it is configured for load shedding.
TRIP_OF1M	Overfrequency element 1 masked trip	Trip of the frequency elements affected by their corresponding trip masks.
TRIP_OF2M	Overfrequency element 2 masked trip	
TRIP_OF3M	Overfrequency element 3 masked trip	
TRIP_OF4M	Overfrequency element 4 masked trip	
TRIP_UF1M	Underfrequency element 1 masked trip	
TRIP_UF2M	Underfrequency element 2 masked trip	
TRIP_UF3M	Underfrequency element 3 masked trip	
TRIP_UF4M	Underfrequency element 4 masked trip	
TRIP_ROC1M	Rate of Change element 1 masked trip	
TRIP_ROC2M	Rate of Change element 2 masked trip	
TRIP_ROC3M	Rate of Change element 3 masked trip	
TRIP_ROC4M	Rate of Change element 4 masked trip	

Table 3.6-2: Auxiliary Outputs and Events of the Frequency Modules		
Name	**Description**	**Function**
CLS_LS1M	Masked close of Load Shedding element 1	Close of the overfrequency element 1 when it is configured for load shedding affected by their corresponding mask.
IN_BLK_OF1	Overfrequency element 1 block input	The same as for the Digital Inputs.
IN_BLK_OF2	Overfrequency element 2 block input	
IN_BLK_OF3	Overfrequency element 3 block input	
IN_BLK_OF4	Overfrequency element 4 block input	
IN_BLK_UF1	Underfrequency element 1 block input	
IN_BLK_UF2	Underfrequency element 2 block input	
IN_BLK_UF3	Underfrequency element 3 block input	
IN_BLK_UF4	Underfrequency element 4 block input	
IN_BLK_ROC1	Rate of Change element 1 block input	
IN_BLK_ROC2	Rate of Change element 2 block input	
IN_BLK_ROC3	Rate of Change element 3 block input	
IN_BLK_ROC4	Rate of Change element 4 block input	
ENBL_OF1	Overfrequency element 1 enable input	The same as for the Digital Inputs.
ENBL_OF2	Overfrequency element 2 enable input	
ENBL_OF3	Overfrequency element 3 enable input	
ENBL_OF4	Overfrequency element 4 enable input	
ENBL_UF1	Underfrequency element 1 enable input	
ENBL_UF2	Underfrequency element 2 enable input	
ENBL_UF3	Underfrequency element 3 enable input	
ENBL_UF4	Underfrequency element 4 enable input	
ENBL_ROC1	Rate of Change element 1 enable input	
ENBL_ROC2	Rate of Change element 2 enable input	
ENBL_ROC3	Rate of Change element 3 enable input	
ENBL_ROC4	Rate of Change element 4 enable input	
OF1_ENBLD	Overfrequency element 1 enabled	Enable or disable status indication of the frequency elements.
OF2_ENBLD	Overfrequency element 2 enabled	
OF3_ENBLD	Overfrequency element 3 enabled	
OF4_ENBLD	Overfrequency element 4 enabled	
UF1_ENBLD	Underfrequency element 1 enabled	
UF2_ENBLD	Underfrequency element 2 enabled	
UF3_ENBLD	Underfrequency element 3 enabled	
UF4_ENBLD	Underfrequency element 4 enabled	
ROC1_ENBLD	Rate of Change element 1 enabled	
ROC2_ENBLD	Rate of Change element 2 enabled	
ROC3_ENBLD	Rate of Change element 3 enabled	
ROC4_ENBLD	Rate of Change element 4 enabled	
BLK_MIN_V	Minimum voltage block	Blocking of Frequency and Phase Angle Measuring elements.

3.6.12 Frequency Elements Test

Before testing these elements, the voltage elements that are not being tested must be disabled.

- **Pickup and Reset of the Overfrequency and Underfrequency Elements**

Depending on the settings of the Frequency elements (Overfrequency / Underfrequency), the pickups and resets must be within the margins indicated in tables 3.6-3 and 3.6-4 for their rated voltage.

Table 3.6-3: Pickup and Reset of the Overfrequency Elements

Setting	Pickup		Reset	
	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
XHz	X - 0.005Hz	X + 0.005Hz	(X - 0.01Hz) + 0.005Hz	(X – 0.01Hz) - 0.005Hz

Table 3.6-4: Pickup and Reset of the Underfrequency Elements

Setting	Pickup		Reset	
	ΦA_MIN	ΦA_MAX	ΦR_MIN	ΦR_MAX
XHz	X + 0.005Hz	X - 0.005Hz	(X + 0.01Hz) - 0.005Hz	(X + 0.01Hz) + 0.005Hz

- **Voltage Reset**

The Frequency elements must reset within the margin indicated in table 3.6-5 for set voltage value X.

Table 3.6-5: ·Voltage Reset

Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.03 x X	0.97 x X	1.08 x X	1.02 x X

- **Operating Times**

They are verified with trip outputs C1-C2.

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 for a setting of Xs must be between (1.01 × X – 0.99 × X) or between (X + 20ms – X - 20ms). If the setting is 0, the operating time will be close to 60 ms.

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.

- **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.

3.7 Breaker Failure Unit

3.7.1 Introduction

The Breaker Failure unit detects malfunctions following trip commands and generates a signal to trip other breakers to clear the fault. The operation of this function is outlined in the block diagram of figure 3.7.1.

A trip command generated by the IED's internal protection elements (**TRIP**) or an external protection device (**EXT_TRIP**) activates the breaker failure initiate signal (**I_BF**).

When the **I_BF** signal is activated and current is still detected by the unit (**P_CUR** signal), starts the counter for the breaker failure time delay (**T_BF**). If **T_BF** times out before **I_BF** resets, indicating that the initial breaker failure conditions are no longer present, or **P_CUR** resets, indicating that the unit no longer detects current, the **OUT_BF** output will activate.

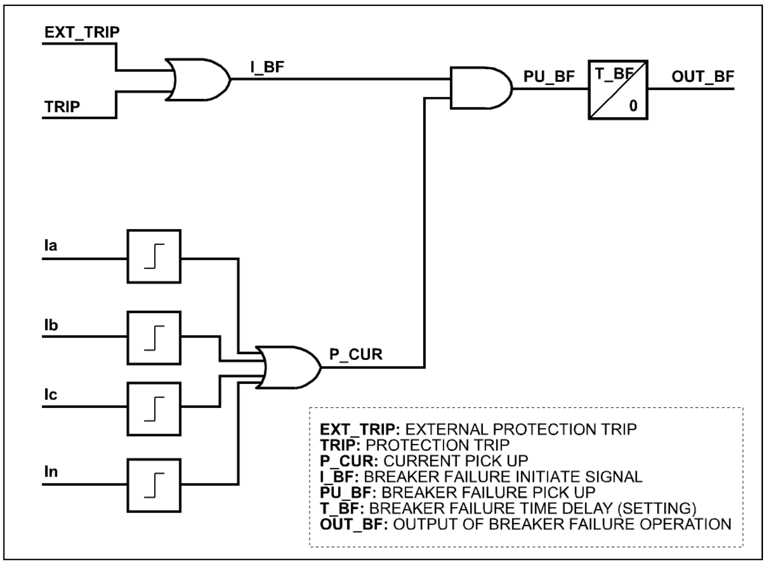


Figure 3.7.1 Block Diagram of the Breaker Failure Function.

The reset of either of the signals, **I_BF** or **P_CUR**, will immediately reset the timer, impeding the generation of the **OUT_BF** signal.

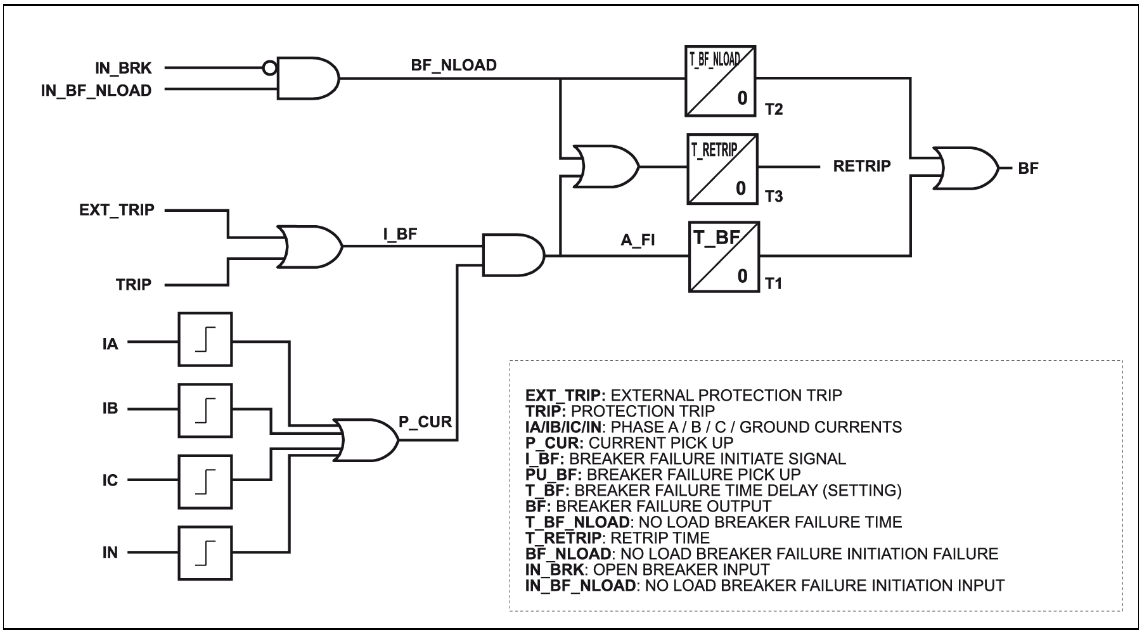


Figure 3.7.2 Block Diagram of the Breaker Failure Function (2IRX-B-****D0** Models).**

2IRX-B-****D0**** relays include retrip function. In these, signal **PU_BF** not only starts timer **T_BF** but also starts timer **T_RETRIP**. Once this last timer times out, signal **RETRIP** activates aiming at issuing a new trip command to the failed breaker before generating a **Breaker Failure** command (**OUT_BF**). Obviously, the retrip time setting must be less than the breaker failure time. **2IRX-B**-****D0**** relays include, also, detection of breaker failure with no phase overcurrent. Trip signals, whether from the same relay or external relay, which would produce the initiation of the breaker failure, can be activated without the pickup of the phase current detection elements. This situation can take place, in general, upon any type of disturbance tripped by elements independent from the measured current, such as voltage elements, frequency elements, transformer own protection elements etc. In this case, breaker failure detection is made based on breaker contact position: when logic input **No Load Breaker Failure Initiation** (**IN_BF_NLOAD**) activates, the breaker remaining closed, the timer **T_BF_NLOAD** will start. When said timer times out, signal **OUT_BF** activates. The **No Load Breaker Failure Input** can be configured with the trip of the transformer own protection elements, frequency elements, voltage elements, etc. The pickup of the no load breaker failure element also causes a breaker to retrip (see figure 3.7.2).

Signal **P_CUR** will be activated while the value of any current is above the pick-up level set for any of the phases or ground currents. The most important characteristic of these current detectors is their fast reset time to stop the timer as soon as the breaker has opened and made the current disappear, not allowing the erroneous activation of **OUT_BF**. The operating principle is based not only on the measurement of the RMS value but on the measurement of instantaneous values. This last principle significantly reduces the reset time.

In order to detect as fast as possible that the current value is going down to zero, the device will not check the RMS value but will check if at least 3 instantaneous and consecutive sampled values are under the phases and ground breaker failure pick-up value. If reset time would be too long there would be high risk of non-stopping duly on time the counter and then cause false trips on other circuit breakers different from the one on the faulty circuit, even when the current went to zero.

To be able to use the external operation signal (**EXT_TRIP**) as part of this function, you must program one of the IED's status contact inputs to be connected to this signal. Otherwise, the **EXT_TRIP** signal will default to a logic "0".

The same applies to the **No Load Breaker Failure Initiation Input** (**IN_BF_NLOAD**). Likewise, the external use of the logic output of Breaker Failure (**OUT_BF**) requires programming the connection between it and one of the auxiliary contact outputs.

3.7.2 Breaker Failure Settings

Breaker Failure Unit			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Phase Pickup	(0.02 - 2) In	0.01 A	0.10 A
Ground Pickup	(0.02 - 2) In	0.01 A	0.10 A
Time Delay	0.00 - 2.00 s	0.01 s	0 s

Breaker Failure Unit (2IRX-B**-*******D0** Models)			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Phase Pickup	(0.02 - 2) In	0.01 A	0.05 In
Ground Pickup	(0.02 - 2) In	0.01 A	0.05 In
Breaker Failure Time Delay	0.00 - 2.00 s	0.01 s	0 s
Retrip Delay	0.00 - 2.00 s	0.01 s	0 s
No load Breaker Failure Delay	0.00 - 2.00 s	0.01 s	0 s

- **Breaker Failure: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	**3 - BREAKER FAILURE**
4 - INFORMATION	...	...

0 - OVERCURRENT	**0 - BF ENABLE**
1 - VOLTAGE	**1 - BF PHASE PICKUP**
2 - FREQUENCY	**2 - BF GROUND PICKUP**
3 - BREAKER FAILURE	**3 - BF DELAY**
...	

2IRX-B-*******D0** MODELS**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - ACTIVATE GROUP	2 - RECLOSER	2 - FREQUENCY
3 - CHANGE SETTINGS	3 - LOGIC	**3 - BREAKER FAILURE**
4 - INFORMATION	...	...

0 - OVERCURRENT	**0 - BF ENABLE**
1 - VOLTAGE	**1 - BF PHASE PICKUP**
2 - FREQUENCY	**2 - BF GROUND PICKUP**
3 - BREAKER FAILURE	**3 - BF DELAY**
...	**4 - RETRIP DELAY**
	5 - NO LOAD BF TIME

3.7.3 Digital Inputs of the Breaker Failure Module

Table 3.7-1: Digital Inputs of the Breaker Failure Module

Name	Description	Function
ENBL_BF	Breaker Failure unit 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.”
EXT_TRIP	External protection trip	Activation of this input indicates to the Breaker Failure unit that an external protection has an active trip and in case enough current is available, it has to start counting the breaker failure time
IN_BF_NLD	No load breaker failure initiation input winding 1 (2IRX-B**-*******D0**)	The activation of this input initiates the no load or no overcurrent breaker failure. The timer of this breaker failure will only start when said input activates, and the applicable breaker contacts indicate it is closed.

3.7.4 Auxiliary Outputs and Events of the Breaker Failure Module

Table 3.7-2: Auxiliary Outputs and Events of the Breaker Failure Module		
Name	**Description**	**Function**
OUT_BF	Output of breaker failure operation	Signal for alarm or trip initiation of other breakers.
ENBL_BF	Breaker Failure unit enable input	The same as for the digital inputs.
BF_ENBLD	Breaker Failure unit enabled	Indication of enabled or disabled status of the unit.
EXT_TRIP	External protection trip	The same as for the digital inputs.
RETRIP	Retrip (2IRX-B**-*******D0**)	Breaker retrip output

3.7.5 Breaker Failure Unit Test

To test this unit, one of the auxiliary contact outputs is configured for the Breaker Failure function. All the units are disabled except the phase and neutral instantaneous overcurrent and breaker failure units.

The phase and neutral instantaneous overcurrent pickups are set to 0.5 A and their time delay to zero. The reset levels of the breaker failure units are set to the desired current reset and operating time values. A trip is provoked by applying a 1 A current phase to neutral and maintaining the current after the phase and neutral units trip. The breaker failure element will operate in a period of time between ±1% and ±20 ms of the set value. To verify the operation of this unit, an auxiliary output is configured as Breaker Failure.

The current is gradually reduced until the breaker failure unit reaches a stable reset. This must occur for a value between ±1% of the set value.

3.8 Open Phase Detector

3.8.1 Introduction

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). The element picks up when this ratio exceeds the set pickup value. Figure 3.8.1 is the block diagram of this element.

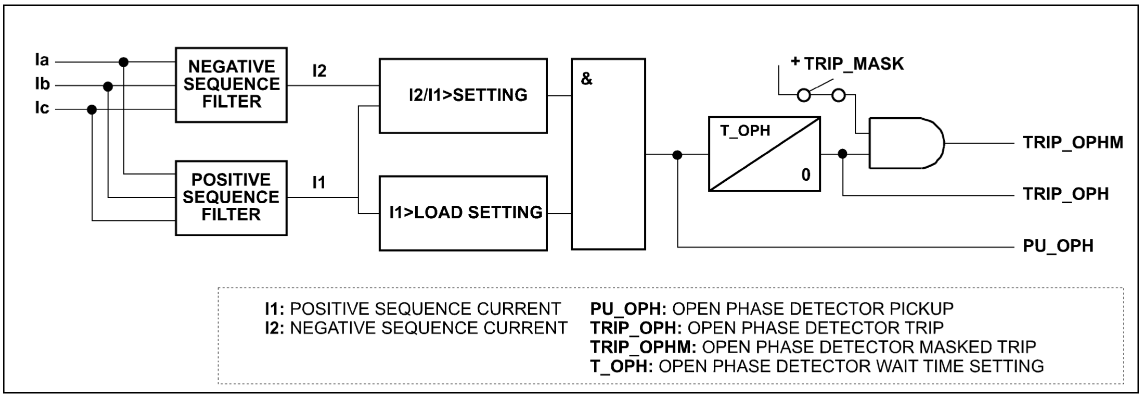


Figure 3.8.1 Block Diagram of the Open Phase Detector.

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 **Positive Sequence Sensitivity** 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 1.02 times the pickup setting and resets at 0.97 times the pickup setting.

3.8.2 Application of the Open Phase Detector

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 **Positive Sequence Sensitivity** setting.

To avoid trips in situations in which, for example, the current of one phase is interrupted before the rest—which derives in a calculation of negative sequence current (normal behavior)—the recommendation is to establish a minimum time setting of, for example, 100 ms or more, depending on the common imbalances anticipated on the grid, to distinguish these situations from those of a fallen conductor.

3.8.3 Open Phase Detector Settings

Open Phase Detector			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	(0.05 - 0.4) I_2 / I_1 (*)	0.01	0.05 I_2 / I_1
Wait Time	0.05 - 300 s	0.01 s	0.05 s
Min. Load Open Phase	(0.02 - 1) In	0.01 A	0.50 A

(*) I_2 = negative sequence current.
I_1 = positive sequence current.

- **Open Phase Detector: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	1 - VOLTAGE
2 - ACTIVATE GROUP	2 - RECLOSER	...
3 - CHANGE SETTINGS	3 - LOGIC	**5 - OPEN PHASE DETECTOR**
4 - INFORMATION	...	...

0 - OVERCURRENT	**0 - OPEN PHASE ENABLE**
1 - VOLTAGE	**1 - OPEN PHASE PU**
...	**2 - OPEN PHASE WAIT TIME**
5 - OPEN PHASE DETECTOR	**3 - MIN. LOAD OPEN PHASE**
...	

3.8.4 Digital Inputs of the Open Phase Module

Table 3.8-1: Digital Inputs of the Open Phase Module		
Name	**Description**	**Function**
ENBL_OPH	Open Phase Detector enable input	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.”

3.8.5 Auxiliary Outputs of the Open Phase Module

Table 3.8-2: Auxiliary Outputs of the Open Phase Module

Name	Description	Function
PU_OPH	Open Phase Detector pickup	Pickup of the element and start of the time count.
TRIP_OPH	Open Phase Detector trip	Trip of the element.
ENBL_OPH	Open Phase Detector masked trip	Trip of the element affected by its trip mask.
OPH_ENBLD	Open Phase Detector enable input	The same as for the digital inputs.
PU_OPH	Open Phase Detector enabled	Indication of enabled or disabled status of the element.

3.8.6 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.

In model **IRX**, the unit is set to 0.2 I2/I1 and the **Minimum load in the line** to 1.2 A. Applying Ia = 1/0º and Ib = 2/60º, the unit should not operate. If, under the same conditions, the **Minimum Load in the Line** is set to 0.8 A, the unit should pick up.

3.9 Residual Current Element

3.9.1 Description

Zero sequence (residual) current elements detect, eventually tripping, sustained residual currents or unbalanced situations with presence of zero sequence currents lower than the setting value for ground fault detection. Figure 3.9.1 shows the block diagram for this function.

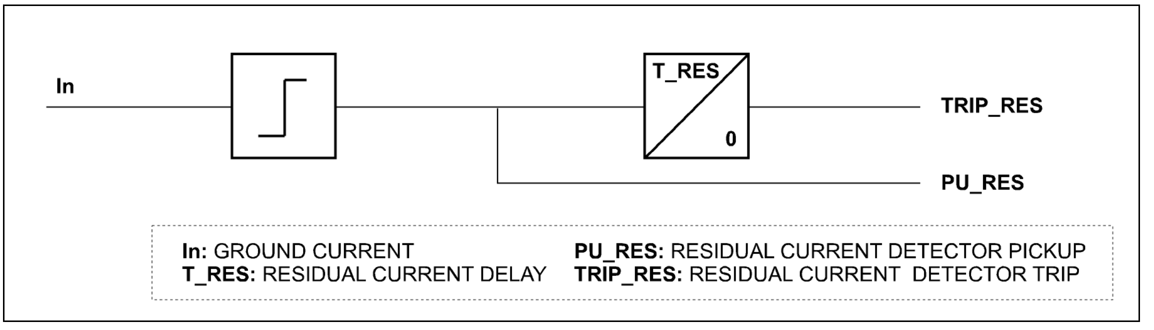


Figure 3.9.1 Block Diagram of Residual Current Detection Element.

The measured current for this function comes from the same input used for ground fault detection, namely, the neutral. When the current exceeds the setting value, element pickup signal (**PU_RES**) is enabled and a trip signal **TRIP_RES** is sent provided pickup condition remains for a time period equal to or higher than the setting value.

Function is disabled when any of phase or ground instantaneous or time overcurrent elements pickup.

Pickup takes place when mean value exceeds 1.05 times the setting value and resets at 1 time the setting value.

3.9.2 Residual Current Element Settings

Residual Current Element			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	(0.02 - 10) In	0.01 A	0.10 A
Delay	0.05 - 300 s	0.01 s	0.05 s

- **Residual Current Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**4 - RESID. CURRENT DET.**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - RESID. CURRENT ENA.**
...	**1 - RESID. CURRENT PU**
4 - RESID. CURRENT DET.	**2 - RESID. CURR. DELAY**
...	

3.9.3 Digital Inputs of the Residual Current Module

Table 3.9-1: Digital Inputs of the Residual Current Module

Name	Description	Function
ENBL_RES	Residual Current detector enable input	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.”

3.9.4 Auxiliary Outputs and Events of the Residual Current Module

Table 3.9-2: Auxiliary Outputs and Events of the Residual Current Module

Name	Description	Function
PU_RES	Residual Current detector pickup	Pickup of the element and start of the time count.
TRIP_RES	Residual Current detector trip	Element trip.
TRIP_RESM	Residual Current detector masked trip	Trip of the element affected by its trip mask.
ENBL_RES	Residual Current detector enable input	The same as for the digital inputs.
RES_ENBLD	Residual Current detector enabled	Indication of enabled or disabled status of the element.

3.9.5 Residual Current Element Test

Check that element picks up (pickup flag to "1") for a given (X) setting when a current between (X **x** 1.08 - X **x** 1.02) is applied to the neutral input; for low ranges, pickup interval can be extended to ±5mA. Apply a current 2 X and check that trip occurs before a time period between (Y **x** 1.01 - Y **x** 0.99) or Y ±20ms, where Y is element timer setting.

3.10 Synchronism Unit

3.10.1 Description

IRX IEDs have a Synchronism check unit to verify whether the conditions on both sides of the breaker are favorable to closing it (either by reclosure or by manual reset) and that there will be no oscillations.

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 (see Note 3), that is, in terms of the possible combinations of presence/absence of voltage on sides A and B.

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 line-to-neutral and between-phase 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 3.10-1. For both cases, the phase to neutral voltages VA are used internally by the unit to check if both sides of the Switch are Synchronized.

The magnitudes are standardized and the angles are compensated according to the following settings:

- **VT Number**: With the set point at 3, the voltages on **Side A** are phase-to-neutral (phase-ground). The magnitude measured by the first voltage channel is VA. With the set point at 2, the voltages on **Side A** are phase-to-phase 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**.
- **Compensation Factor for Voltage on Side B** (**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 modules**.

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 3.10-1 lists all the angle compensation possibilities:

Table 3.10-1: Angle compensation (Phase Sequence)

Side A	Side B Voltage Setting	ABC Sequence	ACB Sequence
V_A	V_A	+0º	+0º
V_A	V_B	+120º	+240º
V_A	V_C	+240º	+120º
V_A	V_{AB}	+330º	+30º
V_A	V_{BC}	+90º	+270º
V_A	V_{CA}	+210º	+150º
V_{AB}	V_A	+0º	+0º
V_{AB}	V_B	+120º	+240º
V_{AB}	V_C	+240º	+120º
V_{AB}	V_{AB}	+330º	+30º
V_{AB}	V_{BC}	+90º	+270º
V_{AB}	V_{CA}	+210º	+150º

All the angles indicated refer to V_A.

See the block diagram of the Synchronism unit in figure 3.10.1.

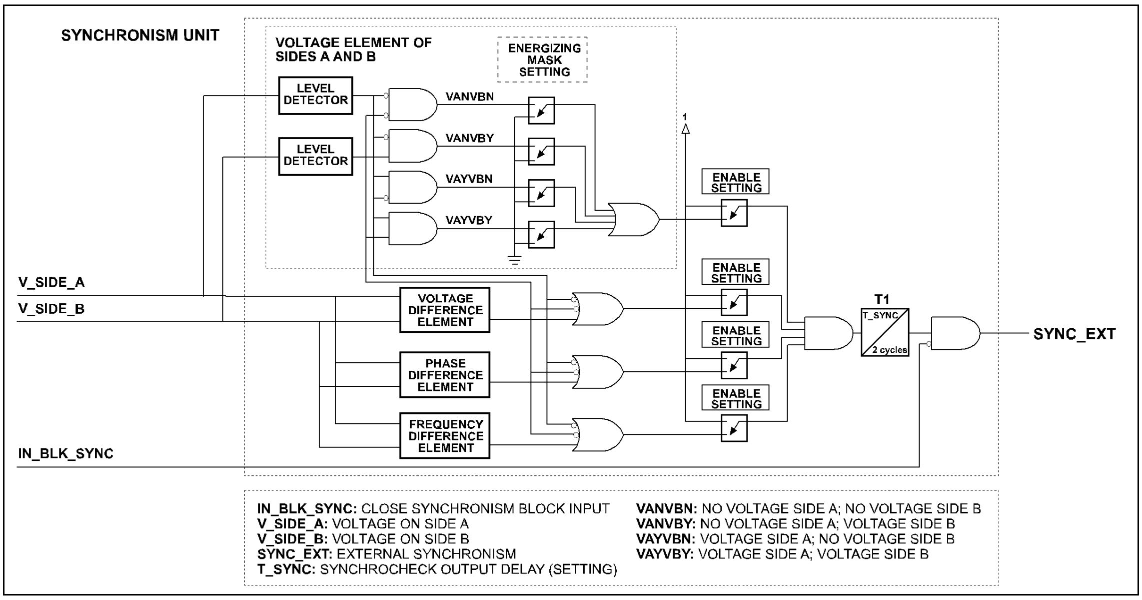


Figure 3.10.1 Block Diagram of the Synchronism Unit.

Note1: 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).

Note2: 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.

Note 3: The synchronism element determines the close conditions by the criterion of voltage presence / absence on sides A and B provided the "Voltage Supervision Enable on both Sides of the Breaker" setting is enabled. If this setting is disabled, the synchronism element will enable closing without checking the voltage presence / absence on both sides of the breaker.

The Synchronism unit output (**SYNC_CALC**) can be blocked with the **Synchronism Check Block** (**IN_BLK_SYNC**) digital input.

The Synchronism unit is comprised of four elements (voltage elements of sides A and B, voltage, phase and frequency difference elements). Each has an **Enable** setting. Details of its operation are explained next.

3.10.2 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).

3.10.3 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 3.10-1.

3.10.4 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.

3.10.5 Voltage Element of Sides A and B

This element is comprised of two overvoltage elements (for sides A and B respectively). Each overvoltage element picks up when the RMS value of the input voltage exceeds 100% of the pickup value (set value) and resets when it is below 95% of this value. The voltages used are values standardized as line-to-neutral voltages.

The Voltage Element of Sides A and B has two outputs that indicate the presence of voltage on each of the sides.

These outputs are generated whether they have been selected or not with the **Energization** setting, whose only function is to set the combinations to detect synchronism.

3.10.6 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 resetting the breaker.

This information can be supplied to the **IRX** 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 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**).

3.10.7 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.

3.10.8 Synchronism Unit Settings

Synchronism Unit			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Type of Sync	0: External 1: Internal		0: External
Bus Voltage Selection	V_A / V_B / V_C / V_{AB} / V_{BC} / V_{CA}		V_A
Compensation Factor for Voltage on Side B (K_{LB})	0.1 - 4	0.01	1
Voltage Supervision Enable	YES / NO		NO
Line Voltage Pickup	0 - 200 V	1 V	20 V
Bus Voltage Pickup	0 - 200 V	1 V	20 V
Energization Mask D BUS / D LINE H BUS / D LINE D BUS / H LINE H BUS / H LINE	 YES / NO YES / NO YES / NO YES / NO		 NO YES NO YES
Voltage Difference Enable	YES / NO		NO
Maximum Voltage Difference	2 % - 30 % 2% - 80 % (2IRX-***-****D0**)	1 %	2 %
Phase Difference Enable	YES / NO		NO
Maximum Phase Difference	2 - 80º	1º	2º
Frequency Difference Enable	YES / NO		NO
Maximum Frequency Difference	0.005 - 2.00Hz	0.01 Hz	0.01 Hz
Synchrocheck Output Delay	0.00 - 300 s	0.01 s	0 s

- **Synchronism Unit: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**7 - SYNCROCHECK**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - SYNC ENABLE**
...	**1 - TYPE OF SYNC**
7 - SYNCROCHECK	**2 - BUSBAR SELECTION**
...	**3 - BUS VOLT. COMPENS.**
	4 - VOLTAGE SUPRV ENBL
	5 - SIDE A VOLT. PU
	6 - SIDE B VOLT. PU
	7 - ENERGIZATION MASK
	8 - VOLT. DIFF. ENABLE
	9 - MAX. VOLTAGE DIFF.
	10 - PHASE DIFF. ENABLE
	11 - MAX. PHASE DIFF.
	12 - FREQ. DIFF. ENABLE
	13 - MAX. FREQ. DIFF.
	14 - SYNC DELAY

3.10.9 Digital Inputs of the Synchronism Module

Table 3.10-2: Digital Inputs of the Synchronism Module

Name	Description	Function
IN_BLK_SYNC	Close synchronism block input	Activation of the input blocks the activation of the synchronism unit output (calculated synchronism).
ENBL_SYNC	Close synchronism enable input	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.”
SYNC_EXT	External synchronism	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.”

3.10.10 Auxiliary Outputs and Events of the Synchronism Module

Table 3.10-3: Auxiliary Outputs and Events of the Synchronism Module

Name	Description	Function
IN_BLK_SYNC	Close synchronism block input	The same as for the digital input.
P_SYNC_DPH	Permission to close by phase difference	The synchronism unit determines that there are close conditions by the phase difference criterion.
P_SYNC_DPH	Permission to close by frequency difference	The synchronism unit determines that there are close conditions by the frequency difference criterion.
P_SYNC_DV	Permission to close by voltage difference	The synchronism unit determines that there are close conditions by the voltage difference criterion.
P_SYNC_EL	Permission to close by energization on the sides	The synchronism unit determines that there are close conditions by the criterion of presence/absence of voltages on sides A and B.
SYNC_R	Close by synchronism enabled	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.
ENBL_SYNC	Close synchronism enable input	The same as for the digital input.
SYNC_ENBLD	Close synchronism enabled	Indication of enabled or disabled status of the unit.
V_SIDE_A	Voltage on side A	It indicates presence of voltage on side A.
V_SIDE_B	Voltage on side B	It indicates presence of voltage on side B.
SYNC_EXT	External synchronism	The same as for the digital input.

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.

3.10.11 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 3.10-4 are checked.

Table 3.10-4: 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 Supervisory Elements

Enable	**YES**
Side A detection pickup	**25 V**
Side B detection pickup	**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	**20º**

Frequency Difference Element

Enable	**YES / NO**
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 3.10-5.

Table 3.10-5: 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 3.10-5 corresponding to the setting used.

- **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 3.10-6.

The reset must be instantaneous and a voltage included in the range of Table 3.10-6 corresponding to the setting used.

Table 3.10-6: 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 3.10-7.

The reset must be instantaneous and a voltage included in the range of Table 3.10-7 corresponding to the setting used.

Table 3.10-7: 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 3.10-8.

The reset will be instantaneous and for a frequency difference within the range specified in Table 3.10-8.

Table 3.10-8: 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.

3.11 Out of Step Element

3.11.1 Description

Out of Step elements aim at quick disconnecting synchronous generators working in parallel with the system when a system disturbance occurs: failure in the system proper or short system voltage outage

Out of Step protection detects anomalies much sooner than other types of protection, such as voltage or frequency protection. Operate magnitudes for these protection elements are modified by the disturbance in times that can reach hundreds of milliseconds, due to both system electrical inertia and generator set mechanics.

3.11.2 Measuring principle

Out of Step measuring principle allows detecting the disturbance within the cycle in which it is produced, resulting into disconnection times of less than 100ms, including breaker operating time.

The operation of a synchronous generator is such that a phase difference between terminal voltage (V1) and rotor electromotive force (Eg) exists; the generated current (I1) and thus the supplied power, are a function of this phase difference.

Figure 3.11.1 concisely represents a generator equivalent circuit and the relationship between the electrical magnitudes involved. Figure 3.11.2 represents voltage magnitudes involved and their phase angle relationship.

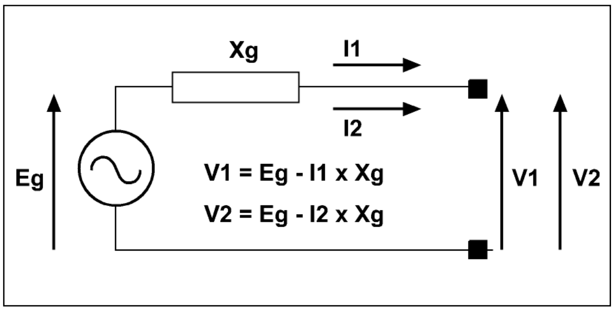


Figure 3.11.1 Generator Equivalent Circuit.

When system disturbance occurs, current changes abruptly to I2, whereas voltage keeps its value for a longer time period due to electrical and mechanical inertia. As the relationship between the electrical magnitudes shown in figure 3.11.1 do not change, a change in the current results into a change in the voltage (V2) phase angle with respect to rotor electromotive force.

As a result of the above, a phase difference exists between generator terminal voltage before and after the disturbance:

$$\Delta\Phi = \Phi 2 - \Phi 1$$

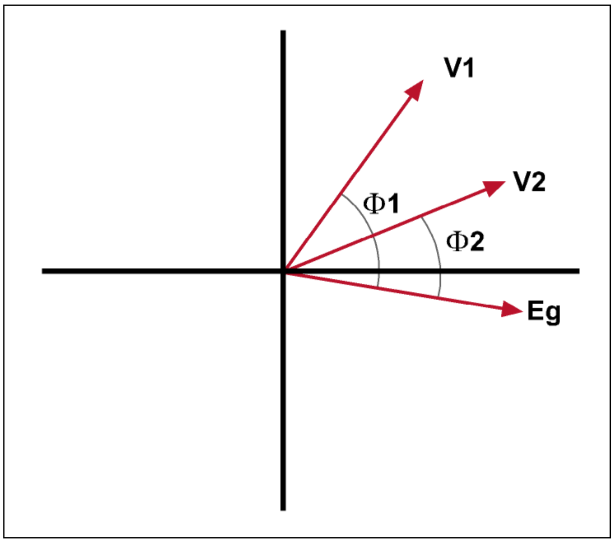


Figure 3.11.2 Circuit Magnitudes.

This change in phasor angle or magnitude is only present during the system cycle in which the disturbance occurs, as later cycles keep the new F2 phase angle with respect to the rotor electromotive force.

Representing the above by means of voltage waveforms, as shown in figure 3.11.3, will contribute to explain how the disturbance is detected.

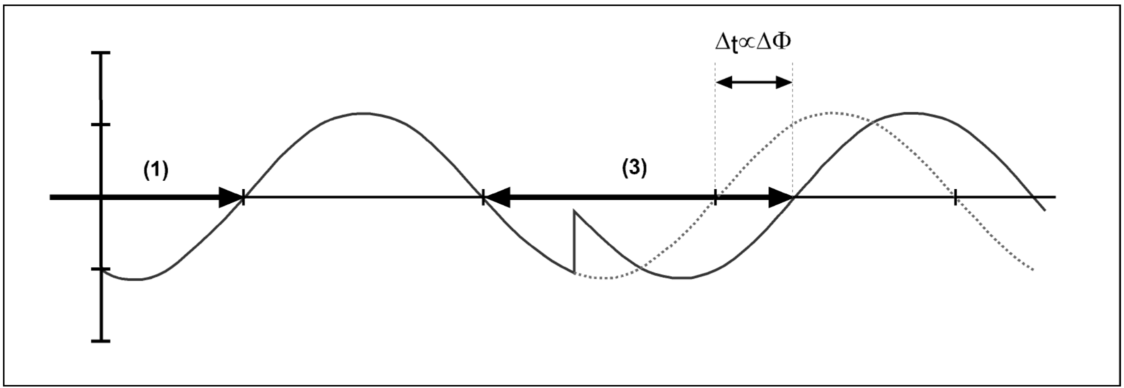


Figure 3.11.3 Voltage Waveform Representation.

The duration of the half cycle in which the disturbance occurs will be different from previous and later cycles, the difference of which is proportional to ΔΦ phase variation that can therefore be used as measurement characteristic magnitude.

Relay detects zero crossings: the time lapse between two consecutive zero crossings is measured and the difference between values obtained for two consecutive half periods of same voltage sign is calculated. In the figure, the time difference Δt that makes the element to operate is obtained by the difference in duration of half cycles (1) and (3).

3.11.3 Logic of Out of Step Measurement Element

Out of Step element operation logic is shown in figure 3.11.4 below:

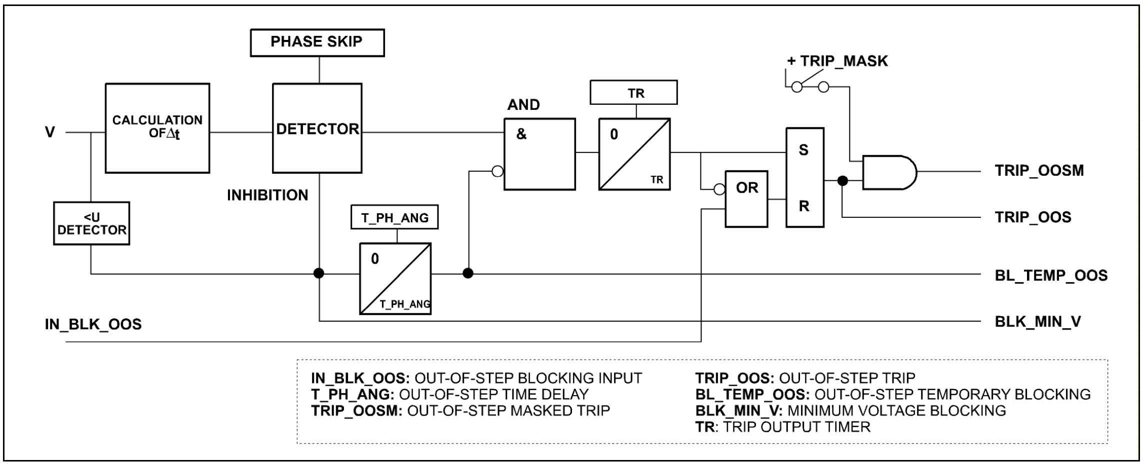


Figure 3.11.4 Block Diagram of Out of Step Element.

Input magnitude used is A-phase voltage or AB voltage if phase-to-phase voltage is used. The value of Δt is calculated from input voltage zero crossings; Δt is compared with Detector setting value. Setting is introduced in terms of degrees and relay obtains from said value in degrees the equivalent time value:

$$\Delta t(ms) = \Delta\Phi \cdot \frac{1000}{360 \cdot F}$$

where F represents the frequency of system voltage in Hz.

The operation of these elements is conditioned to the breaker position; if breaker is open the element is disabled.

- **Undervoltage Blocking**

Detector operation is supervised by the minimum voltage blocking function, so that output will not take place until A-phase or AB voltage input is below the blocking voltage setting value.

When it comes to set the detector operate threshold value, attention shall be paid to whether the measured voltage is phase-to-neutral (VA) or phase-to-phase (VAB). There is only a single setting, with a range ample enough to cover both cases.

Detector output is supervised by the settable timer output (**T_PH_ANG**), the aim of which is blocking the element, for a settable time, after the application of the measured voltage.

Detector output is a temporary signal that, as mentioned above, disappears in the following half cycle. A settable timer (**TR**) guarantees a minimum duration of the trip output.

- **Element Blocking**

An input connected to any of the programmable digital inputs can be used to block element operation.

3.11.4 Out-of-Step Element Settings

Out-of-Step Element			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Pickup	1 - 25°	1°	1°
UV Blocking Time	0.05 - 30 s	0.01 s	0.05 s
Trip Hold Timer	0.1 - 300 s	0.01 s	0.1 s

- **Out-of-Step Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**13 - OUT OF STEP**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - OUT OF STEP ENABLE**
...	**1 - OUT OF STEP PU**
13 - OUT OF STEP	**2 - BLOCKING TIME**
...	**3 - TRIP DURATION**

3.11.5 Digital Inputs of the Out of Step Module

Table 3.11-1: Digital Inputs of the Out of Step Module		
Name	**Description**	**Function**
IN_BLK_OOS	Out of Step blocking input	Activation of input before trip is generated blocks element operation. If activated after, element resets.
ENBL_OOS	Out of Step enable input	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."

3.11.6 Auxiliary Outputs and Events of the Out of Step Module

Table 3.11-2: Auxiliary Outputs and Events of the Out of Step Module

Name	Description	Function
TRIP_OOS	Out of Step trip	Out of Step element trip (not affected by its trip mask)
TRIP_OOSM	Out of Step element masked trip	Out of Step element trip (affected by its trip mask)
BL_TEMP_OOS	Temporary Out of Step blocking	Out of Step element blocking
BLK_MIN_V	Minimum voltage blocking	Frequency and out of step element blocking
IN_BLK_OOS	Out of Step blocking input	The same as for the digital inputs.
ENBL_OOS	Out of Step enable input	The same as for the digital inputs.
OOS_ENBLD	Out of Step enabled	Indication of enabled or disabled status of the unit.

3.11.7 Out of Step Element Test

Set Out of Step element settings as follows:

Pickup	**10º**
Reset time	**5 s**
Temporary blocking	**3 s**
Blocking voltage	**50 V**
Frequency	**50 Hz**

Proceed to disable all elements except the Out of Step element.

Temporary Blocking signal will be active. Apply a voltage of 65 V at rated frequency. Check that **Temporary Blocking** signal drops in a time period between 2.97 and 3.03 s.

Change the input voltage frequency in 5 Hz so that the frequency change takes place just at zero crossing. Check that element output activates during a time period between 4.95 and 5.05 s.

Disconnect measurement voltage.

3.12 Thermal Image Unit

3.12.1 Operating Principles

Thermal relays, which directly measure the temperatures of the machine to be protected, have very serious problems in accomplishing their function in more sensitive areas (windings), having to take measurements in nearby areas (oil, insulators, etc.). This indirect measurement involves drawbacks because the points where the direct temperature measurements are made belong to elements with significant thermal inertia. Therefore, indirect measurement requires the use of thermal units with algorithms that require experimental studies of the element to be protected, which generally are unavailable.

For this reason, instead of using thermal relays, thermal image protections are commonly used. Using mathematical algorithms based on the material's physics, they estimate the temperature of the machine to be protected using the currents that flow through the machine.

It is assumed that when machine overloads occur, the main cause for deterioration is the thermal phenomenon; possible dynamic effects are not considered.

IRX protection terminals have a Thermal Image protection unit that 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 rated range 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 time constant. Adjustable parameter.
- Imax: Value of the maximum admissible sustained current. Adjustable parameter.

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:

$$\theta_i = \theta_0 + (\theta_\infty - \theta_0) * 0.63$$

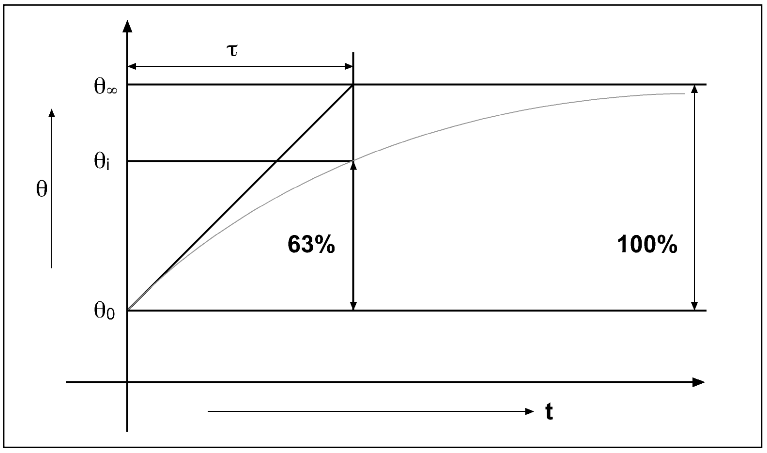


Figure 3.12.1 Time Constant (Thermal Image).

Temperature values (θ) are always stored in case there is a failure in the IED's power supply. There is a **Thermal Memory** setting that you can set to YES so that the initial temperature value will be the stored one whenever the IED is reinitialized.

This unit is prepared to protect lines, motors and transformers from overheating. A setting is selected to indicate which of these types are to be protected.

For lines, the measuring current used is the sum of the square of phase A. It has two time constants, one for heating (while there is current) and one for cooling (when the positive sequence current is under 0.1 amperes).

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. It has two time constants, one for motor stopped (when the positive sequence is under 0.15 times the maximum current) and another for motor running (when the positive sequence is above 0.30 times the maximum current).

For transformers, the measuring current used is the square of the current flowing through a winding determined by setting. It has two time constants, one for being ventilated and the other for not being ventilated. A digital input changes from one to the other. The default time constant is "with ventilation." To change it, the change-of-constant input must be configured. Activating this input changes the constant to "without ventilation."

The thermal image unit estimates the thermal state in each case (line/motor/transformer) and, when it reaches the level equivalent to that obtained by the constant flow of Imax, it provides a trip output.

In addition to the trip level, the unit has an adjustable alarm level.

The thermal state is estimated thus:

- The initial value is $\theta = 0$ or $\theta \neq 0$, 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 - θ
- The value obtained is divided by the time constant and multiplied by 500 milliseconds.
  -B = A * (0.5 sec / τ (in sec)
- This value is added to the preceding θ to obtain the current
  θ = θ + 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 value:

$$\theta_{TRIP} = Imax^2$$

The **Thermal Image Trip** signal resets when θ descends below:

$$\theta_{RST\_TRIP} = \theta_{TRIP} * \text{Connection\_PermissionSetting (\%)} / 100$$

The **Thermal Image Alarm** output is activated when the θ value reaches the value:

$$\theta_{ALARM} = \theta_{TRIP} * \text{AlarmSetting(\%)} / 100$$

The **Thermal Image Alarm** signal resets when θ descends below:

$$\theta_{RST\_ALARM} = 0.95 * \theta_{ALARM}$$

After applying a current **I** and starting with a current value of zero, the trip time is:

$$t = \tau \cdot \mathrm{Ln}\frac{I^2}{I^2 - {I_{max}}^2}$$

If you start with a preliminary Ip current level, the operating time is:

$$t = \tau \cdot \mathrm{Ln}\frac{I^2 - {I_p}^2}{I^2 - {I_{max}}^2}$$

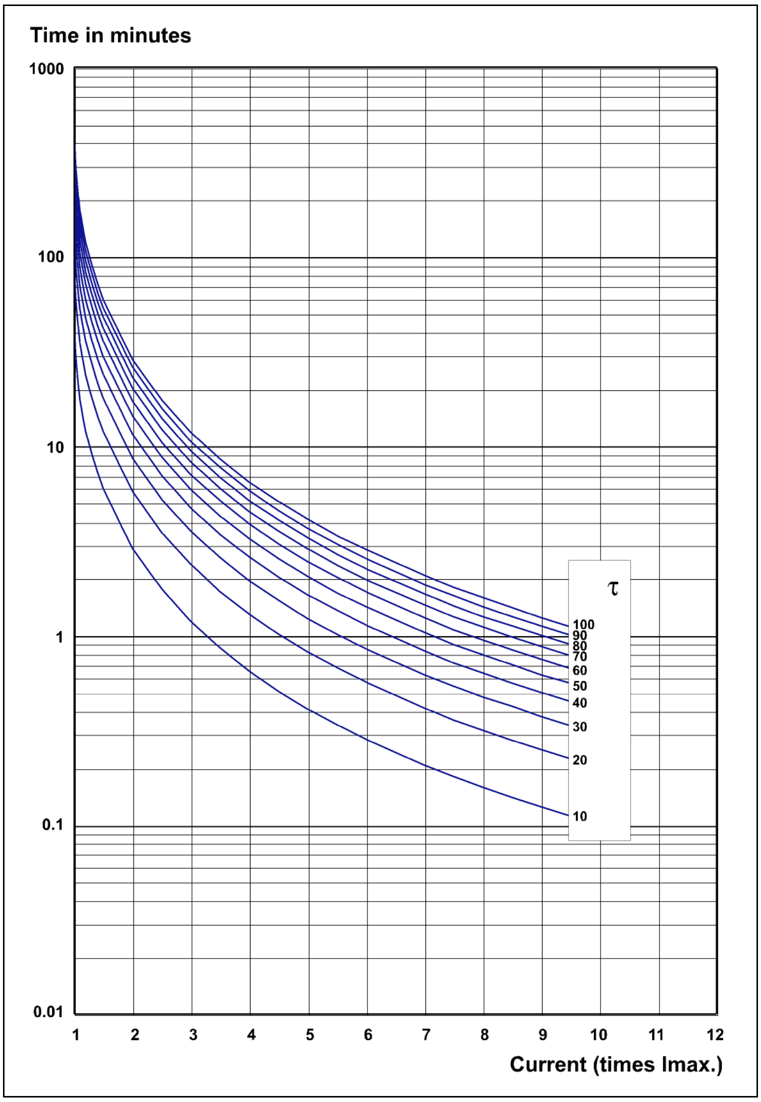


Figure 3.12.2 Operating Time Curves of the Thermal Image Unit.

3.12.2 Applying 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.).

3.12.3 Thermal Image Unit Settings

Thermal Image Unit			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Type of Magnitude (*)	Fundamental / RMS		Fundamental
Type of Device	0: Lines 1: Motor 2: Transformer		0: Lines
Constant ζ1 Line Heating Xfmer Fan On Motor On	0.5 - 300 min	0.01 min	0.5 min
Constant ζ2 Line Cooling Xfmer Fan Off Motor Off	0.5 - 300 min	0.01 min	0.5 min
Max. Operating Current	(0.20 - 2.5) In	0.01A	5.00 A
Alarm Level	50 - 100 %	1 %	50 %
Reset Threshold	50 - 90 %	1 %	80 %
Motor Scaling Factor	1 - 10	1	1
Thermal Memory Enable	YES / NO		NO

(*) In the models 2IRX-B **-** B *** there exists a setting that allows to select that the unit of Thermal Image operates, based on the fundamental value of the intensity or based on the RMS value.**

- **Thermal Image Unit: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**8 - THERMAL IMAGE**
3 - MODIFICAR AJUSTES	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - THERMAL IMG. ENA**
...	**1 - TYPE OF DEVICE**
8 - THERMAL IMAGE	**2 - CONSTANT 1**
...	**3 - CONSTANT 2**
	4 - MAX. SUST. CURR.
	5 - ALARM LEVEL
	6 - RESET THRESHOLD
	7 - MOTOR CONSTANT
	8 - THERMAL MEMORY

3.12.4 Digital Inputs of the Thermal Image Module

Table 3.12-1: Digital Inputs of the Thermal Image Module

Name	Description	Function
C_CONST_T	Change thermal constant	Its activation changes the constant in the thermal image unit.
RST_MEM_T	Thermal Image reset input	Its activation resets the memorized value.
IN_BLK_THERM	Thermal Image blocking input	Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_THERM	Thermal Image 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.”

3.12.5 Auxiliary Outputs and Events of the Thermal Image Module

Table 3.12-2: Auxiliary Outputs and Events of the Thermal Image Module

Name	Description	Function
C_CONST_T	Change thermal constant	The same as for the digital input.
RST_MEM_T	Thermal Image reset input	The same as for the digital input.
AL_THERM	Thermal Image alarm	Alarm of the unit.
TRIP_THERM	Thermal Image trip	Trip of the unit.
TRIP_THERMM	Thermal Image masked trip	Trip of the unit affected by its trip mask.
IN_BLK_THERM	Thermal Image blocking input	The same as for the digital input.
ENBL_THERM	Thermal Image enable input	The same as for the digital input.
THERM_ENBLD	Thermal Image enabled	Indication of enabled or disabled status of the unit.

3.12.6 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.

3.13 Directional Power Elements

3.13.1 Description

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. Elements are designed for synchronous machine applications or cogeneration interconnections, and can be used as protection against power reversal or power limiting.

Both elements are provided with settable characteristic angles and minimum operating power, and fit the following equation:

$$P * \cos\theta + Q * \mathrm{sen}\theta > S_{MIN}$$

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).

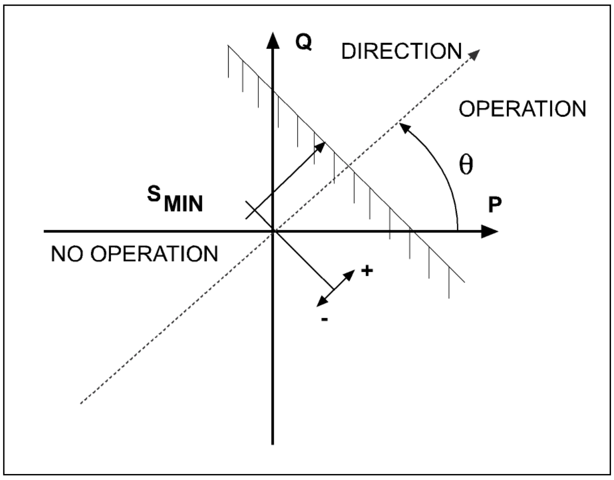


Figure 3.13.1 Directional Power Element Operation.

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”.

For example, to check for negative active power (power reversal) angle must be set to 180º and pickup to a negative value.

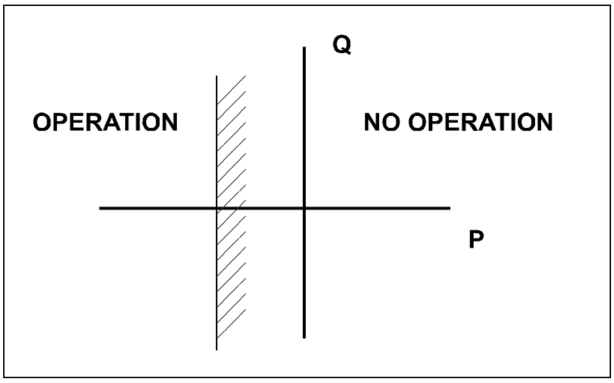


Figure 3.13.2 Angle Setting 180º and Pickup Setting Negative.

To check for not excessively low active power, angle must be set to 180º and pickup to a positive value.

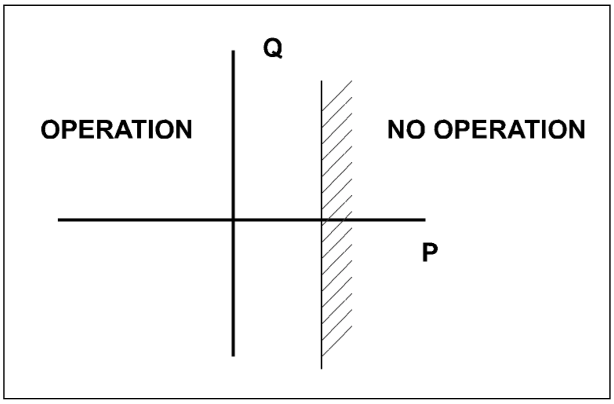


Figure 3.13.3 Angle Setting 180º and Pickup Setting Positive.

Other settings are:

Angle 0º and pickup positive

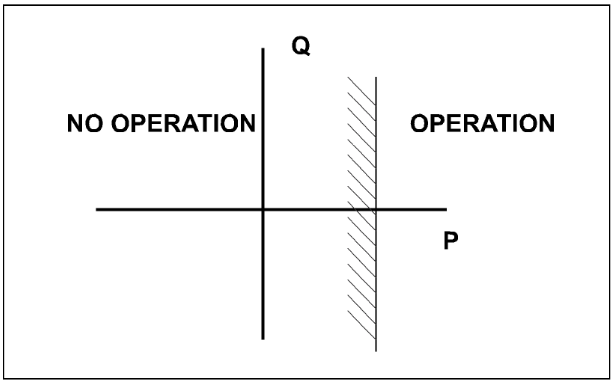


Figure 3.13.4 Angle Setting 0º and Pickup Setting Positive.

Angle 90º and pickup positive

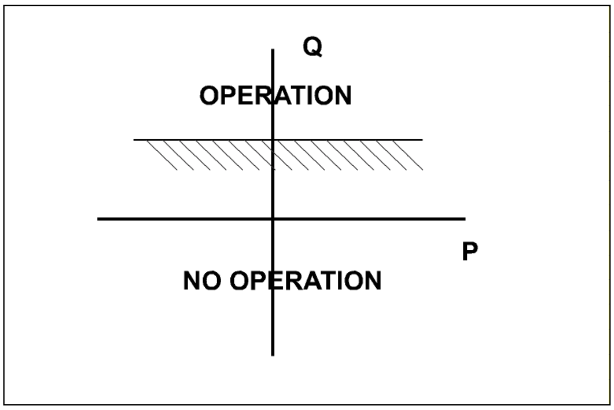


Figure 3.13.5 Angle Setting 90º and Pickup Setting Positive.

Power element characteristic angle allows:

- Elements to operate for active or reactive power in any direction.
- Angular error compensation in CT and VT.

Pickup takes place when the measured value exceeds 1.00 time 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 Fixed Time characteristic.

Operation of these elements is conditioned to breaker position; if breaker is open the element is disabled.

3.13.2 Directional Power Elements Settings

Directional Power Elements (Elements 1 and 2)			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Angle	0.00 - 359.95º	0.05º	0º
Pick Up	-16000 to 16000 VA	1 VA	0 VA
Time	0.00 - 300 s	0.01 s	0 s

- **Directional Power Elements: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**9 - DIRECTIONAL POWER**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - UNIT 1**	**0 - DIR. POWER ENABLE**
...	**1 - UNIT 2**	**1 - DIR. POWER ANGLE**
9 - DIRECTIONAL POWER		**2 - DIR. POWER PU**
...		**3 - DIR. POWER TIME**

3.13.3 Digital Inputs of the Directional Power Elements Module

Table 3.13-1: Digital Inputs of the Directional Power Elements Module		
Name	**Description**	**Function**
IN_BLK_DIRP1	Directional power blocking input 1	Input activation before trip generation blocks element operation. If activated after trip, trip resets.
IN_BLK_DIRP2	Directional power blocking input 2	
ENBL_DIRP1	Directional power enable input 1	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	Directional power enable input 1	

3.13.4 Auxiliary Outputs and Events of the Directional Power Elements Module

Table 3.13-2: Auxiliary Outputs and Events of the Directional Power Elements Module		
Name	**Description**	**Function**
PU_DIRP1	Directional Power element 1 pickup	Pickup of power elements and timing start.
PU_DIRP2	Directional Power element 2 pickup	
TRIP_DIRP1	Activation of Directional Power element 1	Trip of power elements.
TRIP_DIRP2	Activation of Directional Power element 2	
TRIP_DIRP1M	Power element 1 masked trip	Trip of power elements affected by trip masks.
TRIP_DIRP2M	Power element 2 masked trip	
IN_BLK_DIRP1	Directional Power blocking input 1	The same as for the Digital Inputs.
IN_BLK_DIRP2	Directional Power blocking input 2	
ENBL_DIRP1	Directional Power enable input 1	The same as for the Digital Inputs.
ENBL_DIRP2	Directional Power enable input 1	
DIRP1_ENBLD	Directional Power 1 enabled	Indication of enabled or disabled status of the element.
DIRP2_ENBLD	Directional Power 2 enabled	

3.13.5 Directional Power Element 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.

3.14 Undercurrent Element

3.14.1 Description

This function is used in motor applications to detect a drop in current as a result of load reduction, as is the case for pump motors. If current is below a setting value for a given time while the motor is in operation, the element sends a trip signal.

Trip delay time setting value must be long enough to prevent ill-timed tripping as a result of momentary drop in current.

For this function to start the breaker must be closed. Then, as a function of a setting, the positive sequence current or phase currents (one logic OR of the three currents) are compared with the pickup setting. The element picks up if current is less than the setting for a set time period.

Pickup takes place when the measured value is below 0.98 times the setting, and resets at 1.05 times the setting value.

3.14.2 Undercurrent Element Settings

Undercurrent Element			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Current Select	0: Direct 1: Phase Current		0: Direct
Pickup	(0.02 - 2.00) In	0.01 A	0.25 A
Delay	0.05 - 300 s	0.01 s	0.05 s

- **Undercurrent Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**10 - UNDERCURRENT**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - UNDERCURRENT ENABLE**
...	**1 - CURRENT SELECT**
10 - UNDERCURRENT	**2 - UNDERCURR. PU**
...	**3 - UNDERCURRENT DELAY**

3.14.3 Digital Inputs of the Undercurrent Module

Table 3.14-1: Digital Inputs of the Undercurrent Module		
Name	**Description**	**Function**
IN_BLK_MIN_I	Undercurrent Element blocking input	Activation of input before trip is generated blocks element operation. If activated after, element resets.
ENBL_MIN_I	Undercurrent Element enable input	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.”

3.14.4 Auxiliary Outputs and Events of the Undercurrent Module

Table 3.14-2: Auxiliary Outputs and Events of the Undercurrent Module		
Name	**Description**	**Function**
PU_MIN_I	Undercurrent Element pickup	Element pickup and timing starts.
TRIP_MIN_I	Undercurrent Element trip	Undercurrent Element trip.
TRIP_MIN_IM	Undercurrent Element masked trip	Undercurrent Element trip affected by trip mask.
IN_BLK_MIN_I	Undercurrent Element blocking input	The same as for the Digital Inputs.
ENBL_MIN_I	Undercurrent Element enable input	The same as for the Digital Inputs.
MIN_I_ENBLD	Undercurrent Element enabled	Indication of enabled or disabled status of the element.

3.14.5 Undercurrent Element Test

Bring elements not tested out of operation and select phase current operation mode.

- **Pickup and Reset**

Apply current through three phase terminals.

Keep current through two phases above element pickup setting and lower the current of the other phase. Check that, for settings in table 3.14-3, the pickup state flag of the Undercurrent element sets to a permanent "1", when the current reaches a value between VA_MIN and VA_MAX.

Table 3.14-3: Undercurrent Element Test (Pickup and Reset)

Undercurrent element pickup			Undercurrent element reset	
Setting	VA_MIN	VA_MAX	VR_MIN	VR_MAX
x	x • 0.98 •·0.97	x • 0.98 •·1.03	x • 1.05 •·0.97	x • 1.05 •·1.03

- **Operating Times**

Set timer to 0 s and check that operating time is less than 30 ms.

Repeat test with X s timer setting and check that measured time is within the margin X ±1% or ±20 ms.

3.15 Restricted Earth Faults Element

3.15.1 Description

This function is used to detect faults in grounded wye connected transformer and generator windings. Grounded wye connected transformer or generator winding internal faults result in fault currents dependant on ground impedance and the position of the winding fault with respect to ground connection. Depending on the fault position, fault current may be very small.

The operating principle is based on comparing the measured ground current with the neutral current calculated from the three phase currents going into or leaving the machine. For element connection, the winding ground connection channel must have the same polarity than phase currents of same winding. This way, when an internal fault occurs, both currents will be facing each other, and a differential current will result; on the other hand, if the fault is external, both ground current and zero sequence line current will have the same direction towards the fault, and the differential current will disappear.

Comparison is made by the vector sum of three phase currents and corresponding winding ground current measured through the polarization current channel, obtaining **I_{diffN}**. If fault is external to the transformer, **I_{diffN}** must be zero.

To avoid errors due to current transformer measurement tolerances, for element activation, **I_{diffN}** must exceed a minimum setting and must also exceed a percentage of the maximum phase current. This percentage can be set.

3.15.2 Differential Current

Differential current is found by subtracting the magnitudes of the neutral current calculated from the winding phase currents and the neutral ground current measurement of the same winding (polarization current). Differential element operate magnitude is obtained from this differential current.

$$I_{diffN} = \frac{\bar{I}_A + \bar{I}_B + \bar{I}_C}{t_N} - \bar{I}_{POL} = \frac{3\bar{I}_0}{t_N} - \bar{I}_{POL}$$

Where:

I_{diffN} is winding neutral differential current.

$\bar{I}_A$, $\bar{I}_B$ and $\bar{I}_C$ are winding A, B and C phase currents, respectively.

$\bar{I}_{POL}$ is winding ground current measured through polarization current channel.

t_N is the ratio between turn ratios of winding neutral (polarization current) and phases.

$$t_N = \frac{CTIpol}{CTPhase}$$

3.15.3 Restraint Current and Slope of the Restricted Earth Faults Element

Restraint current of Restricted Earth Faults Element is the highest phase current of the same machine winding.

Winding slope is figured out from corresponding restraint current RMS and neutral differential current RMS:

$$P_N = \frac{I_{diffN}}{\frac{I_{restrN}}{t_N}} \times 100$$

Where:

I_{restrN} is restraint current of winding ground fault element.

I_{diffN} is winding neutral differential current.

t_N is the ratio between turn ratios of winding neutral (polarization current) and phase.

P_N is restraint magnitude of winding ground fault element.

This value is calculated whenever restraint current exceeds a minimum value of 10mA indicating a closed breaker.

3.15.4 Operate Magnitude Calculation

Once the difference in magnitude as a result of the turn ratios of phase and ground current transformers is compensated, element uses the calculated differential current as operate magnitude, checking that no transformer saturation exists and bearing in mind the sensitivity of the same, comparing neutral current with restraint current.

Operate characteristic is divided into two parts, as a function of the maximum winding phase current, restraint current. In any case, the fundamental harmonic of the calculated neutral differential current must always exceed the setting value.

Also, if restraint current exceeds a given limit, the operate characteristic is proportional to the restraint current, fundamental harmonic of the maximum phase current, as a function of the slope setting value. This way, the magnitude of the neutral differential current causing the element to operate varies.

The operate characteristic of the Restricted Earth Faults Element is obtained as shown in figure 3.15.1

For greater restraint currents the unbalances are greater and a neutral differential current is needed for element operation.

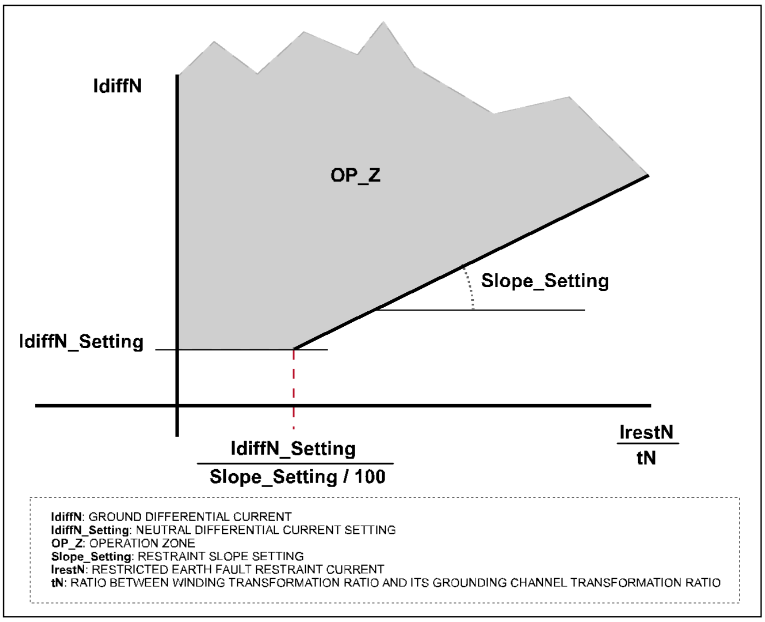


Figure 3.15.1 Restricted Earth Faults Element Operate Characteristic.

Differential setting parameter must take into account differential element and current transformer sensitivity, which define the minimum neutral differential current needed for element operation.

3.15.5 Operation

Restricted Earth Faults Element provides an output as the result of the comparison between the differential current and a value dependant of the operate characteristic, provided the measured polarization current exceeds a minimum threshold of 0.01 x In confirming once more it is an internal fault.

In as much as the restraint current is kept below a given level, the element operates by comparison of the calculated neutral differential current with the setting value. But, when restraint current exceeds a given limit, a value dependant on the restraint current is needed for activation.

On the other hand, two different ground fault element blocking conditions exist, which block element activation upon external faults. Any of them can activate separately said blocking, namely blocking is a logic OR of both conditions.

- **First condition**: when zero sequence current value exceeds a minimum saturation value under external fault conditions, the element is blocked until said external fault clears.

  Established criteria is $$3I_0 \cdot \frac{CTIPhase}{CTIpol} \geq 16 \cdot I_{NOMINAL}$$

- **Second condition**: when zero sequence current and ground current are in phase, fault is deemed external and the element is blocked.

Currents are considered to be in phase, calculating in degrees for each of the 4 quadrants, when $\beta_{IN\_I0} < 60^{\circ}$, where β_{IN_I0} is as follows:

$$\text{For } \alpha_{IN\_I0} = | \text{arctg} [\text{Im(IN)} / \text{Re(IN)}] - \text{arctg} [\text{Im(3I0)} / \text{Re(3I0)}] |$$

$$\text{If } [\alpha_{IN\_I0} > 180^{\circ}] \rightarrow \beta_{IN\_I0} = 360^{\circ} - \alpha_{IN\_I0}$$
$$\text{If } [\alpha_{IN\_I0} \leq 180^{\circ}] \rightarrow \beta_{IN\_I0} = \alpha_{IN\_I0}$$

A **Trip Blocking** input can be programmed into the element, which blocks element activation if input is activated before trip is generated. If activated after, trip resets. For this blocking logic to be used the **Restricted Earth Faults Trip Blocking** input must be programmed.

Restricted Earth Faults Element is provided with a settable timer for time delayed trips if required.

Element pickup takes place at 100% of operate characteristic setting and resets at 80% of this setting.

3.15.6 Application of Restricted Earth Faults element

Restricted Earth Faults Elements allow for transformer and generator protection upon internal ground faults not seen by phase differential elements.

When a machine winding is delta connected, the current cannot flow to ground, whereas if the other winding is wye or zig-zag connected, zero sequence current flows through the ground connection. The differential protection allows the activation of a zero sequence filter to prevent false trips upon external faults in said type connections. On the other hand, the activation of said filter neither allows detecting internal faults. Ground faults can be detected through Residual Ground Overcurrent Element. 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 current 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 current 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.

3.15.7 Restricted Earth Faults Element Settings

Restricted Earth Faults Element			
Setting	**Range**	**Step**	**Default**
REF Enable	YES / NO		NO
REF Pickup	(0.04 - 2.00) In	0.01 A	0.25 A
REF Restraint Slope	0 - 100 %	1 %	0 %
REF Delay	0.00 - 300 s	0.01 s	0.01 s

- **Restricted Earth Faults Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**12 - RESTRICTED EARTH**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - R EARTH ENABLE**
...	**1 - R EARTH PICKUP**
12 - RESTRICTED EARTH	**2 - R EARTH RESTRAINT**
...	**3 - R EARTH DELAY**

3.15.8 Digital Inputs of the Restricted Earth Faults Module

Table 3.15-1: Digital Inputs of the Restricted Earth Faults Module		
Name	**Description**	**Function**
IN_BLK_REF	Restricted Earth Faults blocking input	Activation of input before trip generation blocks element operation. If activated after tripping, trip resets.
ENBL_REF	Restricted Earth Faults enable input	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."

3.15.9 Auxiliary Outputs and Events of the Restricted Earth Faults Module

Table 3.15-2: Auxiliary Outputs and Events of the Restricted Earth Faults Module		
Name	**Description**	**Function**
PU_REF	Restricted Earth Faults element pickup	Element pickup and timing start.
TRIP_REF	Restricted Earth Faults trip	Restricted Earth Faults element trip.
TRIP_REFM	Restricted Earth Faults masked trip	Restricted Earth Faults trip affected by trip mask.
IN_BLK_REF	Restricted Earth Faults blocking input	The same as for the Digital Inputs.
ENBL_REF	Restricted Earth Faults enable input	The same as for the Digital Inputs.
REF_ENBLD	Restricted Earth Faults enabled	Indication of enabled or disabled status of the element.

3.15.10 Restricted Earth Faults Element Test

- **Settings**

Relay settings to be as per table 3.15-3 below:

Table 3.15-3: Restricted Earth Faults Element Test (Settings)	
Setting Label	Value
Phase CT Ratio	300
Ground CT Ratio	600
REF Enable	YES
REF Pickup	2
REF Restraint Slope	2
REF Delay	5
Element Trip Mask	YES
Rest of Elements Enable	NO

- **Element Sensitivity**

Apply current to neutral and one phase only (at 180º) and check that Restricted Earth Faults Element picks up and resets, for all pickup settings, when said current is within the margin indicated in table 3.15-4.

Table 3.15-4: Restricted Earth Faults Element Test (Element Sensitivity)		
Pickup setting	Pickup	Reset
2 A	0.97 - 1.03 A	0.72 - 0.78 A
1 A	0.485 - 0.515 A	0.364 - 0.386 A
0.04 A	0.0194 - 0.0206 A	0.14 - 0.16 A

Check that upon element activation a trip occurs activating all trip contacts.

- **Element Timer**

Apply a current 2.5 A to neutral and check that trip occurs within the margin ±1% or ±20ms (whichever is greater) of the timer setting value. Bear in mind that operate time for a 0 ms setting is between 20 and 25 ms.

- **Element Characteristic**

Apply current to A-phase and neutral. A-phase current will be constant and current to be injected to neutral for the element to operate shall be measured.

When in phase, test will be started with neutral value equal to phase value and then step down. For 180º out of phase, test will start with neutral to 0 and then step up.

Check that operate current is within the margin stated in table 3.15-5.

Table 3.15-5: Restricted Earth Faults Element Test (Element Characteristic)

A-Phase	B-Phase	Neutral - Pickup	
1 A (0º)	-	0º	Never
1 A (0º)	-	180º	0.018 A - 0.022 A
0.5 A (0º)	-	180º	0.01 A - 0.012 A
0.8 A (0º)	0.8 A (180º)	180º	0.016 - 0.064 A
3.2 A (0º)	3.2 A (180º)	180º	0.000 - 0.136 A

Repeat tests using B and C Phases.

3.16 Cold Load Element

3.16.1 Description

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 Table 4 can be used to this end as a second group with higher calibration settings.

Assuming the relay works using Table 1 and a breaker trips, a timer starts timing and if breaker remains open after time-out, settings in Table 4 apply. **This time delay must be higher than the highest recloser time delay programmed in the relay**. Table 4 will be the active table while breaker remains open.

When breaker closes, the equipment 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, Table 4 can be used in the same way as other tables.

It could happen that with the Cold Load Element enabled, the breaker changes state while the equipment is switched off. In this case, the element works as follows:

- **If equipment is switched off when breaker is closed and breaker is open when switched on**, Cold Load Element activates 100 milliseconds after equipment is switched on, and Table 4 will apply.
- **If equipment is switched off with Cold Load Element activated (Table 4 applies after breaker trips) and breaker is closed when switched on**, Cold Load Element remains activated during 100 milliseconds (Table 4 active) after pickup. When time expires the element resets and the last relay operate table before activation of Cold Load Element will apply.
- **If equipment is switched off with Cold Load Element activated and element disable digital signal is active when switched on**, element 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 Element deactivated and breaker opens within 100 milliseconds wait time for element pickup**, element output will activate instantaneously after said time.
- **If equipment is switched off with Cold Load Element activated and breaker remains open when switched on**, element continuous its normal operation as if nothing had happened.

3.16.2 Cold Load Element Settings

Cold Load Element			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Timer for Group 4 Activation after Trip	0 - 1800 s	0.1 s	120 s
Timer for Previous Group Activation after Closing	0 - 1800 s	0.1 s	120 s

- **Cold Load Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**11 - COLD LOAD**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - COLD LOAD ENABLE**
...	**1 - GROUP 4 ACT. TIME**
11 - COLD LOAD	**2 - PREV GRP ACT TIME**
...	

3.16.3 Digital Inputs of the Cold Load Module

Table 3.16-1: Digital Inputs of the Cold Load Module

Name	Description	Function
ENBL_CLPU	Cold Load enable input	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.”

3.16.4 Auxiliary Outputs and Events of the Cold Load Module

Table 3.16-2: Auxiliary Outputs and Events of the Cold Load Module

Name	Description	Function
ACT_CLPU	Cold Load activation (Table 4)	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.
ENBL_CLPU	Cold Load enable input	The same as for the Digital Inputs.
CLPU_ENBLD	Cold Load enabled	Indication of enabled or disabled status of the element.

3.17 Current Measurement Supervision

3.17.1 Introduction

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 **IRX** relay itself.

3.17.2 Operation Principles

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.

Figure 3.17.1 shows the supervision algorithm used for current measurement in phase A.

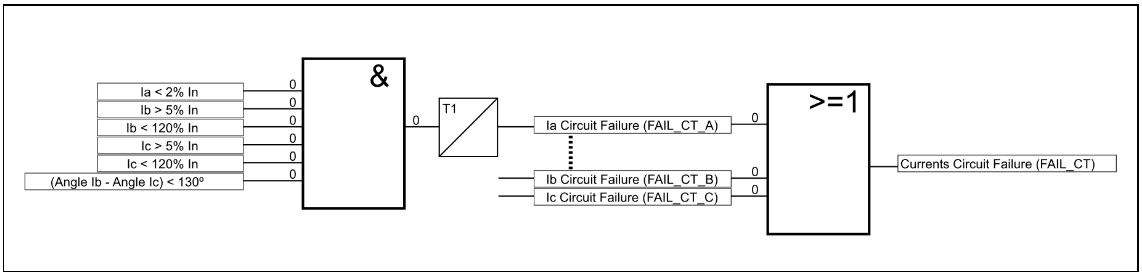


Figure 3.17.1 Supervision Algorithm for Current Measurement in Phase A.

Failure detection in any of the measuring circuits only generates the activation of the following signals: **FAIL_CT_A**, **FAIL_CT_B**, **FAIL_CT_C** and **FAIL_CT**. Blocking the operation of protection elements that are affected by measurement unbalance of phase currents must be programmed in ***ZIVerComPlus***® logic.

3.17.3 Current Measurement Supervision Settings

Current Measurement Supervision			
Setting	**Range**	**Step**	**Default**
CT Supervision Enable	YES / NO		NO
CT Supervision Time	0.15 - 300 s		0.5 s

- **Restricted Earth Faults Element: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - OVERCURRENT
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**6 - CT SUPERVISION**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	
...	**0 - CT SUPERV ENABLE**
6 - CT SUPERVISION	**1 - CT SUPERV TIME**
...	

3.17.4 Digital Inputs of Current Measurement Supervision Module

Table 3.17-1: Digital Inputs of the Current Measurement Supervision Module		
Name	**Description**	**Function**
ENBL_SUPCT	CT Supervision enable input	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".
EB_SUPCT	CT Supervision block input	Activation of this input generates the blocking of the supervision.

3.17.5 Auxiliary Outputs and Events of the Current Measurement Supervision Module

Table 3.17-2: Auxiliary Outputs and Events of the Current Measurement Supervision Module		
Name	**Description**	**Function**
FAIL_CT_A	Activation of CT Supervision Element for Phase A	Its activation indicates the existence of a failure in the measuring system of one of the phases
FAIL_CT_B	Activation of CT Supervision Element for Phase B	
FAIL_CT_C	Activation of CT Supervision Element for Phase C	
FAIL_CT	Activation of CT Supervision Element	
ENBL_SUPCT	Activation of CT Supervision enabled	Block output due to condition of fuse failure detected by the element in question.
EB_SUPCT	Activation of CT Supervision block Input	Block output due to condition of fuse failure (either detected by the element itself, or else by digital input).

3.18 Fuse Failure Detector

3.18.1 Introduction

When any of the fuses from the secondary circuit of the voltage transformers blows, the relay loses its corresponding voltage input, that is, the value of the voltage is zero. Consequently, overcurrent elements depending on voltage, undervoltage, ground overvoltage or voltage unbalance can operate improperly; hence, this condition must be detected before the element trips, in order to block these measuring elements.

3.18.2 Detection of Voltage Circuit Failure

This element blocks inputs from overcurrent elements dependent on voltage, undervoltage, ground overvoltage and voltage unbalance, when the magnetic-thermal circuit breaker of the busbar 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.

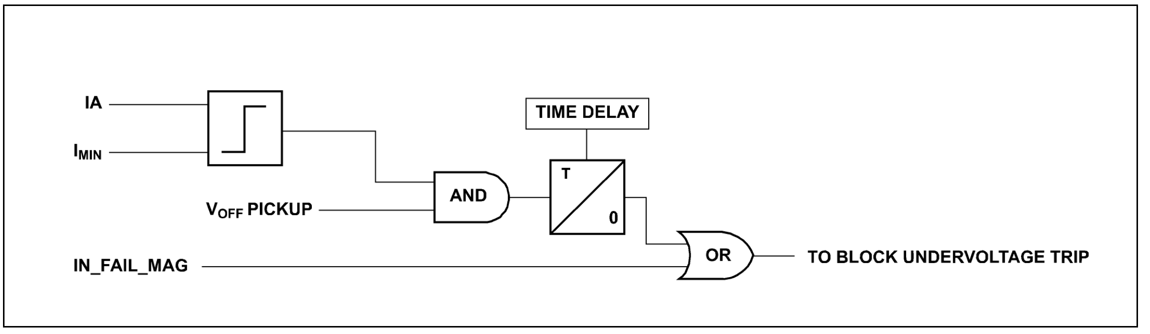


Figure 3.18.1 Voltage Circuit Failure Detection Element Scheme.

The value of phase A current is compared to the Imin element setting. Should this value be exceeded, it must be checked that the **Uzero Pickup** signal, corresponding to the Automatic Control device, is set to 1. If this is the case, and after a T1 time delay, the open command of the overvoltage elements that depend on voltage, undervoltage, ground overvoltage and voltage unbalance is blocked.

3.18.3 Fuse Failure Detector Settings

Fuse Failure Detector Settings			
Setting	**Range**	**Step**	**Default**
Voltage Circuit Supervision Enable	YES / NO		
Current Pickup	0.2 - 2 A	0.01	0.5 A
Voltage Circuit Supervision Time	0.01 - 5.00 s	0.01	0.4 s

- **Fuse Failure Detector: HMI Access**

0 - CONFIGURATION	0 - GENERAL	
1 - OPERATIONS	1 - PROTECTION	
2 - ACTIVATE GROUP	...	**0 - FF DET ENABLE**
3 - CHANGE SETTINGS	*** - FUSE FAILURE**	**1 - SUP PICKUP**
4 - INFORMATION	...	**2 - FUSE FAILURE TIME**

3.18.4 Digital Inputs of the Fuse Failure Detector Module

Table 3.18-1: Digital Inputs of the Fuse Failure Detector Module		
Name	**Description**	**Function**
IN_FAIL_MAG	Circuit Breaker Failure Input	The activation of this input means direct activation of voltage circuit failure Detector signal.

3.18.5 Digital Outputs and Events of the Fuse Failure Detector Module

Table 3.18-2: Digital Outputs and Events of the Fuse Failure Detector Module		
Name	**Description**	**Function**
IN_FAIL_MAG	Circuit Breaker Failure Input	The activation of this input means direct activation of voltage circuit failure Detector signal.
FAIL_V_CIRCUIT	Fuse Failure	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.

3.19 Recloser

3.19.1 Introduction

IRX recloser allows four reclose attempts with separate reclose and security timer settings.

Recloser can be set with different reclose and security times, upon a reclosing, depending on whether phase-to-phase fault or any ground element is involved.

Controlled reclose types are:

- Reclose initiate for ground faults tripped by time-overcurrent elements (Ground, Sensitive Ground and Ungrounded Neutral Time Overcurrent).
- Reclose initiate for phase-to-phase faults tripped by time-overcurrent elements (Phase Time Overcurrent).
- Reclose initiate for faults tripped by Negative Sequence Time elements.
- Reclose initiate for ground faults tripped by instantaneous elements (Ground and Sensitive Ground Instantaneous Overcurrent).
- Reclose initiate for phase-to-phase faults tripped by instantaneous elements (Phase Instantaneous Overcurrent).
- Reclose initiate for faults tripped by Negative Sequence Instantaneous elements.
- Reclose initiate by Open Phase Element trip.
- Reclose initiate by Residual or Zero Sequence Current Element trip.
- Reclose initiate by operation of external protection.

Figures 3.19.1 and 3.19.2 show flow charts describing recloser operation. Signal **INIT_RCL** (**Recloser Start**) in charts is the logic sum of:

INIT_RCL_F (Reclose initiate for phase-to-phase faults)
INIT_RCL_PP (Reclose initiate for ground faults)

Thus:

INIT_RCL = INIT_RCL_F + INIT_RCL_PP

Phase-To-Phase Reclose Initiate (**INIT_RCL_F**) and **Ground Reclose Initiate** (**INIT_RCL_PP**) activate only upon activation of phase-to-phase or ground elements producing the trip, respectively, and deactivate when both are deactivated. **In case both phase-to-phase and ground element activations are present for the trip, the type of INIT_RCL depends on which element has been activated first.**

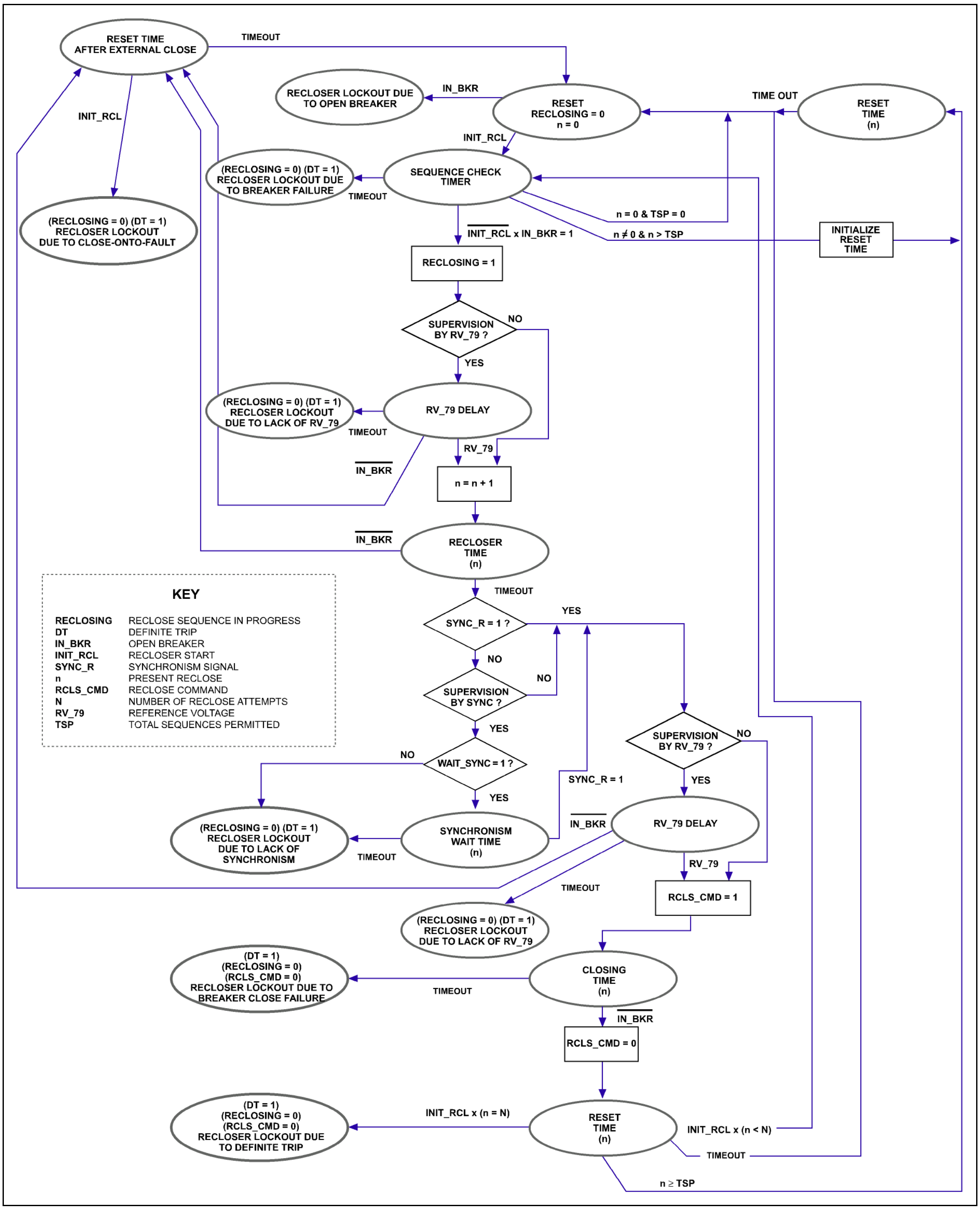
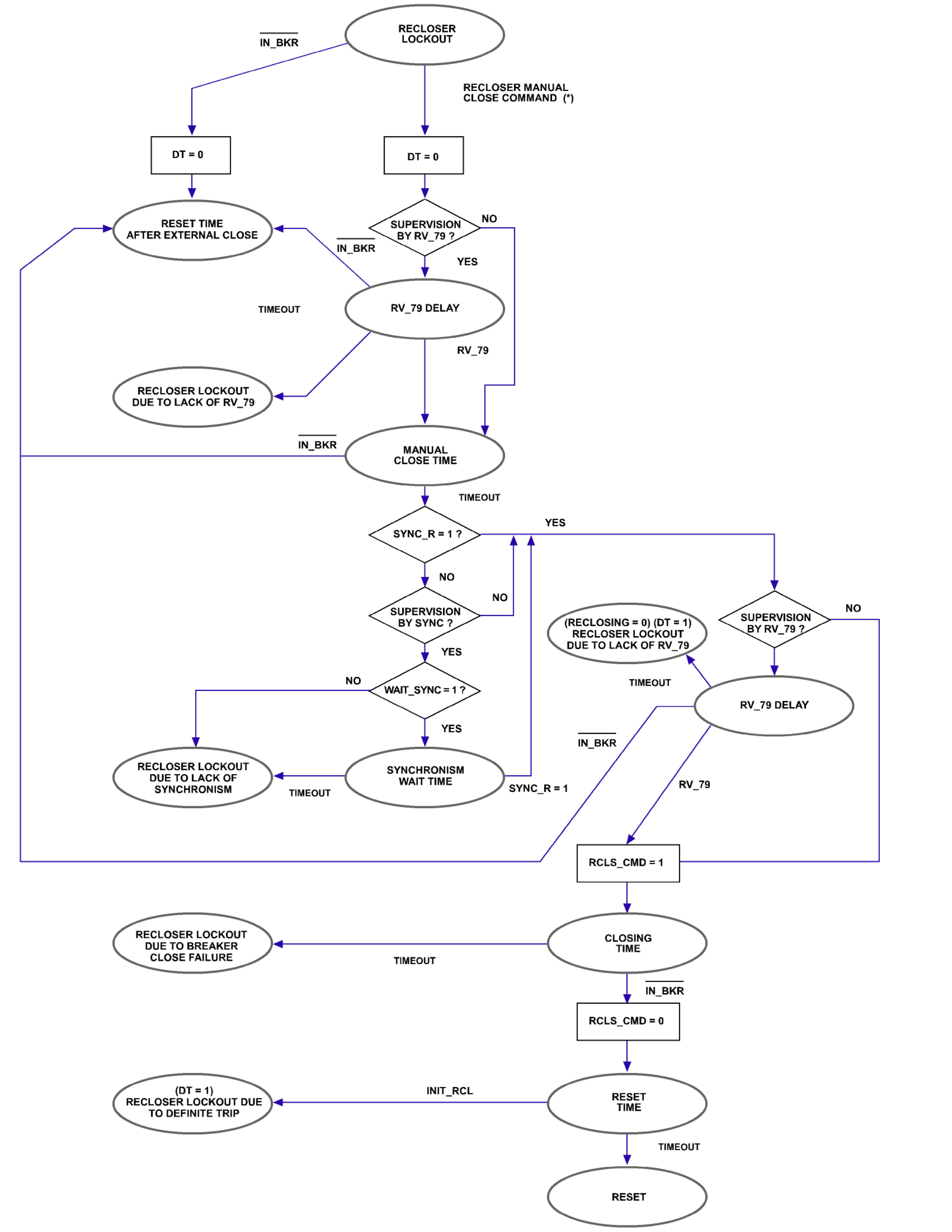


Figure 3.19.1 Recloser Operation Flow Diagram (I).



(*) To operate this way, the LOGIC \ CLOSURE VIA RECLOSER FUNCTION setting must be YES.

Figure 3.19.2 Recloser Operation Flow Diagram (II).

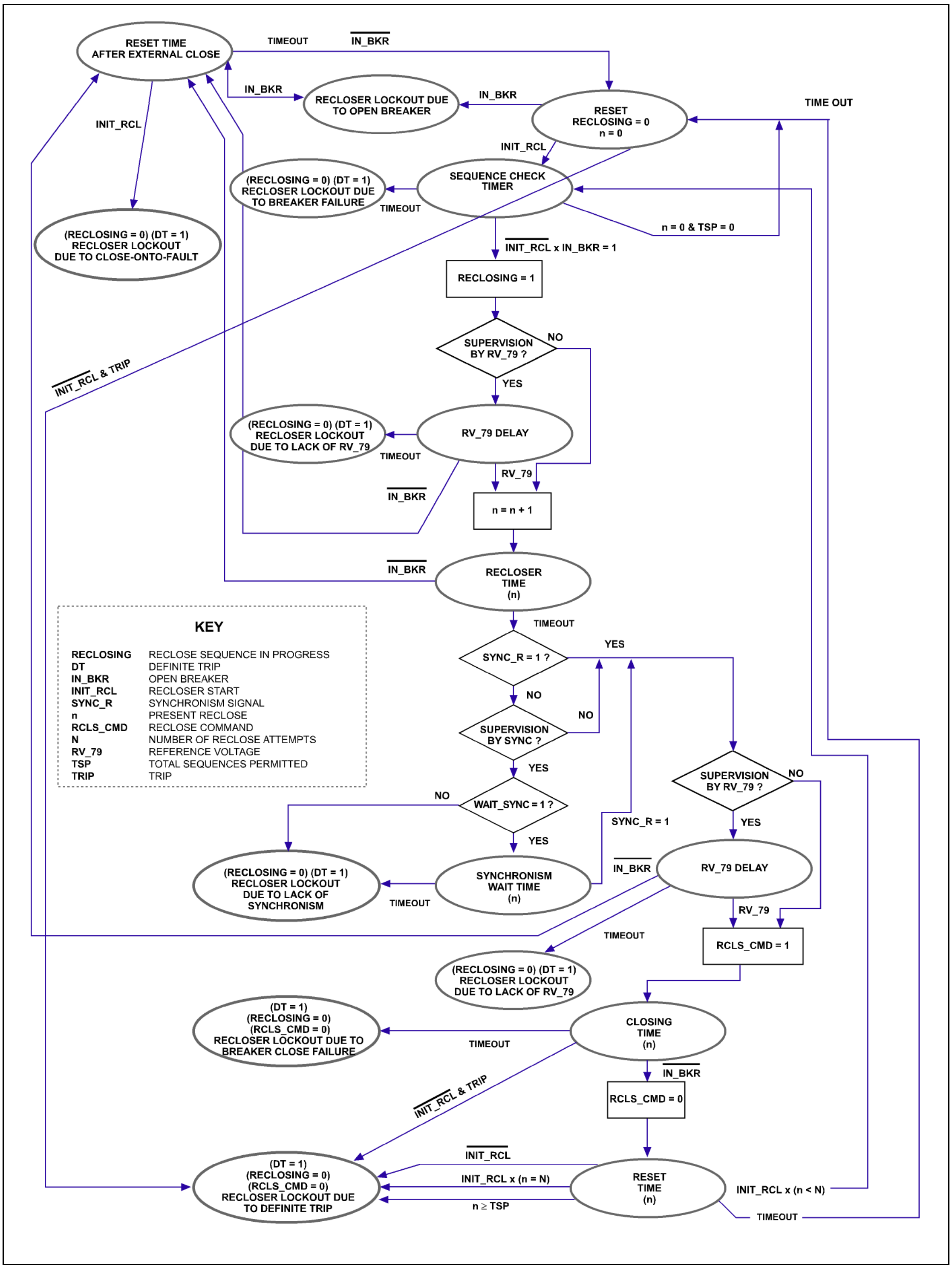


Figure 3.19.3 Recloser Operation Flow Diagram Applicable from Firmware Version 3.70 onwards.

3.19.2 Reclose Sequence

There are as many reclose attempts as have been programmed (up to four). Every reclose attempt comprises a number of operations, the sequence of which is controlled by recloser settings and a number of external events detected through the digital input system or received from relay protection elements.

3.19.2.a Sequence Start

Starting from rest, recloser operation initiates upon tripping of any enabled protection element or activation of **External Protection Trip** digital input (**EXT_TRIP**). In both cases, signal **INIT_RCL** (**Recloser Start**) activates, which brings the recloser out of rest state into **Sequence Check Time** state, and a timer with Sequence Check Time setting starts timing. If time expires before detecting fault reset (**INIT_RCL** reset) and breaker opening (**IN_BKR**), the system evolves into **Internal Lockout** on initiate failure state, from which it can only exit by means of a breaker closing command. Otherwise, recloser initiates and signal **RECLOSING** activates (**Sequence in Progress**).

3.19.2.b Monitoring the Reference Voltage

Digital signal **RV_79** (**Auxiliary Reference Voltage**) and a settable **Timer** (Reference Voltage Presence Time) are used to ensure that recloser supervision voltage is stable. Said digital signal **RV_79** must remain active during a time period equal or higher than the setting value in order that signal **VAL_RV_79** (**Asserted Auxiliary Reference Voltage**) used by recloser supervision process asserts to logical “1”.

When digital signal **RV_79** deactivates, **VAL_RV_79** deactivates and voltage presence time must expire to activate again.

This way, after leaving **Sequence Check Time** state, if reclose **Supervision by Reference Voltage** is set to **YES**, **Reference Voltage Wait Time** status is reached, during which, activation of signal **VAL_RV_79** (**Asserted Auxiliary Reference Voltage**) is supervised during **Reference Voltage Wait Time** setting. If said voltage is detected within mentioned wait time, recloser goes into **Reclose Time** state corresponding to first reclose shot. If time expires before mentioned voltage is detected, system goes into **Recloser Lockout due to Lack of Reference Voltage** state.

If, on the contrary, reclose **Supervision by Reference Voltage** is set to **NO**, **Reclose Time** state is reached without going through **Reference Voltage Wait Time** state.

Then, if all conditions upon which a **Reclose Command** (**RCLS_CMD**) is generated have been complied with, if reclose **Supervision by Reference Voltage** is set to **YES**, **Reference Voltage Wait Time** state is reached again and the above explained process is repeated.

3.19.2.c Reclose Time

When this state is reached, **Reclose Time** starts timing, timer setting being different for each of the close shots. After said time expires, signal **SYNC_R** (**Close by Synchronism Enabled**) state is checked, signal being generated as follows:

Depending on setting, external or calculated synchronism signal (see section 3.10.6) will be connected to **SYNC_R**.

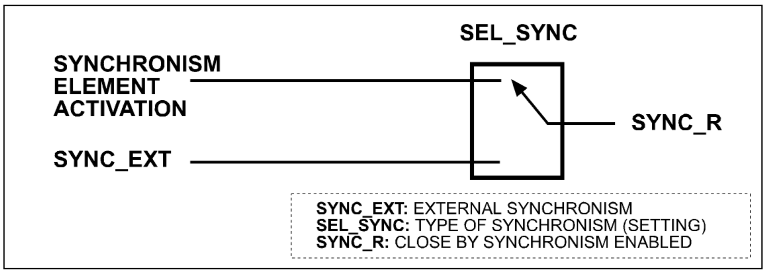


Figure 3.19.4 Synchronism Signal.

If this signal is active, output **RCLS_CMD** (**Reclose Command**) activates and **Closing Time** state is reached. In case the mentioned signal is not active, **Synchrocheck Supervision** setting is checked: if set to **NO**, **RCLS_CMD** (**Reclose Command**) activates and **Closing Time** state is reached; if, on the contrary, if set to **YES**, **Wait Time** setting is checked. If setting is **YES**, recloser goes into **Wait Time** state in order to wait for signal **SYNC_R** activation before time setting expires. If **Wait Time** setting is **NO**, meaning that said activation must not be waited for, **Recloser Lockout due to Lack of Synchronism** state is reached.

3.19.2.d Closing Time

When this state is reached a timer starts timing with setting **Close Failure Time** and output **RCLS_CMD** activates, sending a close command signal to the breaker. If closed breaker is detected before the time expires, **Reset Time** state is reached. If, on the contrary, time expires without closing, **Recloser Lockout due to Breaker Close Failure** state is reached. In both cases, output **RCLS_CMD** deactivates.

If **Reclose Command** (**RCLS_CMD = 1**) is activated and active **Trip Circuit Failure** signal (**FAIL_SUPR**) is asserted, close command does not activate and **Close Command Disable** signal (**CCR**) activates. The **Close Failure Time** expires and finally recloser reaches **Recloser Lockout due to Breaker Close Failure** state.

3.19.2.e Reset Time

If this state is reached a timer with **Reset Time** setting corresponding to the actual recloser shot starts. This time is used to discern if two consecutive trips correspond to same fault that has not successfully been cleared or, otherwise, correspond to two consecutive faults. If **Reset Time** expires and no trip occurs, recloser goes into **Reset** state, and process is finalized.

If a trip occurs (**INIT_RCL** activation) before **Reset Time** expires, the following step will depend on whether the number of reclose shots has been reached or not. If said limit has been reached, recloser goes into **Recloser Lockout due to Definite Trip** state, and process is finalized. Otherwise, the new trip initiates a new close sequence, the system going into **Sequence Check Time** state.

3.19.3 Recloser Lockout

Recloser Lockout states correspond to situations where the recloser will not initiate shots upon a trip, thus, all trips occurring under this circumstance are **definite**.

Recloser Lockout states reached when recloser leaves Reset state on fault occurrence and related trip have been explained above. Nevertheless, another circumstance exists that can bring the recloser into **Lockout** state: breaker opening not associated to a fault. Under this circumstance, recloser goes into **Recloser Lockout due to Open Breaker** state, and closing is disabled.

Recloser remains in either of the **Lockout** states reached until a closed breaker is asserted or a close command is given through them.

3.19.4 Manual Close

There exist two manual closing situations leading to different recloser actions and states:

- **External Manual Close**

This situation is reached when recloser detects a breaker closed through breaker status input, the command coming neither from the recloser nor from the relay command system.

When said situation is detected, if closing command comes from **HMI** (front display and buttons) or **Communications** (local or remote) or else from a **Digital Input** (external closing command), the command logic checks for synchronism (signal **SYNC_R**), provided **Synchrocheck Supervision** setting is **YES**.

If no synchronism exists (**SYNC_R** deactivated) the command logic generates event **Close Command Disable due to Lack of Synchronism**, returning to **Reset**.

If, on the contrary, synchronism is present (**SYNC_R** activated) or else, said supervision is not necessary from the beginning (**Synchrocheck Supervision** setting is **NO**), command logic generates signal **Close Command** when this situation is detected, recloser leaves reached **Lockout** state and goes into **Reset time after external closing**. After reaching this state **Reset Time after External Closing** starts timing. If time expires with no trip, recloser goes into **Reset** state. If, on the contrary, a trip occurs before time-out, recloser goes into **Recloser Lockout due to Close-onto-a-Fault** and the trip is definite, with no later reclose.

If signal **External Close Command** activates and signal **Trip Circuit Failure** (**FAIL_SUPR**) is active, **Close Command** does not activate and **Close Command Disable** (**CCR**) signal activates.

- **Recloser Manual Close**

This situation occurs when relay command function generates a **Close Command** to be executed by the recloser proper. For this to happen **Manual Closing Through Recloser** setting must be **YES** (this setting belongs to **Logic** group). A **Close Command** of this type initiates a process entirely identical to the last programmed shot, except that no **Sequence Check Time** exists and different values are used for the following settings:

- **Manual close supervision through recloser by reference voltage** (equivalent to reclose supervision by reference voltage setting).
- **Reference voltage wait time.**
- **Synchronism wait time.**
- **Manual close time** (equivalent to reclose time).
- **Reset time.**

After performing the same process as for last reclose shot, **Reset Time** starts timing, and a **Recloser Lockout** will be reached if a trip occurs before time expires. If a trip does not occur, Reset state is reached.

3.19.5 Manual and External Blocking

As for manual and external blockings recloser has preference over the first block commands received. Said blocking situation can only be reversed sending an opposite command.

- **Manual Blocking**

Recloser can be brought into **Blocking** state through a **HMI** or **Communication** channel command signal (local or remote mode). If recloser is under a reclose shot sequence, this will stop upon receipt of the block command. In this case, no shot attempt will take place after a trip, so that, in all cases, trip will be definite.

The **Blocking** state can be exited only by an unblock command through **HMI** or **Communications** channel (local or remote). If breaker is open when this command signal is received, recloser will go into **Reclose Lockout** state, which will be exited when breaker closes. If, on the contrary, breaker is closed, **Reset Time** starts timing and eventually recloser will reach **Reset** state.

- **External Blocking**

What has been said for **Manual Blocking** is valid for **External Blocking**, except that block and unblock commands are received through one or two configurable digital inputs. **Level** blocking or **Pulse** blocking can be configured through **External Blocking** setting.

Only one digital input is configured for **Level** blocking, allocating recloser block and unblock to each of logic states (logic “1” and “0”)

Two digital inputs are configured for **Pulse** blocking, one for **External Blocking** and one for **External Unblocking**. If block input activates, recloser goes into blocking, state which will be exited when unblock input activates.

3.19.6 Definite Trip

If the fault persists after shot sequence is finalized, recloser generates a **Recloser Lockout Due to Definite Trip** (**LO_DT**) signal.

An auxiliary output such as **LO_DT + DISP* (79BLK_EXT + 79BLK_MAN)** (deemed also as **Definite Trip**) can also be configured, so that, apart from the definite trip itself, if a trip occurs when recloser is manually or externally blocked, recloser state is indicated as **Recloser Lockout**.

When a trip occurs when recloser is blocked, **Definite Trip LO_DT + DISP* (79BLK_EXT + 79BLK_MAN)** signal remains until trip generating element resets. As a general rule, terminals operate this way when a trip not be followed by reclose occurs.

3.19.7 Recloser Not in Service

Recloser is out of operation whenever **Recloser In Service** setting is disabled. If this option is selected, recloser is completely disabled. Protection element trip masks continue in operation no matter their state.

3.19.8 Reclose Counter

Two counters on the display indicate the number of shots from last reset, an action that can be performed from the HMI. First counter assess the number of shots that take place with the recloser at Reset; second counter, the number of shots that take place after this. If the setting for the number of shots is four, and a fault is cleared successfully after the fourth shot, the first counter is incremented one count and three counts in the second.

3.19.9 Trip and Reclose Masks

A number of settings control trip enable and reclose initiate, depending on recloser state.

- **Trip Enable**

Phase IOC (50PH1, 50PH2 and 50PH3)
Phase TOC (51PH1, 51PH2 and 51PH3)
Ground IOC (50G1, 50G2 and 50G3)
Ground TOC (51G1, 51G2 and 50G3)
Negative Sequence IOC (50NS1 and 50NS2)
Negative Sequence TOC (51NS1, 51NS2 and 50NS3)
Sensitive Ground IOC (50SG)
Sensitive Ground TOC (51SG)
Voltage Restraint TOC (51V)
Ungrounded Directional (67UNG)
Open Phase Element
Residual Current Element
Phase Overvoltage Elements (59PH1, 59PH2 and 59PH3) (*)
Phase Undervoltage Elements (27 PH1, 27 PH2 and 27 PH3) (*)
Ground Overvoltage Elements (59G1 and 59G2 or 64_1 and 64_2) (*)
Negative Sequence Overvoltage Element (47) (*)
Overfrequency Elements (81M1, 81M2, 81M3 and 81M4) (*)
Underfrequency Elements (81m1, 81m2, 81m3 and 81m4) (*)
Frequency Rate of Change Elements (81D1, 81D2, 81D3 y 81D4) (*)
Thermal Image Element (49) (*)
Directional Power Elements (32P/Q1 y 32P/Q2) (*)
Restricted Earth Fault Element (87N) (*)
Out of Step Element (78) (*)
Programmable trip (configurable in programmable logic) (**)

(*) Trip of any of these units never initiates reclose sequence.
(**) Breaker trip configured in programmable logic initiates the reclose sequence only if configured for this purpose.

These elements will or will not be trip enabled as a function of the following recloser states:

- Recloser at Reset.
- Recloser timing Reset Time after shot #1, 2, 3 or 4.
- Recloser timing Reset Time after external manual close.
- Recloser timing Reset Time after manual close through recloser.
- Recloser Lockout (internal, external or manual block).

The option Load Restoration Enable can also be configured, which is independent from the shot sequence, and allows enabling or not the next close:

By operation of **Load Shedding Elements** (REP DLS1) (*)

(*) **Load Shedding Element** close mask is not really a recloser-related mask, as generation of said close command depends exclusively Load Shedding and Reset Logic and not on recloser actual shot.

For **Overfrequency Elements** configured for **Load Shedding**, their trip masks have no effect on said **Load Shedding Elements**.

On the other hand, when breaker is closed and recloser is manually or externally unblocked, the corresponding Reset Time after Manual Close starts timing, so that, during this time the mask applicable to any element is **External or Manual Close Reset Time Trip** mask.

Trip mask action depends upon enabling the corresponding element, within its own protection settings, as element pickup process is not initiated if element is disabled. Trip masking, corresponding to **NO** setting, prevents the physical activation of trip output or masked-configured output, but the entire element process from pickup to the decision to generate a trip is executed, and the physical output configured as element output activation is also activated.

- **Reclose Enable**

Reclose may or may not be enabled for following faults:

Faults tripped by Phase Time Overcurrent Elements (51PH1, 51PH2 and 51PH3)
Faults tripped by Phase Instantaneous Elements (50PH1, 50PH2 and 50PH3)
Faults tripped by Ground Time Overcurrent Elements (51G1, 51G2 and 50G3)
Faults tripped by Ground Instantaneous Elements (50G1, 50G2 and 50G3)
Faults tripped by Negative Sequence Time Overcurrent Elements (51NS1, 51NS2 and 5NS3)
Faults tripped by Negative Sequence Instantaneous Elements (50NS1 and 50NS2)
Faults tripped by Sensitive Ground Time Overcurrent Element (51SG)
Faults tripped by Sensitive Ground Instantaneous Element (50NS)
Faults tripped by Voltage Restraint Time Overcurrent Element (51V)
Faults tripped by Ungrounded Directional Element (67UNG)
Open Phase Element trip
Residual Current Element trip
External protection trip
Programmable trip (configurable in programmable logic)

Recloser states for which mentioned masks are defined are:

- Reclose sequence in progress 1, 2, 3 and 4

If recloser is **Not in Service** or **Lockout**, masks are not in operation and all trips become active by default.

The maximum number of shots allowed will be the minimum setting of the tripped elements. Operation is as follows:

- **When an Element trips for the first time**, relay looks into the total number of recloser shots allowed for this element. If successive trips belong to same element, this will be the total number of shots allowed.
- **When an Element trips for the first time and in later shots a different Element trips**, relay compares the number of total shots allowed for both elements and saves the smaller value. The same applies when trips of different elements occur at the same time in the same shot.
- **If the shot in progress is higher than maximum allowed reclose shot saved in the relay**, recloser goes into Recloser Lockout Due to Open Breaker and no Reclose Command takes place.

Important: as settings do not depend on each other, at least one unmasked measurement element must exist. Otherwise, protection trip will be disabled. Element is unmasked if setting is **YES** (check box activated).

3.19.10 Recloser Settings

Recloser In Service			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO

Recloser Timers			
Setting	**Range**	**Step**	**Default**
Phase Reclose (1, 2, 3 and 4) Delay	0.05 - 300 s	0.01 s	2 s
Gnd Reclose (1, 2, 3 and 4) Delay	0.05 - 300 s	0.01 s	4 s

Cycle Control Timers			
Setting	**Range**	**Step**	**Default**
Reference Voltage Timer 1	0.5 - 300 s	0.01 s	1 s
Reference Voltage Timer 2	0 - 20 s	0.01 s	0.01 s
Synchrocheck Timer	0.05 - 300 s	0.01 s	2 s
Phase Fault Reset Timer	0.05 - 300 s	0.01 s	3 s
Gnd Fault Reset Timer	0.05 - 300 s	0.01 s	5 s
Manual Close Reset Timer	0.05 - 300 s	0.01 s	3 s
Sequence Check Timer	0.05 - 0.35 s	0.01 s	0.25 s
Manual Close Delay	0.05 - 300 s	0.01 s	2 s

Cycle Control			
Setting	**Range**	**Step**	**Default**
Maximum Recloser Shots	1 - 4		4
Manual Close - Vref Supervision	YES / NO		YES
Recloser - Vref Supervision	YES / NO		YES
Manual Close - Synchrochek Supervision	YES / NO		YES
Recloser - Synchrocheck Supervision	YES / NO		YES
Synchrocheck Supv. Delay Enable	YES / NO		YES
External Blocking	Level / Pulse		Level

Trip Enable		
Setting	**Step**	**Default**
Phase IOC (50PH1, 50PH2 and 50PH3)	YES / NO	YES
Phase TOC (51 PH1, 51 PH2 and 51 PH3)	YES / NO	YES
Ground IOC (50N1, 50N2 and 50N3)	YES / NO	YES
Ground TOC (51N1, 51N2 and 51N3)	YES / NO	YES
Negative Sequence IOC (50NS1 and 50NS2)	YES / NO	YES
Negative Sequence TOC (51NS1, 51NS2 and 50NS3)	YES / NO	YES
Sensitive Ground IOC (50SG)	YES / NO	YES
Sensitive Ground TOC (51SG)	YES / NO	YES
Voltage Restrained TOC (51V)	YES / NO	YES
Directional Ungrounded (67NA)	YES / NO	YES
Open Phase	YES / NO	YES
Residual Current Element	YES / NO	YES
Phase Overvoltage (59PH1, 59 PH2 and 59 PH3)	YES / NO	YES
Phase Undervoltage (27 PH1, 27 PH2 and 27 PH3)	YES / NO	YES
Ground Overvoltage (59N1 and 59N2 or 64_1 and 64_2)	YES / NO	YES
Negative Sequence Overvoltage (47)	YES / NO	YES
Overfrequency (81M1, 81M2, 81M3 and 81M4)	YES / NO	YES
Underfrequency (81m1, 81m2, 81m3 and 81m4)	YES / NO	YES
Frequency Rate of Change (81D1, 81D2, 81D3 and 81D4)	YES / NO	YES
Thermal Image (49)	YES / NO	YES
Directional Power (32P/Q1 and 32P/Q2)	YES / NO	YES
Undercurrent Element	YES / NO	YES
Restricted Earth Faults (87N)	YES / NO	YES
Out of Step (78)	YES / NO	YES
Programmable Trip (configurable in the programmable logic)	YES / NO	NO
Recloser states for which these enables are defined: Stand By Recloser Trip Lock Out Recloser Trip Shot (1, 2, 3 and 4) Reset Time Trip External or Manual Close Reset Time Trip Manual Close Through Recloser Reset Time Trip		

Load Restoration Enable			
Setting	**Range**	**Step**	**Default**
Load Restoration 1	YES / NO		YES

Recloser Enable		
Setting	**Step**	**Default**
Phase IOC (50PH1, 50PH2 and 50PH3)	YES / NO	YES
Phase TOC (51 PH1, 51 PH2 and 51 PH3)	YES / NO	YES
Ground IOC (50N1, 50N2 and 50N3)	YES / NO	YES
Ground TOC (51N1, 51N2 and 51N3)	YES / NO	YES
Negative Sequence IOC (50NS1 and 50NS2)	YES / NO	YES
Negative Sequence TOC (51NS1, 51NS2 and 50NS3)	YES / NO	YES
Sensitive Ground IOC (50SG)	YES / NO	YES
Sensitive Ground TOC (51SG)	YES / NO	YES
Voltage Restrained TOC (51V)	YES / NO	YES
Directional Ungrounded (67NA)	YES / NO	YES
Open Phase	YES / NO	YES
Residual Current Element	YES / NO	YES
External Protection	YES / NO	YES
Close Command (configurable in the programmable logic)	YES / NO	YES
Recloser states for which these permissions are defined: Reclose sequence in progress 1, 2, 3 and 4		

- **Recloser: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - RECLOSER IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - RECLOSER TIMERS**
2 - ACTIVATE GROUP	**2 - RECLOSER**	**2 - SEQ CONTROL TIMER**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - SEQUENCE CONTROL**
4 - INFORMATION	...	**4 - TRIP PERMISIONS**
		5 - LOAD RESTORATION ENA
		6 - RECLOSER ENABLE

Recloser Timers

0 - RECLOSER IN SERVICE	**0 - T PHASE RECLOSE 1**
1 - RECLOSER TIMERS	**1 - T GND RECLOSE 1**
2 - SEQ CONTROL TIMER	**2 - T PHASE RECLOSE 2**
3 - SECUENCE CONTROL	**3 - T GND RECLOSE 2**
4 - TRIP PERMISIONS	**4 - T PHASE RECLOSE 3**
5 - LOAD RESTORATION ENA	**5 - T GND RECLOSE 3**
6 - RECLOSER ENABLE	**6 - T PHASE RECLOSE 4**
	7 - T GND RECLOSE 4

Sequence Control Timer

0 - RECLOSER IN SERVICE	**0 - VREF WAIT TIME**
1 - RECLOSER TIMERS	**1 - SYNC WAIT TIME**
2 - SEQ CONTROL TIMER	**2 - PHASE RESET TIME**
3 - SECUENCE CONTROL	**3 - GND RESET TIME**
4 - TRIP PERMISIONS	**4 - MAN CLOSE RESET T**
5 - LOAD RESTORATION ENA	**5 - START TIME**
6 - RECLOSER ENABLE	**6 - MAN. CLOSE DELAY**
	7 - V.REF WAIT TIME

Sequence Control

0 - RECLOSER IN SERVICE	**0 - RECLOSE SHOTS**
1 - RECLOSER TIMERS	**1 - VREF MAN.CLOSE SUP.**
2 - SEQ CONTROL TIMER	**2 - VREF RECLOSER SUP.**
3 - SECUENCE CONTROL	**3 - MAN CLOSE SYNC SUP**
4 - TRIP PERMISIONS	**4 - RECLOSER SYNC SUP**
5 - LOAD RESTORATION ENA	**5 - SYNC DELAY TIMER**
6 - RECLOSER ENABLE	**6 - EXTERNAL BLOCKING**

Trip Permissions

0 - RECLOSER IN SERVICE	**0 - STANDBY RECL. TRIPS**
1 - RECLOSER TIMERS	**1 - BLOCKED RECL. TRIPS**
2 - SEQ CONTROL TIMER	**2 - RESETT CYCL 1 TRIP**
3 - SECUENCE CONTROL	**3 - RESETT CYCL 2 TRIP**
4 - TRIP PERMISIONS	**4 - RESET CYCL 3 TRIP**
5 - LOAD RESTORATION ENA	**5 - RESET CYCL 4 TRIP**
6 - RECLOSER ENABLE	**6 - EXT.MC RESET TRIP**
	7 - RECL.MC RESET TRIP

Load Restoration Enable

0 - RECLOSER IN SERVICE	
1 - RECLOSER TIMERS	
2 - SEQ CONTROL TIMER	
3 - SECUENCE CONTROL	
4 - TRIP PERMISIONS	
5 - LOAD RESTORATION ENA	**0 - LOAD REST1**
6 - RECLOSER ENABLE	

Recloser Enable

0 - RECLOSER IN SERVICE	**0 - RECLOSE CYCLE 1**
1 - RECLOSER TIMERS	**1 - RECLOSE CYCLE 2**
2 - SEQ CONTROL TIMER	**2 - RECLOSE CYCLE 3**
3 - SECUENCE CONTROL	**3 - RECLOSE CYCLE 4**
4 - TRIP PERMISIONS	
5 - LOAD RESTORATION ENA	
6 - RECLOSER ENABLE	

3.19.11 Digital Inputs of the Recloser Module

Table 3.19-1: Digital Inputs of the Recloser Module

Name	Description	Function
BLK_EXT_79	Recloser external blocking	Activation brings recloser into blocked / unblocked state respectively; generally used as command from ED, also from HMI or communications.
RST_EXT_79	Recloser external unblocking	
BLK_MAN_79	Manual block command	Activation brings recloser into blocked / unblocked state respectively; generally used as command from ED, also from HMI or communications.
RST_MAN_79	Manual unblock command	
EXT_TRIP	External protection trip	Receives and uses external signal for breaker failure function and for recloser operation initiate.
RV_79	Reference auxiliary voltage of recloser	Receives voltage signal used by recloser in Reclose Supervision by Reference Voltage.
TRIP_PROG	Programmable trip	Activation is equivalent to activation of protection element output. Application oriented to allocation to protection element output configured into programmable logic.
CMD_MAN_OP	Manual open command	Activation generates open and close commands respectively; Can be allocated to HMI, communications, digital inputs or any programmable logic signal. Application oriented to allocation to COMMANDS.
CMD_MAN_CLS	Manual close command	
TRIP_PROGM	Programmable masked trip	Activation supervised by corresponding recloser trip mask.
CMD_RST_NRCLS	Reclose counter reset command	Activation resets to zero the number of shots saved in counter.

3.19.12 Auxiliary Outputs and Events of the Recloser Module

Table 3.19-2: Auxiliary Outputs and Events of the Recloser Module		
Name	**Description**	**Function**
EXT_TRIP	External protection trip	The same as for the Digital Inputs.
BLK_EXT_79	Reclose external blocking	The same as for the Digital Inputs.
RST_EXT_79	Reclose external unblocking	The same as for the Digital Inputs.
79BLK_EXT	Recloser externally blocked	Externally blocked recloser state.
BLK_MAN_79	Manual block command	The same as for the Digital Inputs.
RST_MAN_79	Manual unblock command	The same as for the Digital Inputs.
79BLK_MAN	Recloser manually blocked	Manually blocked recloser state.
79BLK	Recloser manually or externally blocked	Manually or externally blocked recloser state.
INIT_RCL	Reclose initiate command	Reclose initiate.
INIT_RCL_F	Reclose initiate on ground fault command	Reclose initiate on ground fault.
INIT_RCL_PP	Reclose initiate on phase-to-phase fault command	Reclose initiate on phase-to-phase fault.
LO	Recloser lockout state	LO_NRV + LO_DT + LO_BF + LO_SCF + LO_FLINE + LO_OPEN + LO_NO_SYNC
LO_NRV	Recloser lockout due to lack of reference voltage	
LO_DT	Recloser lockout due to definite trip	
LO_BF	Recloser lockout due to breaker close failure	
LO_SCF	Recloser lockout due to sequence check failure	
LO_FLINE	Recloser lockout due to line fault	
LO_OPEN	Recloser lockout due to open breaker status	

Table 3.19-2: Auxiliary Outputs and Events of the Recloser Module		
Name	**Description**	**Function**
LO_NO_SYNC	Recloser internal lockout due to lack of synchronism	
RCLS1	Reclose attempt 1	
RCLS2	Reclose attempt 2	
RCLS3	Reclose attempt 3	
RCLS4	Reclose attempt 4	
TRST_RCLS_EXT	Reset time after a recloser external close	
TRST_RCLS	Reset time after a recloser close	
TRST_RCLS1	Reset time of recloser closing attempt 1	
TRST_RCLS2	Reset time of recloser closing attempt 2	
TRST_RCLS3	Reset time of recloser closing attempt 3	
TRST_RCLS4	Reset time of recloser closing attempt 4	
VAL_RV_79	Validated reference voltage	Signal VR_79 received, and activated after reference voltage presence time expires.
RV_79	Reference auxiliary voltage of recloser	The same as for the Digital Inputs.
CCR	Close command annulled	When a manual close command is configured to be synchronism supervised, if there is not and command is sent, signal activates.
TRIP_PROG	Programmable trip	The same as for the Digital Inputs.
CMD_MAN_OP	Manual open command	
CMD_MAN_CLS	Manual close command	
CLOSE_79	Closure by recloser	
RCLS_CMD	Reclose Command	
CMD_RST_NRCLS	Reclose counter reset command	
RST_CNT_RCLS	Reclose counter reset signal	
RECLOSING	Reclose sequence in progress	
79_RESET	Recloser reset	
79_INSERV	Recloser in service	

3.19.13 Recloser Test

Recloser testing must take into account the following:

- Reset Time must expire after manual closing. If trip occurs before Reset Time expires recloser goes into lockout state.
- To initiate the reclose sequence, the protection must detect open breaker and no phase current before Sequence Check Time expires (Cycle Control Timers group).
- If opening circuit supervision fails, the relay will not execute recloser shot, and will go into a Lockout state.
- For the recloser to execute the complete shot sequence until the final trip, trips must be generated at time intervals shorter than the Reset Time setting.
- When using reference voltage and disable input as well as element disable options, trip and reclose masks must be taken into account.

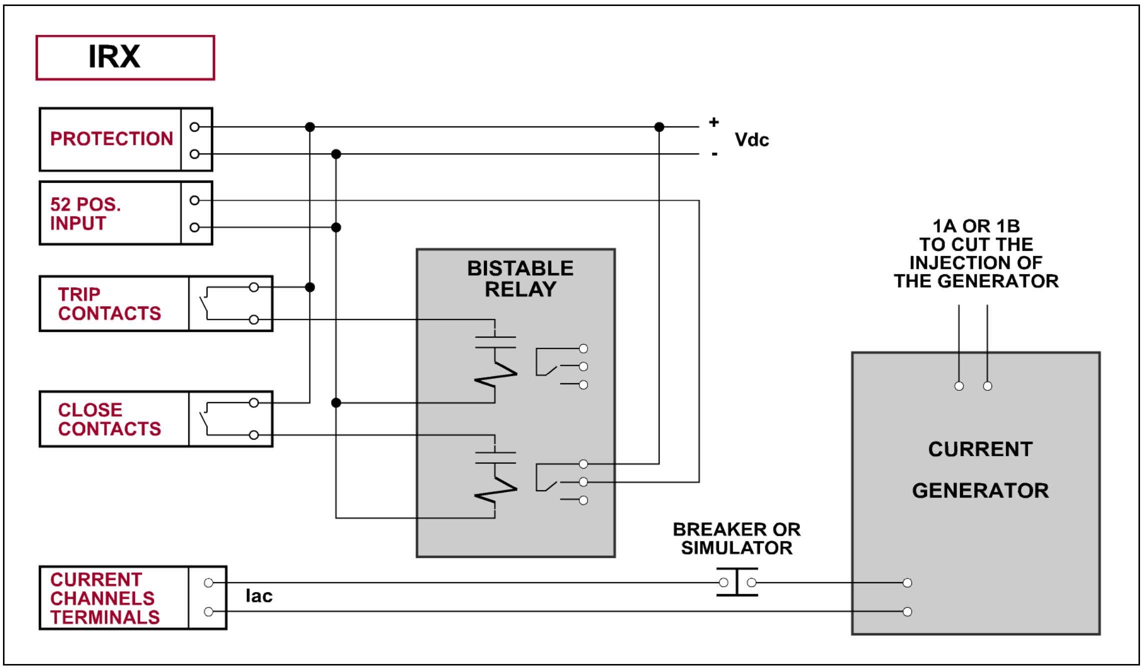


Figure 3.19.5 Connection Diagram for the Recloser Test.

Figure 3.19.5 shows how to carry out recloser testing. If the current generator does not cut out current injection before Sequence Check Time, test can be performed by opening the current circuit (by the breaker or simulator), or else by an instantaneous trip, sending just one pulse. This may be sufficient for the instantaneous element to operate and, at the same time, to stop seeing current flowing before Sequence Check Time.

3.20 Logic

3.20.1 Introduction

Following functions exist within the logic group: Trip Seal-In, Minimum Open Command Activation Time, Minimum Close Command Activation Time, Breaker Open and Close Failure Time, Manual Closing Through Recloser, Manual Close Synchrocheck Supervision and Pickup Reports.

3.20.2 Trip Seal-In

To enable the seal-in function the setting **Trip Seal-In** must be set to **YES**. Under these circumstances, once an opening or trip command and the corresponding breaker operate command has been generated; the command is active until open breaker is detected through the auxiliary contact.

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 open or 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.

3.20.3 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 Activation 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 will be active until an open breaker is confirmed only if setting **Trip Seal-In** is set to **YES**.

A setting **Minimum Close Command Activation 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.

3.20.3.a Auxiliary Outputs and Events of the Command Failure Module

Table 3.20-1: Auxiliary Outputs and Events of the Command Failure Module

Name	Description	Function
FAIL_CLS	Close command failure	Activate when set times expire after sending open or close commands, but do not operate.
FAIL_OPEN	Open command failure	

3.20.4 Manual Closing through Recloser

As mentioned in paragraph 3.19.4, breakers can be closed using Recloser logic in order for the logic to decide to close the breaker. For this to happen, **Manual Closing Through Recloser** setting must be set to **YES**.

3.20.5 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 **Synchronism Check Close Supervision** (**SUP_C_SINC**) must be set to **YES**.

3.20.6 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.

3.20.7 Fault Report with Primary Values

Models **2IRX-***-****F0**** have a setting to display fault report values, whether secondary or primary (affected by the transformation ratio).

3.20.8 Logic Settings

Logic			
Setting	**Range**	**Step**	**Default**
Trip Seal-In	YES / NO		NO
Minimum Open Command Activation Time	0.1 - 5 s	0.1 s	0.2
Fail to Open Time	0.02 - 2 s	0.005 s	0.02 s
Minimum Close Command Activation Time	0 - 5 s	0.1 s	0.2
Fail to Close Time	0.02 - 10 s	0.01 s	0.02 s
Manual Closing Through Recloser	YES / NO		NO
Manual Close Synchrocheck Supervision	YES / NO		NO
Pickup Reports	YES / NO		NO
Fault Report Magnitud	Secondary / Primary		Secondary

- **Logic: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP SEAL-IN**
1 - OPERATIONS	1 - PROTECTION	**1 - MIN OPENING RES T**
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - FAIL TO OPEN TIME**
3 - CHANGE SETTINGS	**3 - LOGIC**	**3 - MIN CLOSING RES T**
4 - INFORMATION	...	**4 - FAIL TO CLOSE TIME**
		5 - PHASE DISTANCE CHAR.
		6 - PICK UP REPORT
		7 - SYNCR. SUPERVISION

3.21 Configuration Settings

3.21.1 Introduction

The following setting groups are included into the Configuration group: Nominal Values, access Passwords, Communications, Date and Time, Display Controls and Command Buttons.

3.21.2 Nominal Values (Operation Mode)

Nominal operating values are selected through Operating Mode settings, both for current and voltage. Following parameters can be selected:

- **Nominal Phase Current.**
- **Nominal Ground Current** (also affecting Ground Polarization Current in models that include it).
- **Voltage**: (for models with voltage measurement) nominal phase-to-phase voltage setting is the reference value for all settings expressed in times or % *nominal voltage*. Applied both to phase and synchronism 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.

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.

3.21.3 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.

3.21.4 Communications

See paragraph 3.32 on Communications.

3.21.5 Date and Time

Selecting date and time in the configuration menu displays this setting to configure relay date and time.

3.21.5.a Local Time Zone Setting

If **Time Zone IRIG-B** is set to **UTC**, a time correction must be introduced to adapt the relay to the local time zone. Setting **Local Time Zone** allows putting UTC time forward or back as required.

3.21.5.b 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 Time / Winter Time Change Enable** setting.

3.21.6 Display Controls

This setting modifies the display contrast value (high value = more contrast).

3.21.7 Command Buttons

Enables or disables front pushbuttons for performing operations associated to them through the relay programmable logic.

3.21.8 Configuration Settings

Nominal Values			
Setting	**Range**	**Step**	**Default**
Nominal IABC	1 A / 5 A		5 A
Nominal IG	1 A / 5 A		5 A
Nominal IPOL	1 A / 5 A		5 A
Nominal VABC	50 - 230 V		110 V
Nominal Freq.	50 Hz / 60 Hz		50 Hz

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**.

Communications
See 3.32

Contrast
Adjustable from the keypad

Date and Time			
Setting	**Range**	**Step**	**Default**
Local Time Zone	GMT+(0, 1, 2, 3, 3:30, 4, 4:30, 5, 5:30, 5:45, 6, 6:30, 7, 8, 9, 9:30, 10, 11, 12) GMT-(1, 2, 3, 3:30, 4, 5, 6, 7, 8, 9, 9:30, 10, 11)		GMT+01:00
Summer Time / Winter Time Change Enable	YES / NO		NO
Summer Begin Time	0 - 23 Hours	1	2
Summer Begin Day Type	0 = Specific day 1 = First Sunday of the month 2 = Second Sunday of the month 3 = Third Sunday of the month 4 = Fourth Sunday of the month 5 = Last Sunday of the month		Last Sunday of the month
Summer Begin Day	1 - 31	1	1
Summer Begin Month	January, February, March, ...	1	March
Winter Begin Time	0 - 23 Hours	1	3
Winter Begin Day Type	0 = Specific day 1 = First Sunday of the month 2 = Second Sunday of the month 3 = Third Sunday of the month 4 = Fourth Sunday of the month 5 = Last Sunday of the month		Last Sunday of the month
Winter Begin Day	1 - 31	1	1
Winter Begin Month	January, February, March, ...	1	October

- **Configuration Settings: HMI Access**

0 - CONFIGURATION	**0 - NOMINAL VALUES**	**0 - NOMINAL IABC**
1 - OPERATIONS	1 - PASSWORDS	**1 - NOMINAL IN**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - NOMINAL INS**
3 - CHANGE SETTINGS	3 - TIME AND DATE	**3 - NOMINAL IPOL**
4 - INFORMATION	4 - DISPLAY CONTROLS	**4 - NOMINAL VABC**
	5 - DISP. LIGHT. T.OUT	**5 - NOMINAL FREC.**
	6 - COMMAND BUTTONS	

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - CONFIGURACION**
1 - OPERATIONS	**1 - PASSWORDS**	**1 - MANIOBRAS**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - AJUSTES EQUIPO**
3 - CHANGE SETTINGS	3 - TIME AND DATE	
4 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - DISP. LIGHT. T.OUT	
	6 - COMMAND BUTTONS	

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - PORTS**
1 - OPERATIONS	1 - PASSWORDS	**1 - PROTOCOLS**
2 - ACTIVATE GROUP	**2 - COMMUNICATIONS**	
3 - CHANGE SETTINGS	3 - TIME AND DATE	
4 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - DISP. LIGHT. T.OUT	
	6 - COMMAND BUTTONS	

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - TIME AND DATE**
1 - OPERATIONS	1 - PASSWORDS	**1 - LOCAL TIME ZONE**
2 - ACTIVATE GROUP	2 - COMMUNICATIONS	**2 - SUMMER/WINTER ENAB**
3 - CHANGE SETTINGS	**3 - TIME AND DATE**	**3 - SUMMER START HOUR**
4 - INFORMATION	4 - DISPLAY CONTROLS	**4 - TYPE OF SUMMER DAY**
	5 - DISP. LIGHT. T.OUT	**5 - SUMMER STARTINGDAY**
	6 - COMMAND BUTTONS	**6 - SUMMER START MONTH**
		7 - WINTER START HOUR
		8 - TYPE OF WINTER DAY
		9 - WINTER STARTINGDAY
		10 - WINTER START MONTH

3.22 General Settings

3.22.1 Introduction

The following settings are included within the General Settings group: Unit in Service, Transformer Ratios, Phase Sequence and Number of Voltage Transformers.

3.22.2 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.

3.22.2.a Auxiliary Outputs and Events (Protection in Service)

Table 3.22-1: Auxiliary Outputs and Events (Protection In Service)

Name	Description	Function
PROT_INSRV	Protection in service	Indicates that the IED is working with all the functions available.

3.22.3 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, sensitive ground, polarization ground, ungrounded neutral currents (as per model).
- Phase, synchronism and ground voltage (as per model).

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.

3.22.4 Input Transducers

Depending on the relay model, input current transducers are included. Depending of the HW, the following converter options can be selected: 0 to 5mA, -2.5 to +2.5 mA or 4 to 20 mA.

It is through the programmable logic that the converter can be allocated with a magnitude and a constant to represent the true reading (current, voltage, power,...) and the transformation ratio. The measured current in mA is turned into the actual measured magnitude and shown on the display (V, A, W,...).

3.22.4.a Models with Power Supply Voltage Monitoring

In models incorporating Power Supply Voltage Monitoring function, the relay is provided with a specific HW that allows direct current measurements. Two types of transducers exist depending on nominal voltage of the digital inputs:

- For 24Vdc and 48Vdc digital input relays.
- For 125Vdc and 250Vdc digital input relays.

The measured magnitude is available for display and recording in all functions using "user magnitudes" (HMI, ***ZivercomPlus***®, Oscillograms, Events, Logs, Programmable Logic, Protocols, ...).

As for the rest of transducers, they have the same characteristics as in paragraph 3.22.3.

3.22.5 Capacitive Transformer Transient Filtering

IRV relays, depending on model, 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 Voltage Transformer**.

3.22.6 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.

3.22.7 Number of Voltage Transformers

Models **2IRX-B** incorporate **Number of Voltage Transformers** setting to adapt the measuring mode for connection to 3 voltage transformers (phase to ground voltage) or two voltage transformers (AB and BC phase to phase voltage).

If it is configured for **3 transformers**, magnitudes directly calculated from currents and voltages (Power P, Q and S) are figured out as follows:

$$\overline{S} = \frac{\overline{Va}\cdot \overline{Ia}^{*}}{2} + \frac{\overline{Vb}\cdot \overline{Ib}^{*}}{2} + \frac{\overline{Vc}\cdot \overline{Ic}^{*}}{2}$$

where:

$P = Re(\overline{S})$ $Q = Im(\overline{S})$ and $S = \sqrt{P^2 + Q^2}$

Whereas if the relay is configured for **2 transformers** measuring VAB and VBC phase to phase voltages, the following calculations are made:

- Third phase to phase voltage calculation:

$$\overline{\mathrm{V}}\mathrm{ca} = -(\overline{\mathrm{V}}\mathrm{ab} + \overline{\mathrm{V}}\mathrm{bc})$$

And power calculation

$$\overline{\mathrm{S}} = \sqrt{3} \cdot \frac{\overline{\mathrm{U}}\mathrm{ab} \cdot \overset{*}{\overline{\mathrm{I}}}\mathrm{a}}{2} \cdot 1\angle -30^{o}$$

P, Q and S values are obtained as above.

For 3-transformer configuration, phase to phase as well as phase angle difference between current and phase to neutral voltage are calculated from phase to ground voltages.

For 2 transformer configuration, phase to ground voltages are calculated as follows:

Based on the fact that local source zero sequence impedance setting (ZSL_0) must be used, the following calculations are made:

- **V_0 Calculation:**

  Calculated from ZS_0 and zero sequence current I_0

  $$V_0 = -I_0 * ZS_0$$

  Real and imaginary parts are:

  $$Re(\mathrm{V}_0) = -\left[Re(\mathrm{I}_0) \cdot \mathrm{ZS}_0 \cdot cos(\mathrm{Arg\_ZS}_0) - Im(\mathrm{I}_0) \cdot \mathrm{ZS}_0 \cdot sen(\mathrm{Arg\_ZS}_0)\right]$$
  $$Im(\mathrm{V}_0) = -\left[Re(\mathrm{I}_0) \cdot \mathrm{ZS}_0 \cdot sen(\mathrm{Arg\_ZS}_0) + Im(\mathrm{I}_0) \cdot \mathrm{ZS}_0 \cdot cos(\mathrm{Arg\_ZS}_0)\right]$$

- **Calculation of Phase to Ground Voltages from Phase to Phase Voltages:**

  Phase to ground voltages are calculated from phase to phase voltages and zero sequence voltage

  B-phase voltage

  $$Re(\mathrm{V_B}) = \frac{3 \cdot Re(\mathrm{V}_0) - Re(\mathrm{V_{AB}}) + Re(\mathrm{V_{BC}})}{3}$$

  $$Im(\mathrm{V_B}) = \frac{3 \cdot Im(\mathrm{V}_0) - Im(\mathrm{V_{AB}}) + Im(\mathrm{V_{BC}})}{3}$$

  A-phase voltage

  $$Re(\mathrm{V_A}) = Re(\mathrm{V_{AB}}) + Re(\mathrm{V_B})$$
  $$Im(\mathrm{V_A}) = Im(\mathrm{V_{AB}}) + Im(\mathrm{V_B})$$

  C-phase voltage

  $$Re(\mathrm{V_C}) = Re(\mathrm{V_B}) - Re(\mathrm{V_{BC}})$$
  $$Im(\mathrm{V_C}) = Im(\mathrm{V_B}) - Im(\mathrm{V_{BC}})$$

The rest of calculated magnitudes (PF, Frequency and Energy) are calculated as usual and in the same way for 2 and 3 transformers.

3.22.7.a Information on Magnitudes with 2 or 3 Voltage Transformers

- **On display**

With 2 or 3 voltage transformers the following magnitudes are displayed:

- Phase, ground, sensitive ground and ungrounded neutral if applicable, all with their angles.
- Three sequence currents.
- Three phase voltages and synchronism voltage with their angles.
- Three phase to phase voltages.
- Power, power factor and frequency.
- Energy.

- **Oscillographic recording**

With 3 voltage transformers the following analog magnitudes are displayed:

- Three phase currents, one ground, one sensitive ground and ungrounded neutral or polarization current if applicable.
- Three phase to ground voltages and synchronism voltage.

With 2 transformers the same is saved, except that instead of three phase to ground voltages the two connected phase to phase voltages (Vab and Vbc) are saved.

- **Via communications**

Information on relay-measured magnitudes can be accessed through communication ports, no matter whether set to 2 or 3 transformers.

3.22.8 Ground Voltage Source

IRX-B relays do not incorporate a dedicated analog input **Vn** and so far work is always done through a calculated **Vn**. A new setting is added so as to operate with a different magnitude. With this new setting, the user can select between **Vsync** (analog voltage input used by the Synchronism Element) and the calculated **VN** (used by the Overvoltage Element or as polarizing voltage for the Ungrounded Directional Element).

Relays **2IRX-B**-****F1**** incorporate a new setting to operate with a different magnitude, whether **Vsync** for the Synchronism Element or **Vn** for the Overvoltage Element or as polarization voltage for the Ungrounded Directional Element.

For this, a new setting has been added to **General Settings** group. This setting is known as **Ground Voltage Source** and has two selectable options: **0=Vsync** and **1=Vn**. The default value is **0=Vsync**.

To select the **0=Vsync** option, the Ground Overvoltage elements must be disabled. Otherwise, changing the **V** type setting is not allowed.

To select the **1=Vn** option, the Synchronism Element must be disabled; this change will not be allowed when attempting to enable said element through the **0=Vsync** option.

In no case the change of setting will boot the relay.

3.22.9 General Settings

Unit In Service			
Setting	**Range**	**Step**	**Default**
Unit In Service	YES / NO		NO

Transformation Ratio			
Setting	**Range**	**Step**	**Default**
Phase CT Ratio	1 - 3000	1	1
Ground CT Ratio	1 - 3000	1	1
Sensitive Ground CT Ratio	1 - 3000	1	1
Polarizing CT Ratio	1 - 3000	1	1
Directional Ungrounded CT Ratio	1 - 3000	1	1
Phase VT Ratio	1 - 4000	1	1
Busbar VT Ratio	1 - 4000	1	1
Synchronism VT Ratio	1 - 4000	1	1

Phase Sequence			
Setting	**Range**	**Step**	**Default**
Phase Sequence	ABC / ACB		ABC

Number of VTs			
Setting	**Range**	**Step**	**Default**
Number of VTs	2 / 3		3

Transducers			
Setting	**Range**	**Step**	**Default**
Transducer Type	0: 0 - 5 mA 1: -2.5¸ +2.5 mA		-2.5¸ +2.5 mA

Event Mask (Via Communications)	
Event Mask	YES / NO

- **General Settings: HMI Access**

0 - CONFIGURATION	**0 - GENERAL**	**0 - UNIT IN SERVICE**
1 - OPERATIONS	1 - PROTECTION	**1 - PHASE CT RATIO**
2 - ACTIVATE GROUP	2 - RECLOSER	**2 - GND CT RATIO**
3 - CHANGE SETTINGS	3 - LOGIC	**3 - S.G. CT RATIO**
4 - INFORMATION	...	**4 - POL. CT RATIO**
		5 - PHASE VT RATIO
		6 - BUSBAR VT RATIO
		7 - PHASE SEQUENCE
		8 - NUMBER OF VT
		9 - TRANSDUCERS

0 - GENERAL	0 - UNIT IN SERVICE	
1 - PROTECTION	1 - PHASE CT RATIO	
2 - RECLOSER	2 - GND CT RATIO	
3 - LOGIC	3 - S.G. CT RATIO	
...	4 - POL. CT RATIO	
	5 - PHASE VT RATIO	
	6 - BUSBAR VT RATIO	
	7 - PHASE SEQUENCE	
	8 - NUMBER OF VT	
	9 - TRANSDUCERS	**0 - I1 TRANSDUCER TYPE**

3.23 Trip and Close Coil Circuit Supervision

3.23.1 Description

This 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. Up to three switching circuits can be monitored. Each of them can be set to both breaker positions (open and closed) or only to one of them.

This monitor function can generate three outputs: **Trip Circuit Supervision Failure** (**FAIL_SUPR**), **Switching Circuit Failure 2** (**FAIL_CIR2**) and **Switching Circuit Failure 3** (**FAIL_CIR3**), which the programmable logic can use to activate any of the IED's auxiliary contact outputs, also generating the corresponding events.

The three supervisions are treated separately as independent functions that can be independently set to enabled by means of a setting. Figure 3.23.1 is the block diagram showing the application in the situation of open breaker for two circuits with open and closed monitoring.

Notice that models without I/O expansion module; i.e. basic model, feature circuit supervision just for one coil.

3.23.2 Operation Mode

There are settings for supervising the state of three coils: Trip Coil, Coil 2 and Coil 3. Coils 2 and 3 may be trip or close. Hence their generic name. Nevertheless, one of the 3 coils is identified as trip coil because the activation of its corresponding **Trip Circuit Supervision Failure** (**FAIL_SUPR**) keeps the recloser from moving on to start a reclosure.

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).

Table 3.23-1 identifies the status contact inputs that must be used to monitor each of the circuits in **IRX** models in general.

Table 3.23-1: Configuration of Digital Inputs for Supervision

Monitored Circuit	Supervision in 2 states	Supervision in one state
Trip Coil	IN2	IN2
	IN3	-
Coil 2	IN10	IN10
	IN11	-
Coil 3	IN12	IN12
	IN13	-

All 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.

Moreover, to monitor the Trip Coil and Coil 2, a positive must be entered through terminal C13, and to monitor coil 3, a positive must be entered through terminal D12.

Each of the three 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 3.20.1 and explained in section 3.23.3. 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 used for this purpose (IN2, IN10 or IN12). 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.

Trip and Close Coil Circuit Supervision is not sensitive to the impedance of the circuits seen from the relay. Its operating principle is based on an injection of current pulses that allows detecting continuity in those circuits. Every second a pulse of 100ms is sent, monitoring that the current circulates though the circuit. Current will not circulate if the auxiliary contact is open or the coil circuit is open

3.23.3 Trip Coil Circuit

In the conditions of figure 3.23.1 (open breaker), current pulses are injected through inputs **IN2** and **IN3**.

Because **IN2** is connected to contact **52/b** (closed) current flows through it and this is detected. This current flowing means that the voltage on **IN2** (+) will correspond to the drop of voltage in the coil and then, a too low value to get it activated. Then, **IN2** will not be activated.

There is no current flowing through **IN3** as the contact **52/a** is open. Then, the voltage on **IN3** (+) will almost be the one available on the open circuit and therefore **IN3** will be activated.

Given that the supervision has been programmed for **Supervision in 2 states**, the μController in charge of the management of this supervisory function will send a “0” logic to the main μProcessor and this will set the **FAIL_SUPR** (**Trip Circuit Failure**) signal to “0” logic. In this situation it will be detected that the **IN2** digital input is deactivated and **IN3** is activated.

If the trip coil opens, the input that was deactivated, **IN2**, will activate and **IN3** will remain activated. After the configured reset time for trip circuit failure, the **Trip Circuit Failure** (**FAIL_SUPR**) signal will be given.

If a close or a reclosure occurs while the switching circuit is intact, once the command is executed, the state of the breaker and that of its **52/a** and **52/b** contacts changes. Consequently, the activation or deactivation of inputs **IN2** and **IN3** will invert and the **FAIL_SUPR** output will remain deactivated.

The purpose of the reset time is to compensate for the time gap between the closing of contact **52/a** and the opening of **52/b**. Generally, the **IN2** and **IN3** digital contacts do not change state simultaneously and, therefore, there will be a discordance between the two contacts. This will not modify the state of the **FAIL_SUPR** output as long as its duration is less than the set time.

If a trip occurs with the breaker closed and the breaker opens, inverting the state of contacts **52/a** and **52/b**, the **FAIL_SUPR** signal will not activate regardless of the duration of the trip command. If the breaker does not execute the command and the open command persists longer than the established reset time, the **FAIL_SUPR** signal will activate.

If the switching voltage disappears, the inputs that are energized will de-energize and this will activate both switching circuit failure outputs (**FAIL_SUPR**, **FAIL_CIR2** and **FAIL_CIR3**).

When the supervisory function of the trip coil (**FAIL_SUPR**) detects the rupture of the circuit and, consequently, the impossibility of tripping, the sending of close commands to the breaker through the IED should be impeded, manual as well as from the Recloser.

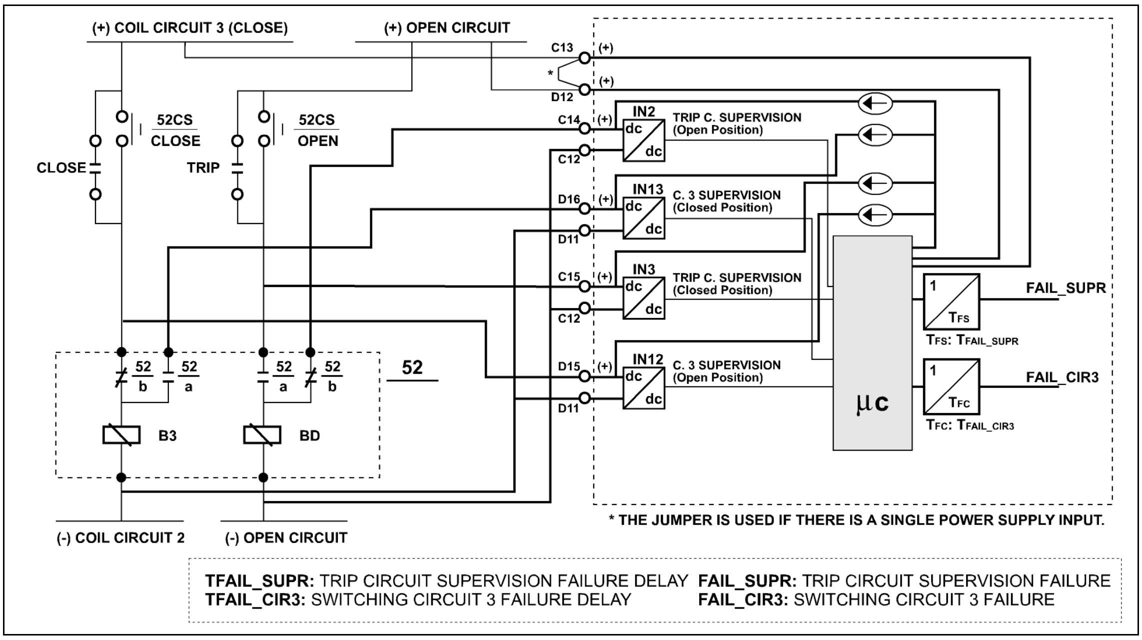


Figure 3.23.1 Trip/Close Coil Circuit Supervision Block Diagram (I).

3.23.4 Coil Circuits 2 and 3

The explanation given for the open circuit is valid for the circuits of coils 2 and 3, referring to a possible close coil and to the corresponding operating circuit and changing the open commands for close commands, or to a second trip coil. Moreover, for coils 2 and 3, the reset times for activating the failure output are independent of that indicated for the open circuit. The failure signal in the switching circuit is called **FAIL_CIR2** and **FAIL_CIR3**.

3.23.5 Trip and Close Coil Circuit Supervision Settings

Trip and Close Coil Circuit Supervision			
Setting	**Range**	**Step**	**Default**
Trip Coil Supervision	0: NO 1: One State 2: Two States		0: NO
Trip Coil Failure Delay	1 - 60 s	1 s	5 s
Coil 2 Circuit	0: NO 1: One State 2: Two States		0: NO
Coil 2 Failure Delay	1 - 60 s	1 s	5 s
Coil 3 Circuit	0: NO 1: One State 2: Two States		0: NO
Coil 3 Failure Delay	1 - 60 s	1 s	5 s

- **Trip and Close Coil Circuit Supervision: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP COIL**
1 - OPERATIONS	1 - PROTECTION	**1 - CIRCUIT 2 COIL**
2 - ACTIVATE GROUP	...	**2 - CIRCUIT 3 COIL**
3 - CHANGE SETTINGS	**5 - CIRCUIT COIL SUPERV**	**3 - TRIP COIL FAIL. DLY.**
4 - INFORMATION	...	**4 - CIR. 2 COIL FAIL.DLY**
		5 - CIR. 3 COIL FAIL.DLY

3.23.6 Digital Outputs and Events of the Trip/Close Coil Circuit Supervision Module

Table 3.23-2: Digital Outputs and Events of the Trip/Close Coil Circuit Supervision Module		
Name	**Description**	**Function**
FAIL_SUPR	Trip circuit supervision failure	They activate when an anomaly is detected in one or more of the switching circuits.
FAIL_CIR2	Switching circuit 2 failure	
FAIL_CIR3	Switching circuit 3 failure	

3.24 Breaker Monitoring

3.24.1 Description

In order to have adequate information for carrying out maintenance operations, the terminal logs up the current interrupted by the breaker associated to the same for each of the phases and accumulates the same as amp squared per second. The number thus stored represents the actual accumulated power interrupted by the breaker.

There is a magnitude known as “interrupted current” for each of the phases that stores the highest value of the current measured between a trip command or manual trip and the opening of the breaker. This magnitude is updated each time a trip or manual open command is issued; in case an Open Command Failure occurs, the magnitude is updated with the value 0.

In case of breaker openings external to the relay, the moment to write is the leading edge of signal **Breaker Status Input**: **Open (1)** / **Closed (0)**. Breaker opening current for this phase will also be the maximum measured current at that moment or **Inominal** value in case no measurement is being taken through the corresponding analog channel.

When a trip occurs, the relay operates as per the formula shown below for the calculation of KA^2sg value:

Accumulated KA^2sg = *(open current x transformation ratio)*^{2} *x opening time*

The values of all the implied variables are updated at the moment of the circuit breaker opening.

When a manual open command is issued, whether through the relay or through external means, the moment to write is the leading edge of signal **Breaker Status Input**: **Open (1)** / **Closed (0)**. Breaker opening current for this phase will also be the phase current interrupted or **Inominal** value in case no measurement is being taken through the analog channels. As for the opening time, an arbitrary value of 20ms is considered in this case.

Once the alarm setting value is reached, the function activates an alarm signal that can be used through the programmable output function to activate an output; also a record is written into the event record.

This function is controlled and monitored through two settings:

- Alarm level for accumulated squared amps.
- Actual accumulated squared amps.

This value is updated by the protection relay each time a trip occurs or the breaker opens, and can be modified manually. The last setting represents the starting value for the accumulated sum on top of which successive values corresponding to later openings will be summed. This manual modification allows taking into account the history of breaker openings before relay installation and is also used to reset the sum following a maintenance operation.

Manual modification is not made through a change in settings, as it is not a setting as such; the modification requires creating a command through the programmable logic.

3.24.2 Excessive Number of Trips

The purpose of Excessive Number of Trips function is to prevent the breaker from an uncontrolled number of open close operations that might damage the breaker. So that when a given number of operations is reached, settable from 1 to 100, during a fixed period of time (30 minutes), an output signal is generated that can be connected to any of the relay physical outputs.

Activation of **Excessive Number of Trips** function output disables new recloser shots, and brings the recloser to **Recloser Lockout Due to Open Breaker** state. This state will reset when a **Manual Close** command is issued or upon a loss of auxiliary power supply.

3.24.3 Breaker Monitoring Settings

Breaker Monitoring			
Setting	**Range**	**Step**	**Default**
Excessive Trips	1 - 40	1	40
I2 Sum Alarm x Seconds	0 - 99,999.99 kA^2s	0.01	99999.992188 kA^2
I2 Dropout Value x Seconds	0 - 99,999.99 kA^2s	0.01	0 kA^2

- **Breaker Monitoring: HMI Access**

0 - CONFIGURATION	0 - GENERAL	
1 - OPERATIONS	1 - PROTECTION	
2 - ACTIVATE GROUP	...	**0 - EXCESSIVE TRIPS**
3 - CHANGE SETTINGS	**4 - BREAKER SUPERV.**	**1 - I^2 SUM ALARM**
4 - INFORMATION	...	**2 - I^2 DROPOUT VALUE**
		3 - I^2 SUM ALARM

3.24.4 Digital Inputs of Breaker Monitoring Module

Table 3.24-1: Digital Inputs of Breaker Monitoring Module		
Name	**Description**	**Function**
RST_CUMI2	Accumulated I^2 reset command	Allows resetting accumulated I^2.

3.24.5 Digital Outputs and Events of Breaker Monitoring Module

Table 3.24-2: Digital Outputs and Events of Breaker Monitoring Module		
Name	**Description**	**Function**
EXC_NTRIP	Excessive number of trips	
AL_KA2	Accumulated I^2 alarm opened	
RST_CUMI2	Accumulated I^2 reset command	The same as for the Digital Inputs.

3.25 Power Supply Voltage Monitoring

3.25.1 Introduction

Models where the Input / Output digit for Model Selection shows that the relay is provided with an input voltage transducer (Sup. VDC), feature a DC Voltage Monitoring function for substation batteries.

Overvoltage and undervoltage condition alarms can be generated through said monitoring function, also allowing recording the evolution of said voltage when trips, closing and other control operations requiring power supply from the monitored batteries take place.

3.25.2 Operating Principle

As the measured battery voltage is relay power supply voltage, measurement is obtained through hard connection of said supply voltage to the input transducer arranged for voltage measurement, in parallel with the relay power supply voltage.

Two measurement elements are available, one overvoltage and the other undervoltage, which compare voltage measured through the transducer with pickup settings.

Elements pickup at 100% of setting and reset at 95% in case of overvoltage and 105% in case of undervoltage.

These elements are not provided with output timers; their activation / deactivation log the events and activate / deactivate the signals shown in table 3.25-1.

Output timers can be incorporated through the programmable logic in order to get the necessary logic function, such as obtaining a new signal as a result of gates AND or OR.

Signals obtained through this logic functions can generate their own events and trigger new actions (led activation, oscillograph starting,...).

When measured voltage is below 10Vdc, transducer power supply is considered unconnected and the oscillograph will not start on undervoltage nor will the event and signal activation corresponding to this undervoltage be generated.

No matter the model (power supply and digital input voltage range), Overvoltage and Undervoltage elements have only one setting (15Vdc to 300Vdc). Nevertheless, 24 Vdc and 48Vdc models will have a common measurement range and 125Vdc and 250Vdc models will have another. Measurement ranges for each of them are shown in Chapter 2.

A Log of said voltages can be saved into oscillographic records attached to each relay operation, logged into the events record, visualized locally or through communications channel and used for the generation of user logic functions in the “programmable logic”.

Note: this monitoring is only valid for direct current power supply, and if the relay works with alternating current power supply, the transducer shall not be connected to said power supply.

3.25.3 Power Supply Voltage Monitoring Settings

DC Power Monitoring			
Setting	**Range**	**Step**	**Default**
DC_OV Pickup	15 - 300 Vdc	0.1 V	300 V
DC_UV Pickup	15 - 300 Vdc	0.1 V	15 V

3.25.4 Auxiliary Outputs and Events of the Power Supply Voltage Monitoring

Table 3.25-1: Auxiliary Outputs and Events of the Power Supply Voltage Monitoring

Name	Description	Function
OVDC	Power supply overvoltage	These signals activate when relay power supply voltage exceeds battery voltage monitoring overvoltage or undervoltage element settings respectively.
UVDC	Power supply undervoltage	

3.26 Change Settings Groups

3.26.1 Description

The Protection, Logic and Recloser settings include four alternative groups (GROUP 1, GROUP 2, GROUP 3 and GROUP 4), 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 behaviour 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 inputs **INH_CGRP_COM** and **INH_CGRP_HMI** 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 (**CMD_GRP1_DI**).
- Command to activate Settings Group 2 by digital input (**CMD_GRP2_DI**).
- Command to activate Settings Group 3 by digital input (**CMD_GRP3_DI**).
- Command to activate Settings Group 4 by digital input (**CMD_GRP4_DI**).

Activating inputs **CMD_GRP1_DI**, **CMD_GRP2_DI**, **CMD_GRP3_DI** and **CMD_GRP4_DI** will activate GROUP 1, GROUP 2, GROUP 3 and GROUP 4 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 and T4 only if the display is in the default screen.

3.26.2 Digital Inputs to Change Settings Groups

Table 3.26-1: Digital Inputs to Change Settings Groups		
Name	**Description**	**Function**
INH_CGRP_COM	Inhibit group change via communications	It blocks any change of the active group by the PROCOME procedure.
INH_CGRP_HMI	Inhibit group change via HMI	It blocks any change of the active group through the HMI menu.
CMD_GRP1_COM	Command to activate Settings Group 1 via communications	Commands to change the active group.
CMD_GRP1_DI	Command to activate Settings Group 1 via DI	
CMD_GRP1_HMI	Command to activate Settings Group 1 via HMI	
CMD_GRP2_COM	Command to activate Settings Group 2 via communications	
CMD_GRP2_DI	Command to activate Settings Group 2 via DI	
CMD_GRP2_HMI	Command to activate Settings Group 2 via HMI	
CMD_GRP3_COM	Command to activate Settings Group 3 via communications	
CMD_GRP3_DI	Command to activate Settings Group 3 via DI	
CMD_GRP3_HMI	Command to activate Settings Group 3 via HMI	
CMD_GRP4_COM	Command to activate Settings Group 4 via communications	
CMD_GRP4_DI	Command to activate Settings Group 4 via DI	
CMD_GRP4_HMI	Command to activate Settings Group 4 via HMI	

3.26.3 Auxiliary Outputs and Events to Change Settings Groups

Table 3.26-2: Auxiliary Outputs and Events to Change Settings Groups

Name	Description	Function
INH_CGRP_COM	Inhibit group change via communications	The same as for the digital input.
INH_CGRP_HMI	Inhibit group change via HMI	The same as for the digital input.
CMD_GRP1_COM	Command to activate Settings Group 1 via communications	The same as for the digital inputs.
CMD_GRP1_DI	Command to activate Settings Group 1 via DI	
CMD_GRP1_HMI	Command to activate Settings Group 1 via HMI	
CMD_GRP2_COM	Command to activate Settings Group 2 via communications	
CMD_GRP2_DI	Command to activate Settings Group 2 via DI	
CMD_GRP2_HMI	Command to activate Settings Group 2 via HMI	
CMD_GRP3_COM	Command to activate Settings Group 3 via communications	
CMD_GRP3_DI	Command to activate Settings Group 3 via DI	
CMD_GRP3_HMI	Command to activate Settings Group 3 via HMI	
CMD_GRP4_COM	Command to activate Settings Group 4 via communications	
CMD_GRP4_DI	Command to activate Settings Group 4 via DI	
CMD_GRP4_HMI	Command to activate Settings Group 4 via HMI	
T1_ACTIVATED	Settings Group 1 activated	Indication of the active group.
T2_ACTIVATED	Settings Group 2 activated	
T3_ACTIVATED	Settings Group 3 activated	
T4_ACTIVATED	Settings Group 4 activated	

3.27 Event Record

3.27.1 Description

The capacity of the recorder is 400 notations in non-volatile memory. 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 3.27-1 -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 3.27-1: Event Record

Name	Description
HMI access	See the description in Auxiliary Outputs.
Clock synchronization	
IRIGB Active	
External oscillography trigger	
Oscillography picked up	
Deletion of oscillographs	
Open command	
Close command	
External trip control	
Trip by Protection	
Open Button 52	
Open Button P1	
Open Button P2	
Open Button P3	
Open Button P4	
Open Button P5	
Open Button P6	
Close Button 52	
Close Button P1	
Close Button P2	
Close Button P3	
Close Button P4	
Close Button P5	
Close Button P6	
Digital Input 1	
Digital Input 2	
Digital Input 3	
Digital Input 4	
Digital Input 5	
Digital Input 6	
Digital Input 7	
Digital Input 8	

Table 3.27-1: Event Record	
Name	**Description**
Digital Input 9	
Digital Input 10	
Digital Input 11	
Digital Input 12	
Digital Input 13	
Digital Input 14	
Digital Input 15	
Digital Input 16	
Digital Input 17	
Digital Input 18	
Digital Input 19	
Digital Input 10	
Digital Input 21	
Digital Input 22	
Digital Input 23	
Digital Input 24	
Digital Input 25 (*)	
Validity of Digital Input 1	
Validity of Digital Input 2	
Validity of Digital Input 3	
Validity of Digital Input 4	
Validity of Digital Input 5	
Validity of Digital Input 6	
Validity of Digital Input 7	
Validity of Digital Input 8	
Validity of Digital Input 9	
Validity of Digital Input 10	
Validity of Digital Input 11	
Validity of Digital Input 12	
Validity of Digital Input 13	
Validity of Digital Input 14	
Validity of Digital Input 15	
Validity of Digital Input 16	
Validity of Digital Input 17	
Validity of Digital Input 18	
Validity of Digital Input 19	
Validity of Digital Input 20	
Validity of Digital Input 21	
Validity of Digital Input 22	
Validity of Digital Input 23	
Validity of Digital Input 24	
Validity of Digital Input 25 (*)	
Auxiliary Output 1	
Auxiliary Output 2	
Auxiliary Output 3	
Auxiliary Output 4	

Table 3.27-1: Event Record

Name	Description
Auxiliary Output 5	See the description in Auxiliary Outputs.
Auxiliary Output 6	
Auxiliary Output 7	
Auxiliary Output 8	
Auxiliary Output 9	
Auxiliary Output 10	
Auxiliary Output 11	
Auxiliary Output 12 (*)	
Input of breaker position: Open (1) / Closed (0)	
LEDs reset input	
Power meters reset input	
Maximeters reset command	
Indicator of current in the line	
Current detected with open breaker status	
Cold load pickup of IED	
Manual reinitialization of the IED	
Change of settings initialization	
Port 0 communication failure	
Port 1 communication failure	
Port 2 communication failure	
Port 3 communication failure	
Remote	
Local Control	
Panel-controlled	
Critical system error	
Non-critical system error	
System event	
Equipment warm start up	
Maximeters reset input	
Distance to the fault reset input	
Reset pending reconfiguration (**)	
Write to flash in progress (**)	
SNTP not synchronized (**)	
Status of communications port LAN1 (**)	
Status of communications port LAN2 (**)	
Communications port LAN active (bonding) (**)	
Network congestion detected in LAN1 (**)	
Network congestion detected in LAN2 (**)	

(*) The number of Digital Inputs and Auxiliary Outputs available will depend on each particular model
(**) 2IRX-*6*-******* Models.**

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.

3.27.2 Organization of the Event Record

The event record capacity is 400 events. When the record is full, a new event displaces the oldest one. 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.

3.27.3 Event Mask

Use the **General** settings in communications to mask unneeded or unused events for system behaviour analysis. Events are masked by communications within the **General** settings.

Important: Events that can be generated in excess should be masked since they could fill the memory (400 events) and erase more important previous events.

3.27.4 Consulting the Record

The communications and remote management program, ***ZivercomPlus***®, has a completely decoded system for consulting the Event Record.

3.27.5 Event Record Settings (via communications)

Events Mask
IED events may be masked separately

Event Magnitudes				
Up to 12 different magnitudes may be selected to be annotated with each equipment event. Said magnitudes are:				
ACTGRP	HARM4 IA	IG	PMAX	VB
ALARMS	HARM4 VA	IGN	PMIN	VBC
ALL RECLOSING	HARM5 IA	IMAX	POS SEQ	VC
CUMULATIVE kA^2	HARM5 VA	IMIN	POS SEQ	VCA
DIST	HARM6 IA	IPOL	Q	VDC
DISTk	HARM6 VA	ISG	QMAX	VG
DISTm	HARM7 IA	N.A.ENGY	QMIN	VMAX
FAULTT	HARM7 VA	N.R.ENGY	ROC FREQ	VMIN
FIRST RECLOSING	HARM8 IA	NEG SEQ	S	VSYNC
FREQ	HARM8 VA	NEG SEQ	SMAX	ZERO SEQ I
FREQ SYNC	IA	Null	SMIN	ZERO SEQ V
HARM2 IA	IAB	OPENC	THERMAL IMG	
HARM2 VA	IB	P	TRANSDUCER C1	
HARM3 IA	IBC	P.Active Energy	VA	
HARM3 VA	IC	P.React.Energy	VAB	
	ICA	PF		

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.

3.28 Fault Reports

3.28.1 Introduction

The terminal incorporates Fault Reports register, which stores the most relevant information about last 15 faults cleared by the IED. Access to this information is available through the communication ports. The information stored in each fault report is listed below:

Models **2IRX-***-****F0**** have a setting to display primary or secondary values (Refer to the chapter Logic).

3.28.2 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, ground, sensitive ground and ungrounded neutral current if there is one, and of the measured voltages (phase and line, depending on the model)) 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 line-to-neutral voltages are recorded with their arguments.

- **Elements picked up** (depending on the model) for full fault duration.

3.28.3 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, ground, sensitive ground and ungrounded neutral current if there is one and of the measured voltages (phase and line, depending on the model) two and a half sequences 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 line-to-neutral voltages are recorded with their arguments.

- **Elements tripped** (depending on the model).
- **Distance to the fault and type of fault** (single-phase, two-phase, etc.)

3.28.4 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.

- **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 line length (%).
- **Thermal State**.
- **Breaker opening current** per phase.
- **Accumulated by time** KA^{2}sg.

3.29 Metering History Log

3.29.1 Operation

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 3.29.1 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.

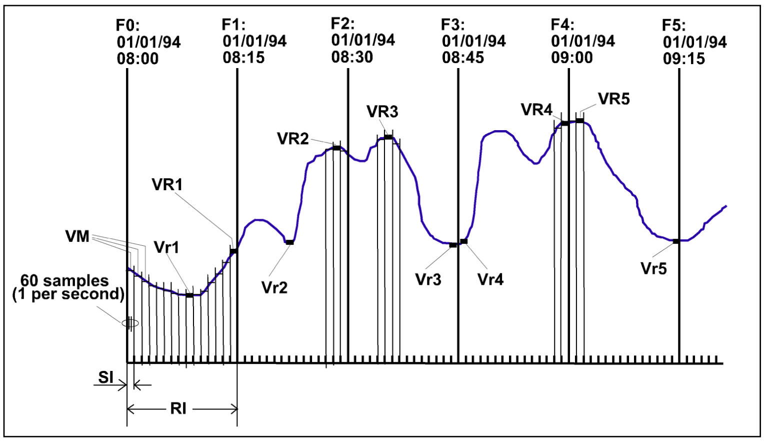


Figure 3.29.1 Explanatory Diagram of the Metering Log.

There are 12 History Log Groups. For each of those 12 values, up to **4 different metering** values can be selected.

Each **TM** 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 3.29.1). Maximum and minimum value of all maximum and minimum group **VMs** computed are stored and shown in each **TR** interval. The profile of figure 3.29.1 yields the following values: VR1 - Vr1; VR2 - Vr2; VR3 - Vr3; VR4 - Vr4 and VR5 - Vr5.

Note: if phase or ground 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 3.29.2.

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.

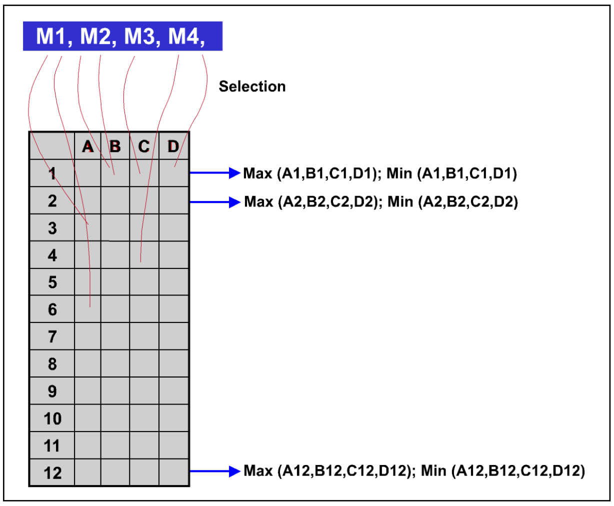


Figure 3.29.2 Metering History Log Logic.

The memory available for the metering log is RAM, large enough for 168 values. 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 ***ZivercomPlus***®.

3.29.2 Metering History Log Settings

Metering History Log			
Setting	**Range**	**Step**	**Default**
Sampling Interval	1 - 15 min	1	1 min
Recording Interval	00.00 to 24:00		00:01
Week Mask	Monday to Sunday	YES / NO	YES
Recording Start Time	00.00 to 24:00		00.00
Recording End Time	00.00 to 24:00		24:00

Log Groups				
There are 12 Log Groups. Up to 4 different magnitudes may be defined within each group for historical record calculations. Said magnitudes are:				
ACTGRP	HARM4 IA	IG	PMAX	VB
ALARMS	HARM4 VA	IGN	PMIN	VBC
ALL RECLOSING	HARM5 IA	IMAX	POS SEQ	VC
CUMULATIVE kA^2	HARM5 VA	IMIN	POS SEQ	VCA
DIST	HARM6 IA	IPOL	Q	VDC
DISTk	HARM6 VA	ISG	QMAX	VG
DISTm	HARM7 IA	N.A.ENGY	QMIN	VMAX
FAULTT	HARM7 VA	N.R.ENGY	ROC FREQ	VMIN
FIRST RECLOSING	HARM8 IA	NEG SEQ	S	VSYNC
FREQ	HARM8 VA	NEG SEQ	SMAX	ZERO SEQ I
FREQ SYNC	IA	Null	SMIN	ZERO SEQ V
HARM2 IA	IAB	OPENC	THERMAL IMG	
HARM2 VA	IB	P	TRANSDUCER C1	
HARM3 IA	IBC	P.Active Energy	VA	
HARM3 VA	IC	P.React.Energy	VAB	
	ICA	PF		

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.

- **Metering History Log: HMI Access**

0 - CONFIGURATION	0 - GENERAL	**0 - SAMPLE INTERVAL**
1 - OPERATIONS	1 - PROTECTION	**1 - LOG REC. INTERVAL**
2 - ACTIVATE GROUP	...	**2 - HIST. START TIME**
3 - CHANGE SETTINGS	**6 - HISTORY**	**3 - HIST. END TIME**
4 - INFORMATION	...	

3.30 Oscillographic Recording

3.30.1 Introduction

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.

The sampling and storage frequency is 32 samples per cycle with 750 cycles of total storage. Permanence of the information, with the IED disconnected from the power supply, is guaranteed during 28 days at 25º (except for models with long term oscillography where 15 days at 25º are guaranteed).

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.

3.30.2 Capture Function

It is possible to record measured analog values, user defined values, 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.

3.30.3 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.

3.30.4 Number of Channels and Digital Signals

Depending on the model is possible to record up to 15 analog values, enabling or disabling them via independent settings.

It is possible to include up to 5 user defined values. User defined values are every calculated value including those values calculated by the programmable logic via ***ZivercomPlus***®software.

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.

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 recorded digital signals is 80. Each user defined value configured in the Oscillography counts as 16 digital signals.

3.30.5 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**.

3.30.6 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.).

3.30.7 Trip Required

Data are stored only if a trip occurs within the time configured as Oscillography record length.

3.30.8 Concatenation Stream Mode

The **YES** / **NO** setting allow 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.

3.30.9 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 25 pre-fault cycles.

3.30.10 Length of the Oscillograph

It is the fault record duration. 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 waveform records is 64, and the maximum number of cycles that can be stored in memory is 725. Depending on the length selected, the maximum number varies.

Set number of cycles	Max. number of oscillographs
725	1
350	2
175	3
...	...
22	32
11	64

Note 1: when selecting the length of each oscillograph, it is important to take into account that if, for example, an oscillography record length greater than 350 cycles is selected, only one oscillograph can be stored.
Note 2: modifying settings belonging to the oscillography recording or loading a programmable logic configuration will erase all the oscillography files recorded in the IED.

3.30.11 Interval between Triggers

This 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.

3.30.12 Oscillography Settings

Oscillography			
Setting	**Range**	**Step**	**Default**
Trip Required	YES / NO		YES
Continuous Mode	YES / NO		NO
Pre-Fault Recording Length	0 - 25 cycles	1	5
Post-Fault Recording Length	5 - 725 cycles	1	5
Interval between Triggers	1 - 725 cycles	1	4

Trigger Mask		
Setting	**Step**	**Default**
Phase Instantaneous Overcurrent (50PH1, 50PH2 and 50PH3)	YES / NO	NO
Phase Time Overcurrent (51PH1, 51PH2 and 51PH3)	YES / NO	NO
Ground Instantaneous Overcurrent (50G1, 50G2 and 50G3)	YES / NO	NO
Ground Time Overcurrent (51G1, 51G2 and 51G3)	YES / NO	NO
Negative Sequence Instantaneous Overcurrent (50NS1 and 50NS2)	YES / NO	NO
Negative Sequence Time Overcurrent (51NS1, 51NS2 and 50NS3)	YES / NO	NO
Sensitive Ground Instantaneous Overcurrent (50SG)	YES / NO	NO
Sensitive Ground Time Overcurrent (51SG)	YES / NO	NO
Voltage Restrained Time Overcurrent (51V)	YES / NO	NO
Directional Ungrounded (67NA)	YES / NO	NO
Open Phase	YES / NO	NO
Residual Current Element	YES / NO	NO
Phase Overvoltage (59PH1, 59 PH2 and 59 PH3)	YES / NO	NO
Phase Undervoltage (27 PH1, 27 PH2 and 27 PH3)	YES / NO	NO
Ground Overvoltage (59N1 and 59N2 or 64_1 and 64_2)	YES / NO	NO
Negative Sequence Overvoltage (47)	YES / NO	NO
Overfrequency (81M1, 81M2, 81M3 and 81M4)	YES / NO	NO
Underfrequency (81m1, 81m2, 81m3 and 81m4)	YES / NO	NO
Frequency Rate of Change (81D1, 81D2, 81D3 and 81D4)	YES / NO	NO
Thermal Image (49)	YES / NO	NO
Directional Power (32P/Q1 and 32P/Q2)	YES / NO	NO
Restricted Earth Faults (87N)	YES / NO	NO
Out of Step (78)	YES / NO	NO
Programmable Trip (configurable in the programmable logic)	YES / NO	NO
External Trigger	YES / NO	YES
Power Supply Undervoltage	YES / NO	NO
Power Supply Overvoltage	YES / NO	NO

Analog Channel Mask (maximum 10 channels)	
1 - Phase A Current	7 - Phase A Voltage
2 - Phase B Current	8 - Phase B Voltage
3 - Phase C Current	9 - Phase C Voltage
4 - Ground Current (depending on model)	10 - Ground Voltage (depending on model)
5 - Sensitive Ground Current (depending on model)	11 - Synchronism Voltage
6 - Ungrounded Neutral Current (depending on model)	

User Defined Values (Up to 5 values)				
ACTGRP	HARM4 IA	IG	PMAX	VB
ALARMS	HARM4 VA	IGN	PMIN	VBC
ALL RECLOSING	HARM5 IA	IMAX	POS SEQ	VC
CUMULATIVE kA^2	HARM5 VA	IMIN	POS SEQ	VCA
DIST	HARM6 IA	IPOL	Q	VDC
DISTk	HARM6 VA	ISG	QMAX	VG
DISTm	HARM7 IA	N.A.ENGY	QMIN	VMAX
FAULTT	HARM7 VA	N.R.ENGY	ROC FREQ	VMIN
FIRST RECLOSING	HARM8 IA	NEG SEQ	S	VSYNC
FREQ	HARM8 VA	NEG SEQ	SMAX	ZERO SEQ I
FREQ SYNC	IA	Null	SMIN	ZERO SEQ V
HARM2 IA	IAB	OPENC	THERMAL IMG	
HARM2 VA	IB	P	TRANSDUCER C1	
HARM3 IA	IBC	P.Active Energy	VA	
HARM3 VA	IC	P.React.Energy	VAB	
	ICA	PF		

Note: each User Defined value configured in the Oscillography counts as 16 digital signals

Digital Channel Selection (maximum 80)
Selectable from all configurable Digital Inputs and Digital Signals

- ## Oscillographic Recording: HMI Access

0 - CONFIGURATION	0 - GENERAL	**0 - TRIP REQUIRED**
1 - OPERATIONS	1 - PROTECTION	**1 - CONTINUOUS MODE**
2 - ACTIVATE GROUP	...	**2 - PRETRIG. LENGTH**
3 - CHANGE SETTINGS	**7 - OSCILLOGRAPHY**	**3 - LENGTH**
4 - INFORMATION	...	**4 - TRIGGERS INTERVAL**
		5 - OSCILLO CHANN. MASK

3.30.13 Digital Inputs of the Oscillographic Recording

Table 3.30-1: Digital Inputs of the Oscillographic Recording		
Name	**Description**	**Function**
TRIG_EXT_OSC	External oscillography trigger	Input intended for external triggering.
DEL_OSC	Deletion of oscillographs	The activation of this input deletes all the oscillographs stored.
ENBL_OSC	Oscillographic recording enable input	Activation of this input puts the element into service. The default value of this logic input signal is a “1.”

3.30.14 Auxiliary Outputs and Events of the Oscillographic Recording

Table 3.30-2: Auxiliary Outputs and Events of the Oscillographic Recording		
Name	**Description**	**Function**
TRIG_EXT_OSC	External oscillography trigger	The same as for the digital input.
PU_OSC	Oscillography picked up	This output indicates that the oscillographic recording is on process.
DEL_OSC	Deletion of oscillographs	The same as for the digital input.
ENBL_OSC	Oscillographic recording enable input	Activation of this input puts the element into service. The default value of this logic input signal is a “1.”
OSC_ENBLD	Oscillographic recording enabled	Indication of enabled or disabled status of the element.

3.31 Inputs, Outputs & LED Targets

3.31.1 Introduction

The **IRX** has a flexible, user-definable structure of **Inputs** / **Outputs** / **LEDs**. It is described in the following sections. Factory programming included default values. Settings can be changed using the software package ***ZivercomPlus***®.

3.31.2 Digital Inputs

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

The **Filtering** of the digital inputs can be configured with the following options:

- **Time between Samplings Filter 1** (**2-10 ms**): to establish the periodicity with which samples of the state of a digital input are taken.
- **Number of Samples with the same Value to Validate a Filter-1 Input** (**1-10**): the number of samples that must be detected consecutively to consider an input deactivated or activated can be set to logical "0" or "1" respectively.
- **Time between Samplings Filter 2** (**2-10 ms**): to establish the periodicity with which samples of the state of a digital input are taken.
- **Number of Samples with the same Value to Validate a Filter-2 Input** (**1-10**): The number of samples that must be detected consecutively to consider an input deactivated or activated can be set to logical "0" or "1" respectively.
- **Filter Assignation** (**Filter 1 / Filter 2**): Each configurable digital input can be assigned to "filter 1" or to "filter 2." The settings previously defined allow constructing filters 1 and 2 to create fast and slow detection inputs.
- **Number of Changes to Deactivate an Input and its Time Slot** (**2-60/1-30s**): an adjustable time slot is established to keep a digital input in which there is an external or internal malfunction to the relay from generating problems. This time slot monitors the number of times that this digital input changes condition. If this number of changes in state exceeds a set value, is disabled and the input keep on quite at its last status. Once an input is disabled, it will be enabled again when the enabling conditions are met or by an enabling command.
- **Number of Changes to Enable an Input and its Time Slot**: as for disabling, to enable an input again, there is also a time slot and a user-definable number of changes within that slot.

The IED's metering elements and logic functions use **Logic Input Signals** in their operation. They are enumerated in the tables nested in the description of each of them. Those corresponding to the IED's general services are listed in table 3.31-1 and can be assigned to the **Physical Digital Inputs** or to logic output signals of opcodes configured in the programmable logic. More than one **Logic Input Signal** can be assigned to a **Single Status Contact Input**, but the same logic input signal cannot be assigned to more than one status contact 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 creates).

3.31.2.a Enable Input

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).

This logic input signal is called **Enable Input…**. It combines with the **In Service** setting in this algorithm.

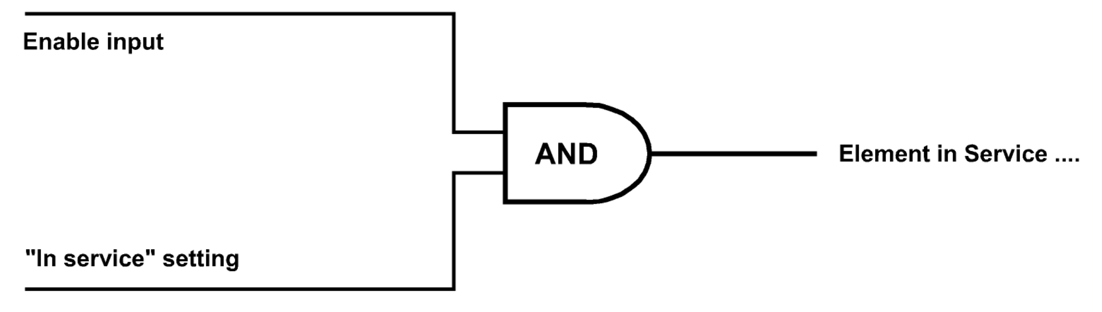


Figure 3.31.1 Element Enable Logic.

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, etc.).

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.

3.31.2.b Digital Inputs Settings

Digital Inputs			
Setting	**Range**	**Step**	**Default**
Time Between Samples (Filter 1)	2 - 10 ms	2	6 ms
Time Between Samples (Filter 2)	2 - 10 ms	2	6 ms
Number of Samples to Validate Changes (Filter 1)	1 - 10 samples	1	2 samples
Number of Samples to Validate Changes (Filter 2)	1 - 10 samples	1	2 samples
Filter Assignation (independent setting for each DI)	0 = Filter 1 1 = Filter 2		0 = Filter 1
Number of Changes to Disable	2 - 60 changes	1	5 changes
Time to Disable	1 - 30 s	1	2 s
Number of Changes to Enable	2 - 60 changes	1	5 changes
Time to Enable	1 - 30 s	1	2 s
Number of Digital Inputs for Supply Voltage Supervision	0 - 18 (*)	1	0
EDs Supply Voltage Control	0 = NO 1 = YES	1	0
EDs Supply Voltage Level	0 = 24 1= 48 2 = 125 3 = 125(>65%) 4= 250	1	24
Automatic ED disable (independent for each IED digital input)	0 = NO 1 = YES	1	1

(*) The total number of Digital Inputs depends on model.

3.31.2.c Digital Inputs Table

Table 3.31-1: Digital Inputs		
Name	**Description**	**Function**
CEXT_TRIP	External trip control	It blocks all trips.
IN_BKR	Input of breaker position: Open (1) / Closed (0)	It monitors breaker status.
IN_RST_MAX	Maximeters reset	Its activation sets the content of the current, voltage and power demand elements to zero.
IN_RST_DIS	Input of distance to the fault reset	Its activation sets the value of the distance to the fault sent via communications to zero.
IN_PMTR_RST	Power meters reset	Its activation sets the content of the power meters to zero.
ENBL_PLL	Digital PLL input enable	Enables the operation of the automatic system to adapt to the frequency. By default, when not configured, it is a logic “1.”

Table 3.31-1: Digital Inputs		
Name	**Description**	**Function**
LED_1	LED 1	They activate their corresponding LEDs.
LED_2	LED 2	
LED_3	LED 3	
LED_4	LED 4	
LED_5	LED 5	
LED_6	LED 6	
LED_7	LED 7	
LED_8	LED 8	
CMD_DIS_DI1	Command to disable digital input 1	Inputs to the module of digital inputs that activate and deactivate each of the digital inputs.
CMD_DIS_DI2	Command to disable digital input 2	
CMD_DIS_DI3	Command to disable digital input 3	
CMD_DIS_DI4	Command to disable digital input 4	
CMD_DIS_DI5	Command to disable digital input 5	
CMD_DIS_DI6	Command to disable digital input 6	
CMD_DIS_DI7	Command to disable digital input 7	
CMD_DIS_DI8	Command to disable digital input 8	
CMD_DIS_DI9	Command to disable digital input 9	
CMD_DIS_DI10	Command to disable digital input 10	
CMD_DIS_DI11	Command to disable digital input 11	
CMD_DIS_DI12	Command to disable digital input 12	
CMD_DIS_DI13	Command to disable digital input 13	
CMD_DIS_DI14	Command to disable digital input 14	
CMD_DIS_DI15	Command to disable digital input 15	
CMD_DIS_DI16	Command to disable digital input 16	
CMD_DIS_DI17	Command to disable digital input 17	
CMD_DIS_DI18	Command to disable digital input 18 (*)	
REMOTE	Remote	Sets the relay in remote mode. Must be activated to enable DNP 3.0 commands.
LOCAL	Local Control	Means 'Local Commands' enabled, whose performance is defined in user's logic module.
CONTROL_PANEL	Operation Desk control	Means 'Operation Desk Commands' enabled, whose performance is defined in user's logic module.

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3. 31-1: Digital Inputs		
Name	**Description**	**Function**
CMD_ENBL_DI1	Command to enable digital input 1	Inputs to the module of digital inputs that activate and deactivate each of the digital inputs.
CMD_ENBL_DI2	Command to enable digital input 2	
CMD_ENBL_DI3	Command to enable digital input 3	
CMD_ENBL_DI4	Command to enable digital input 4	
CMD_ENBL_DI5	Command to enable digital input 5	
CMD_ENBL_DI6	Command to enable digital input 6	
CMD_ENBL_DI7	Command to enable digital input 7	
CMD_ENBL_DI8	Command to enable digital input 8	
CMD_ENBL_DI9	Command to enable digital input 9	
CMD_ENBL_DI10	Command to enable digital input 10	
CMD_ENBL_DI11	Command to enable digital input 11	
CMD_ENBL_DI12	Command to enable digital input 12	
CMD_ENBL_DI13	Command to enable digital input 13	
CMD_ENBL_DI14	Command to enable digital input 14	
CMD_ENBL_DI15	Command to enable digital input 15	
CMD_ENBL_DI16	Command to enable digital input 16	
CMD_ENBL_DI17	Command to enable digital input 17	
CMD_ENBL_DI18	Command to enable digital input 18 (*)	
DO_1	Digital output 1	They activate their corresponding outputs.
DO_2	Digital output 2	
DO_3	Digital output 3	
DO_4	Digital output 4	
DO_5	Digital output 5	
DO_6	Digital output 6	
DO_7	Digital output 7 (*)	

(*)The number of digital inputs and digital outputs available will depend on each particular model.

3.31.3 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.

The IED's metering elements and logic functions generate a series of logic output signals. Each of these signals has either a “true” or “false” value and this status can be used as an input to either of the combinational logic gates shown in figure 3.31.2. The use of the combinational logic gates described in figure is optional. Its purpose is to facilitate the simplest configurations. To develop more complex algorithms and be able to assign the resulting outputs to auxiliary contact outputs, the necessary opcodes must be programmed in the programmable logic.

The outputs from the blocks described in figure 3.31.2 can be connected to one of the programmable auxiliary contact outputs in the IED. There is an additional, non-programmable auxiliary output contact corresponding to relay **In Service**.

Two blocks of eight inputs are available. One of the blocks performs an **OR** operation with the selected signals (any signal activates the logic gate output). The other block performs an **AND** operation with the selected signals (all signals need to be active to activate the logic gate output). The result of these two blocks is then operated through either an **AND** or an **OR** gate. The pulse option can be added to the result of this operation. It works as follows:

- **Without Pulses**: by adjusting the pulse timer to 0, the output signal remains active as long as the signal that activated it lasts.
- **With Pulses**: once the output signal is activated, it remains the set time whether or not the signal that generated it is deactivated before or remains active.

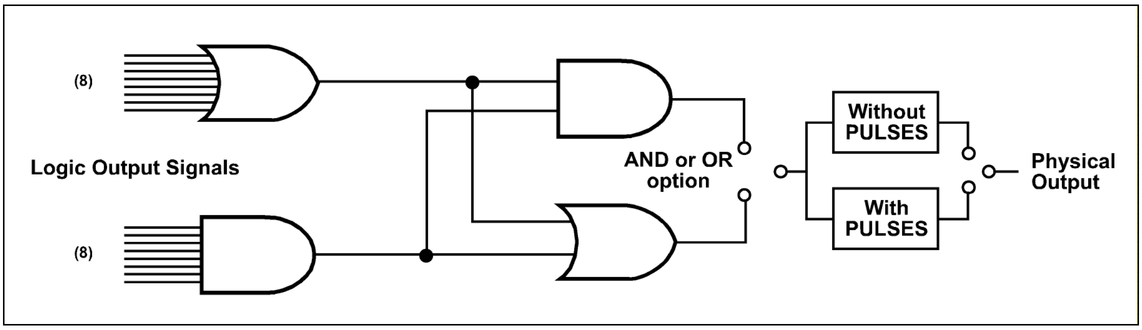


Figure 3.31.2 Auxiliary Contact Output Logic Cell Block Diagram.

All the logic output signals listed in the tables nested in the description of each of the elements are user-definable. Moreover, the signals indicated in Table 3.31-2, all corresponding to the IED's general services, can also be assigned.

The tables mentioned only list the logical outputs available with the default configuration. The list of signals can be expanded with those configured in the programmable logic (any logic signal created in the programmable logic can be used with the description that the user creates).

3.31.3.a Auxiliary Outputs Table

Table 3.31-2: Auxiliary Outputs		
Name	**Description**	**Function**
ACCESS_HMI	HMI access	Indication that the HMI has been accessed.
SYNC_CLK	Clock synchronization	Indication of having received a date / time change.
UN_ACT	Any element activated	They indicate that any protection element is picked up.
UN_PU	Any element picked up	
OPEN_CMD	Open command	Commands that go to the relay's trip and close contacts.
CLOSE	Close command	
RST_IND_TRIP	Reset command of trip indication	When activated, it deletes the information about the last trip the relay has stored, thus also cleaning the display.
CEXT_TRIP	External trip control	The same as for the digital input.
ACT_PROT	Trip by protection	Signal indicating that the open / close command issued by the IED comes from the trip / close of some protection element.
B_OPEN	Open button	They indicate that the corresponding button has been pressed.
B_CLS	Close button	
B_BLOCK	Blocking / Unblocking button	
IN_1	Digital input 1	They indicate that the corresponding input has been activated.
IN_2	Digital input 2	
IN_3	Digital input 3	
IN_4	Digital input 4	
IN_5	Digital input 5	
IN_6	Digital input 6	
IN_7	Digital input 7	
IN_8	Digital input 8	
IN_9	Digital input 9	
IN_10	Digital input 10	
IN_11	Digital input 11	
IN_12	Digital input 12	
IN_13	Digital input 13	

Table 3.31-2: Auxiliary Outputs		
Name	**Description**	**Function**
IN_14	Digital input 14	They indicate that the corresponding input has been activated.
IN_15	Digital input 15	
IN_16	Digital input 16	
IN_17	Digital input 17	
IN_18	Digital input 18 (*)	
VAL_DI_1	Validity of digital input 1	They indicate whether the input has been enabled or disabled.
VAL_DI_2	Validity of digital input 2	
VAL_DI_3	Validity of digital input 3	
VAL_DI_4	Validity of digital input 4	
VAL_DI_5	Validity of digital input 5	
VAL_DI_6	Validity of digital input 6	
VAL_DI_7	Validity of digital input 7	
VAL_DI_8	Validity of digital input 8	
VAL_DI_9	Validity of digital input 9	
VAL_DI_10	Validity of digital input 10	
VAL_DI_11	Validity of digital input 11	
VAL_DI_12	Validity of digital input 12	
VAL_DI_13	Validity of digital input 13	
VAL_DI_14	Validity of digital input 14	
VAL_DI_15	Validity of digital input 15	
VAL_DI_16	Validity of digital input 16	
VAL_DI_17	Validity of digital input 17	
VAL_DI_18	Validity of digital input 18 (*)	
CMD_DIS_DI1	Command to disable digital input 1	The same as for the digital inputs.
CMD_DIS_DI2	Command to disable digital input 2	
CMD_DIS_DI3	Command to disable digital input 3	
CMD_DIS_DI4	Command to disable digital input 4	
CMD_DIS_DI5	Command to disable digital input 5	
CMD_DIS_DI6	Command to disable digital input 6	
CMD_DIS_DI7	Command to disable digital input 7	
CMD_DIS_DI8	Command to disable digital input 8	

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3.31-2: Auxiliary Outputs		
Name	**Description**	**Function**
CMD_DIS_DI9	Command to disable digital input 9	The same as for the digital inputs.
CMD_DIS_DI10	Command to disable digital input 10	
CMD_DIS_DI11	Command to disable digital input 11	
CMD_DIS_DI12	Command to disable digital input 12	
CMD_DIS_DI13	Command to disable digital input 13	
CMD_DIS_DI14	Command to disable digital input 14	
CMD_DIS_DI15	Command to disable digital input 15	
CMD_DIS_DI16	Command to disable digital input 16	
CMD_DIS_DI17	Command to disable digital input 17	
CMD_DIS_DI18	Command to disable digital input 18 (*)	
CMD_ENBL_DI1	Command to enable digital input 1	The same as for the digital inputs.
CMD_ENBL_DI2	Command to enable digital input 2	
CMD_ENBL_DI3	Command to enable digital input 3	
CMD_ENBL_DI4	Command to enable digital input 4	
CMD_ENBL_DI5	Command to enable digital input 5	
CMD_ENBL_DI6	Command to enable digital input 6	
CMD_ENBL_DI7	Command to enable digital input 7	
CMD_ENBL_DI8	Command to enable digital input 8	
CMD_ENBL_DI9	Command to enable digital input 9	
CMD_ENBL_DI10	Command to enable digital input 10	
CMD_ENBL_DI11	Command to enable digital input 11	
CMD_ENBL_DI12	Command to enable digital input 12	
CMD_ENBL_DI13	Command to enable digital input 13	
CMD_ENBL_DI14	Command to enable digital input 14	
CMD_ENBL_DI15	Command to enable digital input 15	
CMD_ENBL_DI16	Command to enable digital input 16	
CMD_ENBL_DI17	Command to enable digital input 17	
CMD_ENBL_DI18	Command to enable digital input 18 (*)	
DO_1	Digital output 1	The same as for the digital inputs.
DO_2	Digital output 2	
DO_3	Digital output 3	
DO_4	Digital output 4	

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3.31-2: Auxiliary Outputs		
Name	**Description**	**Function**
DO_5	Digital output 5	The same as for the digital inputs.
DO_6	Digital output 6	
DO_7	Digital output 7 (*)	
LED_1	LED 1	The same as for the digital inputs.
LED_2	LED 2	
LED_3	LED 3	
LED_4	LED 4	
LED_5	LED 5	
LED_6	LED 6	
LED_7	LED 7	
LED_8	LED 8	
IN_BKR	Input of breaker position: Open (1) / Closed (0)	The same as for the digital inputs.
IN_RST_LED	LEDs reset input	Resets the LEDs that are active because they are memorized.
IN_PMTR_RST	Power meters reset input	The same as for the digital input.
IN_RST_MAX	Maximeters reset	Its activation sets the content of the current, voltage and power demand elements to zero.

(*)The number of digital inputs and digital outputs available will depend on each particular model.

Table 3.31-2: Auxiliary Outputs		
Name	**Description**	**Function**
IN_RST_DIS	Input of distance to the fault reset	Its activation sets the value of the distance to the fault sent via communications to zero.
ENBL_PLL	Digital PLL input enable	The same as for the digital input.
CUR_LINE	Indicator of current in the line	It is activated when some of the phase currents are higher than 0.1 A.
RST_MAN	Manual reinitialization of the relay	It is marked whenever the IED is reset manually.
PU_CLPU	Cold load pickup of relay	It is marked whenever the IED is energized.
PU_WLPU	Warm pickup of relay	It is activated after any reset (configuration loading, manual reset,…), while remaining de device powered-up.
INIT_CH_SET	Change of settings initialization	It is indicated when some setting is modified.
FAIL_COM_L	Port 0 communication failure	They activate when no communication port activity is detected during the set time.
FAIL_COM_R1	Port 1 communication failure	
FAIL_COM_R2	Port 2 communication failure	
FAIL_COM_R3	Port 3 communication failure	
REMOTE	Remote	Sets the relay in remote mode. Must be activated to enable DNP 3.0 commands.
LOCAL	Local Control	Means 'Local Commands' enabled, whose performance is defined in user's logic module.
CONTROL_PANEL	Operation Desk control	Means 'Operation Desk Commands' enabled, whose performance is defined in user's logic module.
ERR_CRIT	Critical system error	They note that some technical problem has cropped up in the IED.
ERR_NONCRIT	Non-critical system error	
EVENT_SYS	System event	Indicates the reset of SW in the IED.

Configuration for outputs can be loaded at the factory. Users can easily program different output configurations using the ***ZivercomPlus***® software via the local communication ports that have the PROCOME protocol configured (the local port is always assigned this protocol).

3.31.3.b Trip and Close Outputs

The **IRX** IED has four switching output signals, two of them normally open (N/O) and the other two definable by jumper as N/O or N/C. Two of these switching outputs are assigned to the logic output called open. These outputs are activated both when the relay generates a trip and when the breaker is opened manually. In all cases, they remain active for at least 100 ms. The logic input External trip control can be used to block all breaker opening commands.

The activation of the logical input **Trip External Control** will block all the open commands to the CB. If activated before the unit pick-up, both internal signals **Trip** and **Masked Trip** would be activated but without causing the trip of the CB. However, if activated after the tripping of the CB then it resets all protection units and tripping commands.

The other pair of switching output signals are assigned to the **Close** logic output. These outputs are activated both when the recloser function generates a reclose command and when the breaker is closed manually.

Breaker trip and close operations can be made using the same trip and reclosure contacts. The operating mode, through the button frame on the front of the IED, is designed to always request confirmation of maneuvers before executing them.

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.

3.31.4 LED Targets

The **IRX** IED has optical indicators (LEDs) on the front panel. One of them indicates whether the IED is **Ready**.

Each of the user-definable optical indicators is associated to a combinatorial function. These are diagramed in figure 3.31.3. The function is similar to the auxiliary contact outputs. One of the two blocks has eight inputs that perform an OR operation (any signal activates the output). The other block has one input. The two blocks together can perform an OR or an AND operation without the subsequent possibility of using pulses.

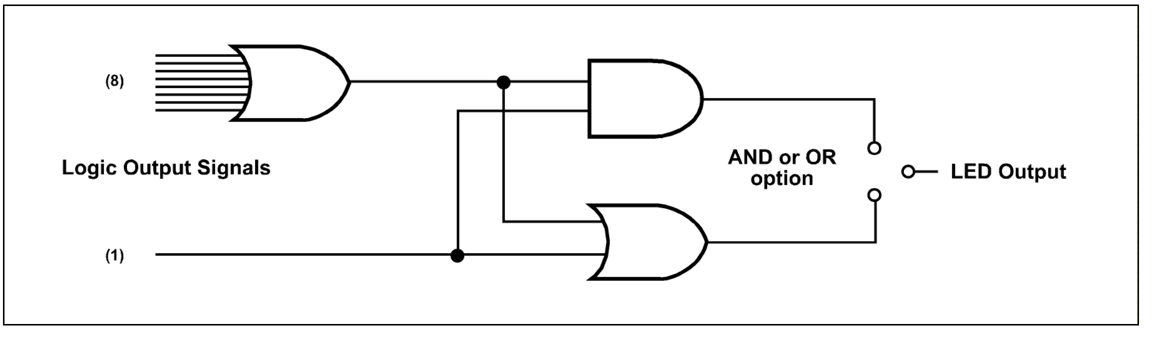


Figure 3.31.3 Target Output Logic Cell Block Diagram.

Each LED can be latched or unlatched. If an LED is latched, it will remain illuminated until reset. It is possible to program one of the programmable buttons, communications command, or digital input with the **Reset LEDs** digital input. Since it is defined as a command it will be available in the operations display menu. The latching function resides in the volatile memory section of the microprocessor. A power supply loss will cause any latched LED to reset.

The LEDs can be associated to any of the available logic output signals indicated in table 3.31-2. Logic equations can be created and modified with the ***ZivercomPlus***® program via the local communication ports that have the PROCOME protocol configured (the local port is always assigned this protocol).

To develop more complex algorithms and be able to assign the resulting outputs to the LEDs, the necessary opcodes must be programmed in the programmable logic. This, for example, allows configuring latched LEDs that do not lose memory after an auxiliary power supply voltage failure. This requires the use of latched bistable circuits.

3.31.5 Digital Inputs, Auxiliary Outputs and LED's Test

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

- **Digital Inputs**

For the inputs test, the rated voltage is applied between the terminals corresponding to the inputs (marked in the external connections diagram), always taking the polarity of the contacts into account.

From the inputs screen of the **Information** menu, it is verified that the inputs are activated ("1"). The voltage is removed and the contact inputs must reset ("0").

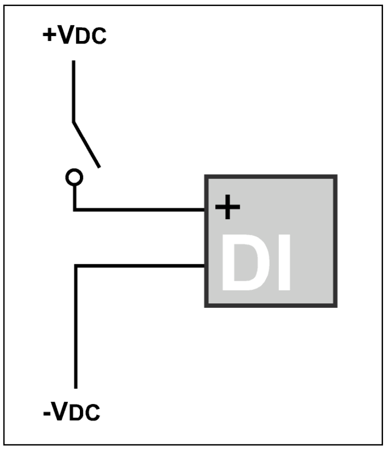


Figure 3.31.4 Digital Inputs Test.

- **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. Part of the inputs test consists in verifying the operation of auxiliary output contacts OUT1 to OUT6.

- **LED Targets**

To check the LED targets, the **F2** key must be pressed from the stand-by screen until the Resetting LEDs screen appears. It is held down until all the LEDs light up. When the push-button is released, they must all go off.

3.32 Programmable Logic

3.32.1 Description

One of the functions of **IRX** models is a fully configurable one called Programmable Logic. The user can freely interconnect this logic digitally and analogically by using the ***ZivercomPlus***® 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 ***ZivercomPlus***® 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.

3.32.2 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.

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 ***ZivercomPlus***®.

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.

The operation chosen to obtain a given output determines the input signals to the *blocks*. The **Input Connection** process is the software process that connects the inputs of the *blocks* with the appropriate inputs to the control subsystem according to the **Configuration**.

Likewise, the output signals from the *blocks* are associated with the appropriate outputs. This is done in the **Output Connecting** process according to the **Configuration**.

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 ***ZivercomPlus***® 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.

3.32.3 Primitive Functions (Opcodes)

3.32.3.a Logic Operations

The following logic operations can be used in the algorithm.

AND	Pulse	Adder	Digital/Analog Converter
OR	Timer A	Subtracter	BCD/Analog Converter
XOR	Timer B	Multiplier	Binary/Analog Converter
NOT	DFF	Divisor	Analog/BCD Converter
Cable	RSFF	Comparator	Analog/Binary Converter
Multifiber Cable	Analog Cable	Level Comparator	Pulse train
Multiplexer	Counter		Rising edge

- **AND**

Performs an AND operation between digital signals.

Operands:

From 2 to 16 digital input signals

Results:

Digital output signal, the outcome of the operation

- **OR**

Performs an OR operation between digital signals.

Operands:

From 2 to 16 digital input signals

Results:

Digital output signal, the outcome of the operation

- **XOR**

Performs an XOR operation between two digital signals.

Operands:

Two digital input signals.

Results:

Digital output signal, the outcome of the operation.

- **NOT**

Moves to a digital signal the outcome of negating another.

Operands:

Digital input signal.

Results:

Digital input signal.

- **Cable**

Moves to a digital signal the value of another.

Operands:

Digital input signal.

Results:

Digital input signal.

- **Multifiber Cable**

Moves to a digital signal the value of another.

Operands:

Digital input signal.

Results:

From 1 to 16 digital output signals.

- **Multiplexer**

Based on a selector, it establishes the value of an output signal with the value of one of the two inputs.

Operands:

Digital input selector signal.
2 digital input signals.

Results:

Digital output signal.

- **Analog Selector**

Based on a selector, it establishes the value of an analog output magnitude with the value of one of the two analog input magnitudes.

Operands:

Digital input selector signal.
2 analog input magnitudes.

Results:

Analog output magnitude.

- **Pulse**

When the input signal goes from 0 to 1, the output signal is activated during the time specified as parameter.

Operands:

Digital input signal.
Setting or pulse time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **Timer A**

When the time set since the input signal went from 0 to 1 is up, the output goes to one until the input resets.

Operands:

Digital input signal.
Setting or delay time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **Timer B**

The output is activated as long as the input is active or has been deactivated after a time no greater than the time set.

Operands:

Digital input signal.
Setting or delay time constant in seconds.

Results:

Digital output signal.

Limits:

The maximum time must be set between 0.0 and 2147483.648 seconds (24 days).

- **DFF**

Type D bistable. Whenever a rising edge occurs in the clock signal, the bistable takes the value of the input.

Operands:

Digital clock signal.
Digital input signal.

Results:

Digital output signal

- **RSFF**

Type RS bistable. As long as the S signal is active, the bistable takes the value of the input. When the R input is activated, the bistable takes value 0.

Operands:

Digital signal R.
Digital signal S.

Results:

Digital output signal.

- **Analog Cable**

Moves to an analog magnitude the value of another.

Operands:

Input magnitude.

Results:

Output magnitude.

- **Counter**

It manages a counter that increases with each rising edge of the clock signal. When the reset input is activated, the counter resets to 0.

Operands:

Digital reset signal.
Digital clock signal.

Results:

Magnitude of counter value.

Limits:

The counter has a saturation value of 65535. Subsequent increments do not modify the output value of the counter.

- **Adder**

It establishes the value of the output magnitude with the result of the sum of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Subtracter**

It establishes the value of the output magnitude with the result of the subtraction of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Multiplier**

It establishes the value of the output magnitude with the result of the product of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Divisor**

It establishes the value of the output magnitude with the result of the division of the input values.

Operands:

2 input values, settings or constants.

Results:

Output magnitude.

- **Comparator**

Compares two input values and establishes the value of the digital output signal according to the outcome of the comparison.

Operands:

2 input values, settings or constants.
Type of comparison as a constant value inserted in the opcode:
Greater than.
Less than.
Equal to.
Not equal to.
Greater than or equal to.
Less than or equal to.

Results:

Digital output signal.

- **Level Comparator**

It compares the input magnitude with respect to a minimum and maximum reference value and establishes the output according to it. Thus:

The output is 1 if the input is greater than the maximum reference value.
The output is 0 if the input is less than the minimum reference value.
Otherwise, the output keeps the same value.

Operands:

Input magnitude (magnitude, setting or constant).
Minimum reference value (magnitude, setting or constant).
Maximum reference value (magnitude, setting or constant).

Results:

Digital output signal.

- **Digital / Analog Converter**

It converts a digital signal to an analog magnitude with value 0 or 1.

Operands:

Digital input signal.

Results:

Analog output magnitude.

- **BCD / Analog Converter**

With 16 digital inputs, it generates an analog magnitude using BCD code.

Operands:

16 digital input signals.

Results:

Analog output magnitude.

- **Binary / Analog Converter**

With 16 digital inputs, it generates an analog magnitude using binary code.

Operands:

16 digital input signals.

Results:

Analog output magnitude.

- **Analog / BCD Converter**

It converts an analog magnitude into 16 digital signals by converting to BCD code.

Operands:

Analog input magnitude.

Results:

16 digital output signals.

- **Analog / Binary Converter**

It converts an analog magnitude into 16 digital signals by converting to binary code.

Operands:

Analog input magnitude.

Results:

16 digital output signals.

- **Pulse Train**

Logic block produced by a pulse train while the digital input signal is active.

Operands:

Digital signal enabling pulse train.
Magnitude, setting or time constant of active pulse in seconds.
Magnitude, setting or time constant of inactive pulse in seconds.

Results:

Digital output signal.

- **Rising Edge**

The output is activated when a change from 0 to 1 is detected in the input.

Operands:

Digital input signal.

Results:

Digital output signal.

3.32.3.b Logic Operations with Memory

Certain logical functions can be configured to preserve the internal state of the function after a shut down. Not all the logical functions have internal states that require this treatment:

Table 3.32-1: Logic Operations with Memory

Logical function	Can be memorized
AND	-
OR	-
XOR	-
NOT	-
Cable	-
Multifiber cable	-
Pulse	Y
Timer A	Y
Timer B	Y
DFF	Y
RSFF	Y
Analog cable	-
Counter	Y
Adder	-
Subtracter	-
Multiplier	-
Divisor	-
Comparator	-
Level comparator	Y
Digital to analog	-
RSFF with timed reset	Y
Pulse train	Y

Memorization mode is selected by means of a memory field inserted in the opcode when configuring with the ***ZivercomPlus***® program.

3.33 Communications

3.33.1 Communications Ports

IRX relays are provided with different types of communications ports as a function of the selected model:

- **1** front **Local Port** type RS232C.
- Up to 3 Remote Ports:
  - Remote Port 1: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS485, interface RJ-45 (ETHERNET).
  - Remote Port 2: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS485.
  - Remote Port 3: optical fiber interface (glass ST or plastic 1mm), electrical interface RS232 / RS232 FULL MODEM.
- **2 LAN Ports** with following configurations (ETHERNET type communications):

	LAN 1	**LAN 2**
1st Combination	RJ45	RJ45
2nd Combination	GFO ST	GFO ST

Technical data for these communications links can be found in Chapter 2.1 (Technical Data). Information on model ports can be found in chapter 1.4 (Model selection).

3.33.2 Communication with *ZivercomPlus*®

Protection, loading or reading programmable logic configuration and reading out protection data (events, fault reports, oscillograms,...) can be configured through communications ports set for PROCOME protocol. The local port is always assigned this protocol, whereas for remote ports it depends on settings.

Communications are established through ***ZivercomPlus***® communications program, which allows dialog between the **IRX** family and other relays, 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..

Local and remote communications ports are configured through HMI.

IRX model features three controllers, one for each communications port, so that communications can be established through all of them at the same time.

The ***ZivercomPlus***® communications program that involves the application of the model involved is protected against non-authorized users through access passwords. The ***ZivercomPlus***®, that runs in WINDOWS™ environment is easy to operate and uses buttons or keys to display the different submenus.

3.33.3 Synchronization by IRIG-B 123 and 003

IRX relays are provided 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.

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.

3.33.3.a UTC / Local Time Configuration

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

3.33.3.b IRIG-B Function Settings

IRIG-B Function Settings			
Setting	**Range**	**Step**	**Default**
IRIG-B Time Zone	0 = Local Time 1 = UTC Time	1	0 = Local Time

3.33.3.c Auxiliary Outputs of the IRIG-B Function

Table 3.33-1: Auxiliary Outputs of the IRIG-B Function		
Name	**Description**	**Function**
SIGNAL_IRIGB	IRIGB Active	Signal indicates that IRIG-B signal is being received.

3.33.4 Communications Protocol

All **IRX** relays are provided with rear communications ports for remote access and one front port for local access. Depending on model, rear ports feature several communications protocols:

- **Local Port**: uses only PROCOME protocol.
- **Remote Ports 1, 2** and **3**: options PROCOME, DNP3.0 and MODBUS are available.
- **LAN 1 and 2 Ports**: can communicate through IEC61850, PROCOME and DNP3.0.

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

PROCOME protocol complies with IEC-870-5 standards and is used for both protection and control information management. On the other hand, protocols DNP 3.0 and MODBUS are used for control information management.

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

3.33.4.a Control Change Recording

Depending on signals configured into the programmable logic through the ***ZivercomPlus***® program, the different system events make changed-state signals to be written.

Different signal lists for PROCOME 3.0 and DNP 3.0 protocols can be configured through the programmable logic, saving changes into different and separate **IRX** relay files for each of the communications ports. This implies that although the tail of changes 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.

Also, from the signals configured in PROCOME, DNP 3.0 or both, signals to be displayed through the HMI can be selected. They are also saved into separate files, so that even if tails of control changes of communications ports are emptied, the information is still available through HMI. Between 100 and 115 records are saved depending on their simultaneity.

Information on the Control Change Record is displayed from the HMI or pressing F1 key through **Information** option, the changes list view or delete options being available. If the view option is selected, the last change generated is always displayed (the most recent). Information is presented as follows:

AA/MM/DD|HH:MM:SS
000 text1 □ or ■
001 text2 □ or ■

AA/MM/DD|HH:MM:SS
000 text3 □ or ■
001 text4 □ or ■

Namely, 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 ***ZivercomPlus***® (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.

3.33.5 Communications Settings

As the below described settings are independent for each port, they are grouped as follows: **Local Port**, **Remote Port 1**, **Remote Port 2**, **Remote Port 3, LAN1** and **LAN2**. Finally specific settings for each protocol are described.

Whenever communication is established through one of these ports, the following codes are displayed on relay alphanumeric HMI:

- **Local port**: **[PL]** code.
- **Remote port 1**, **Remote port 2**, **and Remote port 3**: **[P1]**, **[P2]** and **[P3]** codes.
- **Remote ports LAN1 and LAN 2**: no display on HMI.

These codes, in case of PROCOME 3.0 protocol, remain displayed during **Communications Password TimeOut** setting indicated for 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 three timer settings, one for each communications port (**Communication Failure Time Indication**), which, no matter the assigned protocol, allow configuring the period without communication activity before generating the alarms (digital signals and events) **Communication Failure Port 0**, **1**, **2** and **3**.

3.33.5.a Local Port

The setting options of the local communications port are:

- **Baud Rate**: a value from 300 bauds to 38400 bauds can be chosen, default value being 38400 bauds.
- **Stop Bits**: one of two stop bits can be selected.
- **Parity**: even, odd or no parity (None) can be selected. No parity is configured by default.
- **Character Reception Time** (0-60000 ms): maximum time between characters allowed during the receiving of a message. The current message will be considered cancelled if it exceeds the set time between the reception of two characters.
- **Communication Failure Indication Time** (0-600 s.): maximum time between messages without indication of communication channel blocking.

3.33.5.b Remote Ports 1 and 2

Remote ports 1 and 2 have fiber optic and electrical access RS232 / RS485. Available configuration settings for these ports are similar to the local port settings, and it is possible to select the communications protocol and a specific parameter for RS485 application. Thus, settings are:

- **Baud Rate, Stop Bits, Parity** and **Character Reception Time**.
- **Protocol**: Depending on model, PROCOME 3.0, DNP 3.0 and MODBUS protocols can be selected. The default protocol is PROCOME.
- **Advanced settings**:
  1. Operation Mode (RS232 / RS485): This setting allows selecting the operation mode of DB9 interface of remote port 2 or 3 as a RS232 port or RS485 port.
  2. Time
    Transmission Time Factor (0-100 characters): Per-character time factor which determines when the transmission ends by time-out.
    Transmission Time Constant (0-60000 ms): Fixed time in seconds that is added to the per-character time factor, and that determines when the transmission ends by time-out.
    Number of 485 Stop Bytes (0-4 bytes): It specifies the number of stop bytes between transmit and receive when the port is configured as RS485.
  3. Message modification
    Number of Zeros (0-255): Number of zeros to insert as preamble to each message.
  4. Collisions
    Type of Collision (NO / ECHO / DCE):
      NO: Collision detection disabled.
      ECHO: A collision is considered to have occurred when the characters received do not coincide with the characters transmitted.
    Number of Retries (0-3): Maximum number of retries in the transmission when collisions are detected.
    Minimum Time between Retries (0-60000 ms): Minimum time between retransmissions on collision detection.
    Maximum Time between Retries (0-60000 ms): Maximum time between retries on collision detection.

3.33.5.c Remote Port 3

Remote port 3 has fiber optic and electrical access RS232 / RS232 FULL MODEM. Access through RS232 FULL MODEM has all the MODEM lines in format DB9. The settings available for configuring this port are:

- **Baud Rate, Stop Bits, Parity** and **Character Reception Time**, the same as the local port.
- **Protocol**: depending on model, PROCOME 3.0, DNP 3.0 and MODBUS Protocols can be selected. The default protocol is PROCOME.
- **Advanced settings**:

  1. Flow Control

  CTS Flow (NO / YES): It specifies whether the **Clear to Send** signal is monitored to control the data transmission flow. If the setting is YES and the CTS signal falls to “0”, the transmission is suspended until the CTS signal resets.

  DSR Flow (NO / YES): It specifies whether the **Data Set Ready** signal is monitored to control the data transmission flow. If the setting is YES and the DSR signal falls to “0”, the transmission is suspended until the DSR signal resets.

  DSR Sensitive (NO / YES): It specifies whether the communications port is sensitive to the state of the DSR signal. If the setting is YES, the communications driver ignores any byte received unless the DSR line is active.

  DTR Control (INACTIVE / ACTIVE / ENABLE SEND):

  Inactive: It sets the DTR control signal to permanently inactive.

  Active: It sets the DTR control signal to permanently active.

  Enable Send: The DTR signal remains active as long as the receiving of new characters is allowed.

  RTS Control (INACTIVE / ACTIVE / ENABLE SEND / SOL. SEND):

  Inactive: It sets the RTS control signal to permanently inactive.

  Active: It sets the RTS control signal to permanently active.

  Enable Send: The RTS signal remains active as long as the receiving of new characters is allowed.

  Solicit Send: The RTS signal remains active as long as there are characters pending transmission.

  2. Time

  Transmission Time Factor (0-100 characters): Per-character time factor, which determines when the transmission ends by time-out.

  TRANSMISSION TIME CONSTANT (0-60000 ms): Fixed time in seconds that is added to the per-character time factor, and that determines when the transmission ends by time-out.

  3. Message modification

  Number of Zeros (0-255): Number of zeros to insert as preamble to each message.

  4. Collisions

  Type of Collision (NO / ECHO / DCD):

  NO: Collision detection disabled.

  ECHO: A collision is considered to have occurred when the characters received do not coincide with the characters transmitted.

  DCD: A collision is considered to have occurred when the DCD line is activated.

  Number of Retries (0-3): Maximum number of retries in the transmission when collisions are detected.

  Minimum Time Between Retries (0-60000 ms): Minimum time between retransmissions on collision detection.

  Maximum Time Between Retries (0-60000 ms): Maximum time between retries on collision detection.

3.33.5.d Ethernet Remote Ports 1, 2 and 3

- **Protocol**: Depending on model, PROCOME 3.0, DNP 3.0, MODBUS protocols and Virtual Inputs / Outputs (this last option is only available for remote port 2) can be selected. The default protocol is PROCOME.
- **Ethernet**
  1. Enabling the Ethernet Port (YES-NO): enables (YES) or disables (NO) the Ethernet Port.
  2. IP Address (ddd.ddd.ddd.ddd): Ethernet device ID number.
  3. Net mask (128.000.000.000 – 255.255.255.254): number that indicates to the device what part of the IP address is the network number, and what part of the IP address corresponds to the device.
  4. Port Number (0 - 62235): number used to indicate the delivery route of the data received, to the destination device.
  5. Max. Time between Messages TCP (0-65 sec.): number of seconds between Keepalive packages - if zero then Keepalive packages were not sent. These Packages inform the server if a client is still present on the Ethernet Network.
  6. RX Car Time (0-60000 milliseconds): maximum time between characters allowed while receiving a message through the Ethernet. The message is timed out if the set time is exceeded between the receipt of two characters.
  7. Communication fault indication time (0-600 sec.): maximum time between messages via the Ethernet port before an indication that communications have stopped.

2IRX-*-******-*M*** relays have only one remote ETHERNET port that groups the remote ports 1 and 2, thus, they display only the remote Port 1, **Protocol 1** and **Protocol 2** ports being within it.

- **Protocol 1 / Protocol 2**: can be selected from PROCOME 3.0, DNP3.0 and MODBUS protocols (the default protocol is PROCOME), and for each of the two, the port number to communicate by means of this protocol can be selected. These port numbers are, by default, 32001 for PROCOME, 20000 for DNP3.0 and 502 for MODBUS, but they can be freely configured with the condition that they may not be the same for both ports.

3.33.5.e PROCOME 3.0 Protocol Settings

The configuration settings of the PROCOME 3.0 protocol are:

- **Relay Number** (0-254): it specifies the address of the **IRX** 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).
- **Communications Password Enable** (YES-NO): this setting allows to enable the access password function to establish communication with the relay through the rear port: YES means enabling the permission and NO, disabling.
- **Communications Password TimeOut** (1-10 minutes): this setting allows establishing a period of time for activating a communication blocking with the relay (whenever communication is via the rear port): if the set time expires with no activity taking place in the communications program, the system blocks, and the communication must be reinitiated.
- **Communications Password**: the communications password allows establishing a specific password to access communications with the relay through the rear port. This password must have 8 characters, which will be entered using the numerical keys and the key corresponding to a dot.

3.33.5.f DNP 3.0 Protocol Settings

The DNP 3.0 protocol configuration settings include the definition of:

- **Relay Number** (0-65519): it specifies the address of the **IRX** 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 **IRX** sends a message requesting the master to confirm the Application layer (Level 7), until this confirmation is considered lost. The **IRX** 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.
- **Master Number Unsolicited** (0-65535): it specifies the address of the master station (MTU or Master Terminal Unit) to which the **IRX** relay will send spontaneous (Unsolicited) messages. It is used in combination with Enable Unsolicited parameter. Addresses 0xFFF0 to 0xFFFF are reserved for Broadcast addresses.
- **Enable Unsolicited** (YESI/NO): enables (YES) or disables (NO) sending spontaneous messages (Unsolicited); it is used in combination with the MTU Number parameter. For the **IRX** relay to begin sending spontaneous messages the master must also enable them with the Function Code FC = 20.
- **Unsolicited Start Enable** (YES/NO): enables (YES) or disables (NO) sending spontaneous start messages (Unsolicited after Restart); it is used in combination with the MTU Number parameter. For the **IRX** relay to begin sending spontaneous start messages there is not need for the master to enable them.
- **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.
- **Unsolicited Start Activation** (YES/NO): enables (YES) or disables (NO) sending Forced Unsolicited messages (for compatibility with versions pre DNP3-1998). When Unsolicited Start is activated, the **IRX** relay begins to transmit the existing spontaneous messages without additional enabling by the level 2. For this setting to have effect Enable Unsolicited Start must be enabled.
- **DNP3 Revision** (STANDARD ZIV/2003): indicates the DNP3 certification revision to use. STANDARD ZIV or 2003 (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03).

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 ***Ziverlog***®.

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 ***Ziverlog***®. Namely: 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 Profile II and Profile II Ethernet Protocols**:

- **Class for binary changes** (CLASS..., NONE). Assigns the class to the binary changes.
- **Class for analog changes** (CLASS..., NONE). Assigns the class to the analog changes.
- **Class for counter changes** (CLASS..., 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).
- Change in DNP3 Counter **(1 to 32767). The setting value shows the minimum increase of counts needed to send a new DNP3 message stating a new change in the counter. 20 counters can be configured as maximum under the DNP3 Profile II and Profile II Ethernet Protocols.**

3.33.5.g MODBUS Protocol Setting

The only configuration setting of the MODBUS protocol is the **Relay Number** (0-254), which the same as for the other protocols specifies the **IRX** 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).

3.33.5.h TCP/IP Protocol Settings

TCP/IP protocol configuration settings include the definition of:

- **Ethernet Channel 0** (**LAN 1**). The following settings are available within the channel:
  - IP Address (ddd.ddd.ddd.ddd).
  - DHCP Enable (YES/ NO).
  - Default Gateway (ddd.ddd.ddd.ddd).
  - Network Mask (ddd.ddd.ddd.ddd).
  - DNS Address (ddd.ddd.ddd.ddd).
- **Ethernet Channel 1** (**LAN 2**). The following settings are available within the channel:
  - IP Address (ddd.ddd.ddd.ddd).
  - DHCP Enable (YES/ NO).
  - Default Gateway (ddd.ddd.ddd.ddd).
  - Network Mask (ddd.ddd.ddd.ddd).
  - DNS Address (ddd.ddd.ddd.ddd).
- **SNTP** The following settings are available within SNTP:
  - SNTP enable (YES / NO)
  - Broadcast Synchronization Enable (YES / NO)
  - Unicast Synchronization Enable (YES / NO)
  - IP address of Primary SNTP Server (ddd.ddd.ddd.ddd).
  - IP address of Slave SNTP Server (ddd.ddd.ddd.ddd).
  - Unicast Validity Timer (10 - 1000000)
  - Unicast Error Timer (10 - 1000000)
  - Number of Connection Retries (1 - 10)
  - Tuning period (1 - 1000000)
  - Retry Period (1 - 1000000)
  - Broadcast validity Timer (0 - 1000000)
  - Broadcast Error Timer (0 - 1000000)
  - Maximum Synchronism Time Delay (0 - 1000000)
  - Ignore Synchronization Leap Indicator (YES / NO)
  - Synchronism State Calculation (Timing / Leap Indicator)

2IRX-*6*-******** models include a group of settings related to the Ethernet Redundancy:

- **Redundancy mode** (No Redundancy / Bonding Redund / PRP Redund.).
- **Channel status time** (1 - 60).
- **Bonding** Redundancy
  - Link check interval (25 - 500).
- **PRP** Redundancy
  - Transmission time of supervision frames (0 - 30000).
  - LSB of supervision frame destination MAC address (0 - 255).

3.33.6 IEC61850 Communications Protocol

3.33.6.a Introduction

IEC61850 communications equipment of the ‘X’ family is provided with functions additional to those provided by protection and control equipment.

This equipment may become independent from communications, performing their protection or control functions independently or may be used for data reports, set or receive specific data.

IEC61850 communications provide the following additional services:

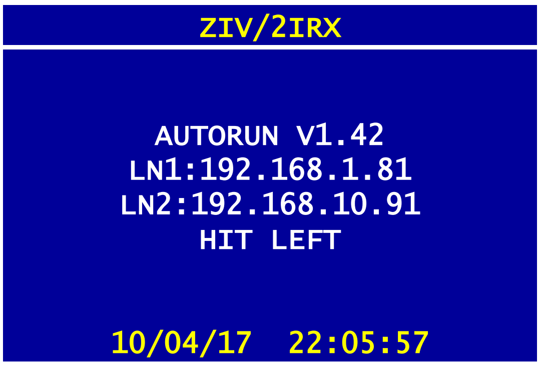
- Report device-generated data (Starting, tripping, blocking, etc.) to higher level equipment (Central unit, remote control, HMI, etc.).
- Report prompt data (GOOSE) to other same level equipment (protections, control equipment, auxiliary services) or even to other higher level equipment.
- MMS communications that allows any MMS browser to receive the model of equipment data and be able to operate with it to edit settings and parameters and execute commands to the equipment.
- Handle a single configuration file (**CID**) that allows having a backup of all parameters whether they are protection, control and communications.
- Web server to provide data about equipment status, errors and state and measurement values.

3.33.6.b Starting Communications

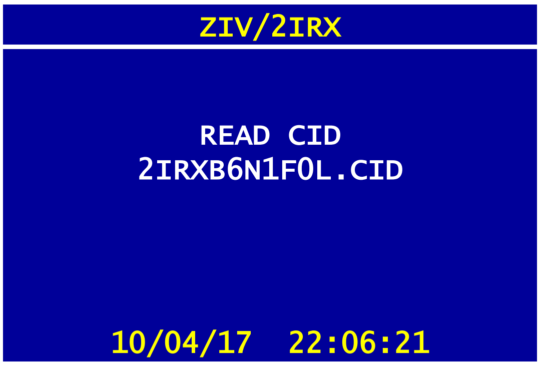
Unlike protection and control functions that start in less than 3 seconds, **IEC61850** communications start in a variable time as a function of the data configured. In a reboot, the main **IEC61850** communications screens are as follows:

Initial moment in which the basic data of the operating system are loaded.

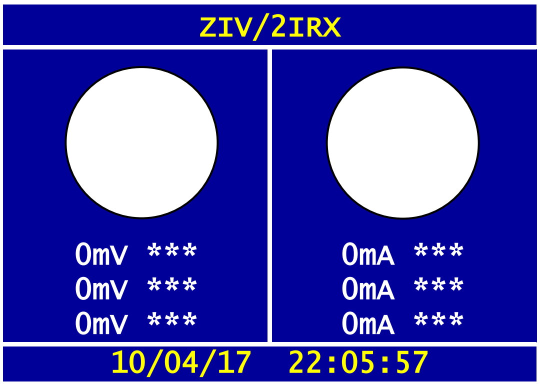
Autorun screen that manages the IP address of the network adapters and allows to carry out maintenance tasks.



Screens to create the **IEC61850** model and read **CID**.



Equipment home screen that indicates the equipment is fully booted and ready for communications.



3.33.6.c Information Screens

Equipment with **IEC61850** communications include a data Menu, access of which is gained pressing the key combination **ESC** and left arrow from the HMI default screen.

This screen displays in the first line the equipment software model, in the second line, versions of the active **IEC61850** application and in the third and fourth, the equipment IP.

From this screen more data can be displayed through the selection keys.

```
ZIV/2IRX

2IRXB6N***1F0*L2F95
V(0.8)[01][03.00.02]
LN1:192.168.1.81
LN2:192.168.10.91

10/04/17   23:18:26
```

By clicking on the right arrow you access a **Goose** message information screen. This screen gives information as to whether the **Goose** message send is activated ([ON]GO), whether the reception is configured ([ON]GI), and if it is, what **Goose** message we are not receiving (01??), or if this is erroneous via error message (01ER).
The → arrow indicates the moment a Goose message is sent.

```
ZIV/2IRX

[ON ]GIe:0000 0000
01?? GIv:0000 0000
[ON ]GOe:0000 0000
GOv:0000 0000

10/04/17   23:18:26
```

Pressing down key displays a screen with expanded data.

```
ZIV/2IRX

Uboot (2010.03)
4WD03620006
SW (3.24.2.29986)
IEC [03.00.02][RUN]

10/04/17   23:18:26
```

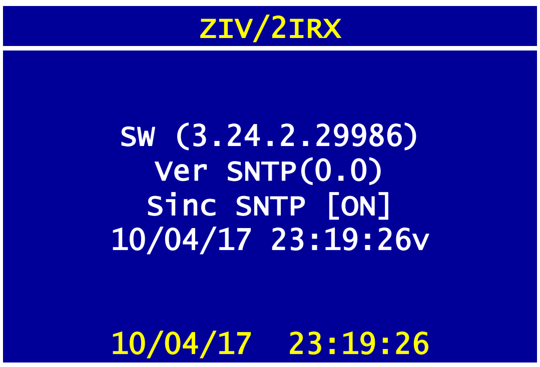
It consists of a screen where you can move about using the up/down arrows and whose complete information will be: Uboot, FW drawing number, software version and as regards IEC61850, checksums, model, information on the net adapters, etc.

```
Uboot (2010.03)
4WD03620006
SW (3.24.2.29986)
IEC [03.00.02][RUN]
CRC:[16364787]
BLD[Jun 16 2014]
BLD[16:12:44]
MMS<->IEC<->IRV
2IRXB6N***1F0*L2F95
(0.8)[01]
[eth0]
192.168.1.81
00:E0:AB:02:98:36
DHCP[0]
Type[6]
GWY[0.0.0.0]
[eth1]
192.168.10.91
00:E0:AB:02:98:37
DHCP[0]
Type[6]
GWY[192.168.10.1]
CONNECTIONS 0

[eth0]
RxERR:[0]
TxERR:[0]
[eth1]
RxERR:[0]
TxERR:[0]

FiFoE:0 Uso:1
FiFoM:0 Uso:17
NmRtr:0 MxMed:4
```

By clicking on the left arrow you access the client's information screen **SNTP**. The screen indicates the client's **SNTP** software version, if the client is switched off (OFF), on (ON) or if there is an error (ERROR), the time when it is received and if it is valid (v) or invalid (i).



Press ESC to return to the default screen from any screen.

3.33.6.d Web Server

Through the web server access can be gained to firmware versions, boot status and useful relay data. Write the equipment IP address in a web browser for access:

Once authenticated, the following information will be displayed:

- **Configuration**: equipment identification information (versions, drawing number, model, etc.) will be displayed, and access control (in the event of administrator permission, users and passwords can be changed).

  - **Administration**: Access to the web is displayed and is allowed, only with administrator permission, a series of maintenance actions, such as erasing the application log, erasing the event folder, erasing the current **CID** back-up file (*bk), erasing the current **CID** file (*.cz), erasing the image file that enables to speed up the equipment booting (*.img), formatting of the flash partition corresponding to the application, with or without restoration of the contents previous to the formatting, restoring the EEPROM and stopping the IEC61850 application. Any of the mentioned actions automatically stops the IEC61850 application and reboots the IEC-61850 board. There is an option that once the action is executed, the IEC-61850 board does not reboot automatically.
    In order to execute the actions you must click on ***Send*** and ***Apply***.
  - **LAN1**: Network adapter LAN1 settings are displayed: if the IP is static or dynamic, IP address, network mask and MAC address.
  - **LAN2**: Network adapter LAN2 settings are shown: if IP is static or dynamic. IP address, network mask and MAC address.

- **IEC-61850**: The different IEC-61850 communications board data are displayed, such as the different booting LOGS (the application log is not volatile), TCP and MMS active connections data and a list of analogical and digital internal signals and its value according to the format of IEC-61850 standard with its real description. The oscillographs generated can be displayed (DAT and CFG) and downloaded from the link. Active **CID** is also available, and can be downloaded from the link.

- **Command** menu: this is the section of the main commands available in the equipment.

  - ***Apply***: The configuration parameters are applied to the equipment.
  - ***Save***: The configuration parameters are saved in a flash memory, and are available when the equipment reboots.
  - ***Reboot***: Forces equipment rebooting.
  - ***Reflash***: Enables the reflashing of the equipment with a new firmware version.

It is very important to take into account the difference between the following actions.

- Send the parameter modifications to the equipment. In order to execute this action ***Send*** must be clicked in the modified page.
- Once the desired parameters have been configured, the ***Apply*** action will activate the above-mentioned changes in the equipment in such a way that they can be tested. Changes are not saved with this action. If the equipment is reset after applying the changes, the changes have not been saved and the last saved configuration will be available in the next rebooting of the equipment.
- Once all the parameters required have been modified, sent and tested, these will be saved in the configuration memory by clicking on ***Save***.
- A reset can be forced on the equipment with the ***Reboot*** action.

Remember to click on *Send, Apply* and *Save* in order to keep the changes if you want to have them available in the next rebooting of the equipment.

3.33.6.e Communications Port Configuration

Relays with **IEC61850** communications use Ethernet network, using TCP/IP protocol for MMS communications (used to pack network data). Therefore, regardless of the physical medium and the connection (fiber, copper, etc.) the IP used by the relay in the network must be configured. For this, knowing the type of Ethernet redundancy implemented in each relay is vital, there being currently three possibilities:

- **No redundancy**

The relay is provided with 2 separate network adapters with different MAC address and different IP address. Both adapters are independent, it being possible to access the MMS data through both adapters. GOOSE messages will be sent and received only through one of the two adapters.

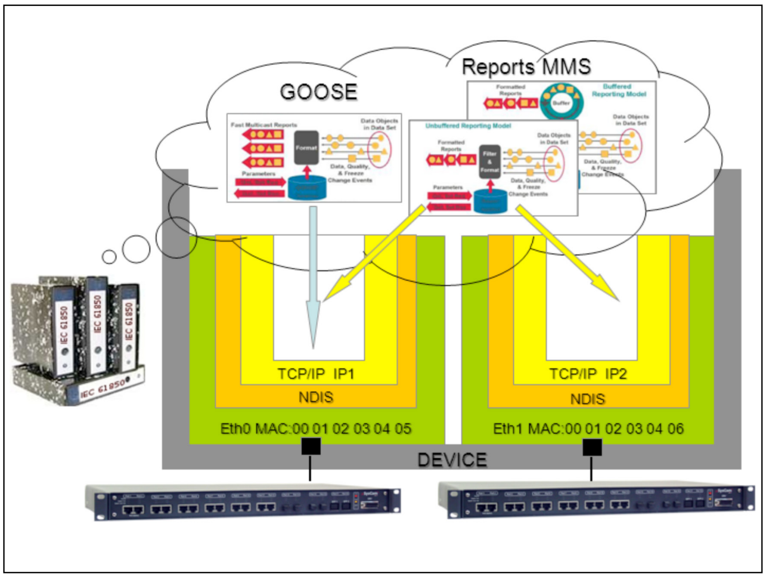


Figure 3.33.1 Configuration of Communications Ports for Relays without Ethernet Redundancy.

- ## Bonding Type Redundancy

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.

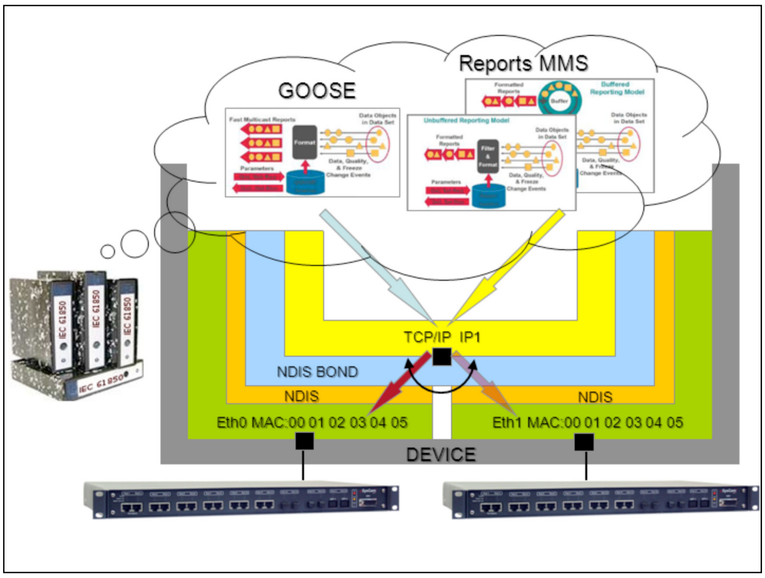


Figure 3.33.2 Configuration of Communications Ports for Relays with Bonding Type Redundancy.

- ## 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 being active at any time and sending the same data through both adapters using the IEC 62439-3 protocol Parallel Redundancy Protocol (PRP).

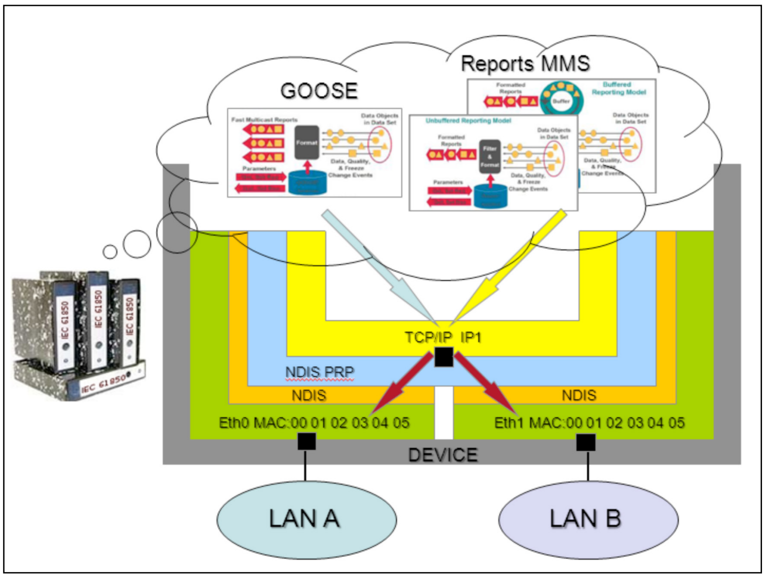


Figure 3.33.3 Configuration of Communications Ports for the Relay with PRP Type Redundancy.

This protocol is based on connecting the relays to two separate Ethernet networks (LAN), not connected to each other. The same data are 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 are received through both adapters and the idea is discarding the duplicate packet at the lowest possible level within the communications stack. The relay will send PRP supervision frames periodically (multicast) to enable system monitoring. Both MMS data and GOOSE messages will be sent through both adapters at the same time.

Relays **2IRX-*3*-********* have no Ethernet redundancy, so they are provided with 2 physical ports with separate IPs, thus separate configuration settings. They will have the following settings per adapter:

- IP Address.
- DHCP Enable.
- Default Gateway.
- Network Mask.
- DNS Address.

2IRX-*3*-******* Model settings are described below.

- **Goose Channel** (**Channel Ethernet 1** - **Channel Ethernet 2**): selects Goose message transmission / reception channel according to IEC-61850.
- **Output Goose**.
    - **Goose Out Enable**(YES / NO): enables output Gooses.

Models **2IRX-*6*-********* implement the three types of redundancy. They will have a setting to configure this mode of redundancy:

- If no redundancy is selected (**No Redundancy**), they will have 2 physical ports with separate IPs, thus, separate configuration settings. They will have the following settings per adapter:

    - IP Address.
    - DHCP Enable.
    - Default Gateway.
    - Network Mask.
    - DNS Address.

  The following settings can also be defined:

    - **Goose Channel** (**Channel Ethernet 1** - **Channel Ethernet 2**): selects Goose message transmission / reception channel according to IEC-61850.
    - **Output Goose**.
        - **Goose Out Enable**(YES / NO): enables output Gooses.

- If Bonding type redundancy is selected (**Bonding Redund.**), they will have 2 physical ports with only one IP and only one set of settings:

    - IP Address.
    - DHCP Enable.
    - Default Gateway.
    - Network Mask.
    - DNS Address.

As there is no setting to configure the GOOSE send / receive channel, as it always is produced through the active adapter, they incorporate the following settings:

- **Output Goose**.
    - **Goose Out Enable**(YES / NO): enables output Gooses.
- **Channel Status Time Delay** (1 – 60 s): time without medium detection to indicate the channel is down.
- **Link Check Interval** (25 – 500 ms): time to determine that no medium is available switching to the other adapter.

- If PRP type redundancy is selected (**PRP Redund.**), it will have 2 physical ports with only one IP and only one set of settings:

    - IP Address.
    - DHCP Enable.
    - Default Gateway.
    - Network Mask.
    - DNS Address.

As there is no setting to configure the GOOSE send / receive channel, as it is always produced through both adapters, they have the following settings:

- **Output Goose**.
    - **Goose Out Enable**(YES / NO): enables output Gooses.
- **Channel Status Time Delay** (1 - 60 s): time without receiving frames to indicate that the channel is down.
- **Transmission Time of Supervision Frames** (0 - 30000): send interval of PRP supervision frames.
- **LSB of Supervision Frame Destination MAC Address** (0 - 255): last octet of the PRP supervision frame destination MAC (destination MAC address will be 01-15-4E-00-01-XX).

3.33.6.f FTP Access

The FTP access will enable a series of equipment folders available. Depending on the user and the password, different folders will be available.

Anonymous access, without username or password, access is granted to a directory with the following structure.

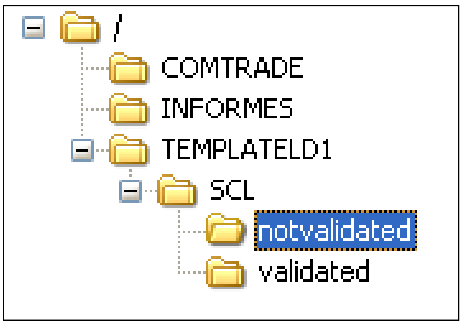


Figure 3.33.4 Directory Structure for an Anonymous FTP.

In this structure the (COMTRADE) oscillographs will be available and copy a new **CID** in the ***NameIEDLD/SCL***/notvalidated directory (See section on how to change the CID configuration file).

Logging in using user *info* and password *info* displays a directory with the following structure as shown in the following figure.

The directories will contain the following information: Booting information (*SYSTEM LOG*), CID active (CID), oscillograph files (*LD/COMTRADE*) and events file (*SOE*).

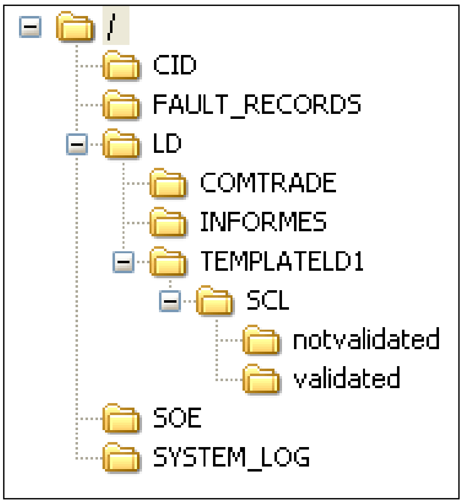


Figure 3.33.5 Directory Structure for an FTP Info.

3.33.6.g CID Configuration File

The equipment includes a file (**CID**) in **IEC61850** standard format according to part 6 (SCL). This file allows knowing the equipment data model in node, data and attribute format.

Also, it allows to configure GOOSE message parameters, receive other GOOSES, create datasets and assign them to Reports, edit settings, change the control logic, descriptions, parameters, etc.

This file can be edited through a SCL file editing program, the ***ZiverCID***®.

This program allows configuring this file to be sent later to the equipment through FTP or USB port.

- **Loading the CID trough FTP**

In order to gain access to the equipment through FTP an FTP client program is required. The Windows browser itself allows making an FTP to the equipment address. For this, enter the equipment IP address in the Address bar in the following way:

Without introducing user and password the **CID** configured in the ***NameIEDLD/SCL/notvalidated*** directory of the FTP can be copied.

The equipment will validate the **CID** (it will check that it is a correct SLC and that the IP of the **CID** matches the one configured on the equipment for any of the network adapters).

Once it has been validated, the equipment carries out a backup and reboot process, rebooting communications and using a new **CID**. If the **CID** fails validation it will be rejected and deleted from the directory, and it will continue to operate in the normal way with the already loaded **CID** without ever losing communications.

If problems arise during loading the new **CID** (control reconfiguration process or loading protection settings), the relay will display a screen that will allow recovering the previous **CID** (refer to the errors section).

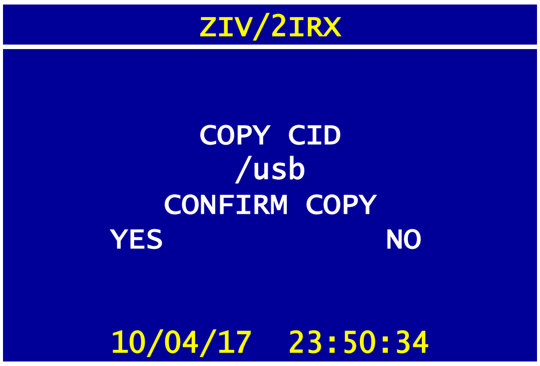
- **Loading the CID through USB by means of a Pendrive**

To load a new **CID** to the equipment through the HMI USB, an empty Pendrive is needed to copy the new CID to the root directory.

With the equipment fully booted and from the home screen, insert the Pendrive and wait for it to be detected.

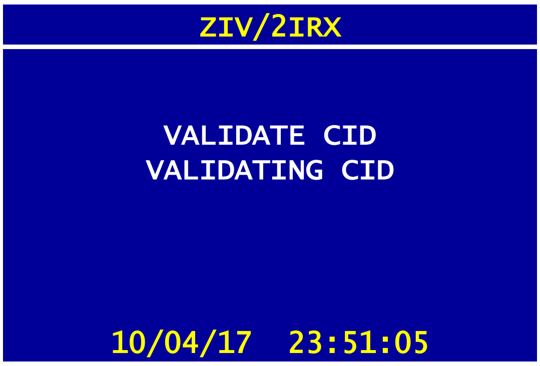
Then confirmation to copy is requested.

Confirm by pressing left key.



Once the **CID** is copied, the equipment will request the removal of the pendrive.

When removing the pendrive, the equipment will copy the CID to a temporary directory (***notvalidated*** directory) where it will validate it (checking that it is a correct SLC and that the IP of the **CID** matches any of those configured for the equipment network adapters.



Once it has been validated, the equipment carries out a backup and reboot process, rebooting communications and using the new **CID**. If the **CID** fails validation it will be rejected and deleted from the directory, and it will continue to operate in the normal way with the already loaded **CID** without ever losing communications.

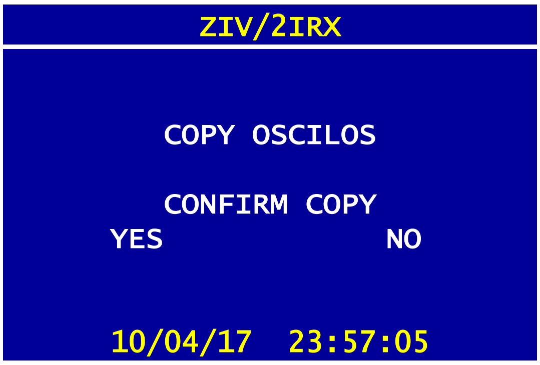
If problems arise during loading the new **CID** (control reconfiguration process or loading protection settings), the relay will display a screen that will allow recovering the previous **CID** (refer to the errors section).

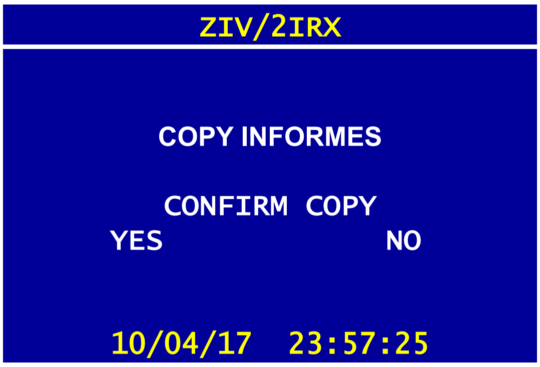
If the USB contains more files or directories apart from the **CID,** the relay will display the message below, refusing to load:

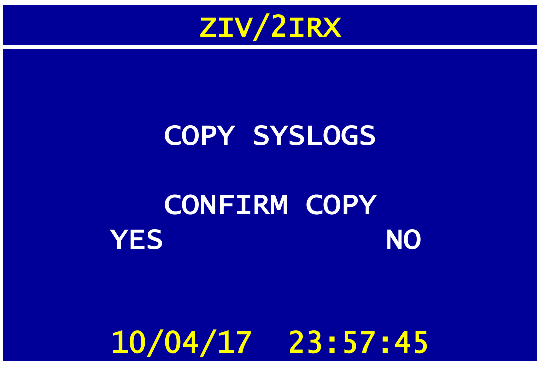
- **Backup**

For a backup protection of the relay data, namely, obtaining the CID, logs, oscillograms and other data, the methods below can be used

- FTP with access as user: *info* and password: **info** (refer to FTP access section)
- Web server (refer to section)
- USB. With the relay booted and with no error messages displayed on the screen, insert an empty USB in the relay to automatically copy the active CID. Then, three screens will be displayed giving the user the option to download the rest of the data.







- **Errors**

During equipment configuration, actions may be carried out resulting in errors that can be identified and corrected.

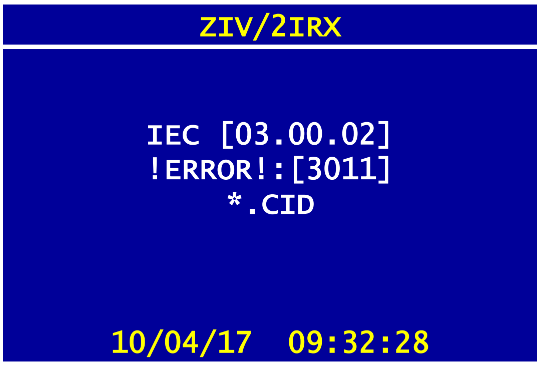
- **Switching the equipment off during the process of CID write to a Flash memory**: during operation, the equipment writes the CID to Flash type non volatile memory.

- If during this process, the equipment is switched off, it is likely that the CID copied to the Flash is lost. In this case, in the next boot up the type of message below will be displayed on the screen, **2IRXB6N1F0L.CID** being the active **CID** file.

For a few seconds, it will be possible to recover the backup copy of the **CID** available in the equipment just before the settings were last changed.

If the left arrow is clicked in order to recover the **CID**, the equipment will use this backup copy to boot. If the right arrow is clicked or if no action is undertaken within the following seconds, the equipment will remain inactive waiting for the introduction of a new **CID** via any of the loading methods of the **CID** (FTP or USB).

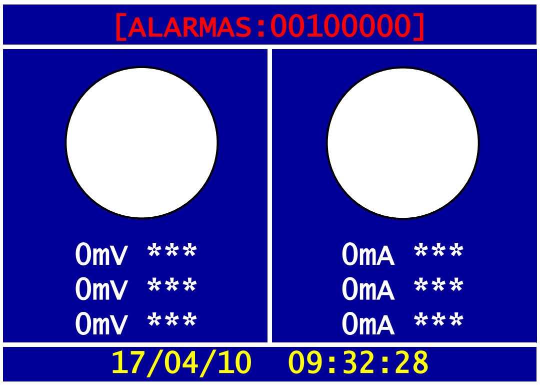
- **In case of multiple undue shutdowns** (e.g. shutdown after **CID** recovery), the backup copy of the **CID** could also be lost. In this case the message on the right will be displayed, waiting for a new **CID** to be introduced by any of the **CID** loading methods (FTP or USB).



The IEC61850 errors that can arise have been summarized in the following table:

3010	General error when loading the profile
3011	Error in the loading process of the CID
3020	The IDS does not correspond with the model
3030	Error generating the logic due to modifications in the CID (InRefs, LOGGAPC....)
3060	Configuration error in the input GOOSEs
3070	Error in file rfc1006.cfg
3080	Error in the relay board interface version
3200	Error in the IRQs of the DPRAM

- **00100000 Alarm**. This means there is a problem with IEC61850 communications that does not affect the protection and control function. In this case, please contact the technical service to identify the nature of the failure.



3.33.6.h PROCOME and DNP3 Protocols for IEC61850 Ports

An instance is available for each protocol on **IEC61850** ports. The 32001 logic port is used for PROCOME and the 20000 for the DNP3. Each single protocol instance can be accessed from either of the two **IEC61850** ports. Simultaneous connection of both protocols is enabled.

3.33.7 Communications Settings

Local Port Communications			
Setting	**Range**	**Step**	**Default**
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time Between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s

Remote Communications Ports 1 and 2			
Setting	**Range**	**Step**	**Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time Between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s
Advanced Settings			
Operation Mode	RS232 / RS485		RS232
Time			
Tx Time Factor	0 -100 characters	0.5	1
Tx Time Constant	0 - 60000 ms	1 ms	0 ms
Number of 485 Stop Bytes	0 - 4 bytes	1 byte	0
Message Modification			
Number of Zeros	0 - 255	1	0
Collisions			
Type of Collision	NO / ECHO		NO
Number of Retries	0 - 3	1	0
Minimum Retry Time	0 - 60000 ms	1 ms	0 ms
Maximum Retry Time	0 - 60000 ms	1 ms	0 ms

Remote Communications Port 3			
Setting	**Range**	**Step**	**Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Baud Rate	300 - 38400 Baud		38400
Stop Bits	1 - 2		1
Parity	None / Even / Odd		None
RX Time between Character	1 - 60000 ms	0.5 ms	40 ms
Communication Failure Indication Time	0 - 600 s	0.1 s	60 s
Advanced Settings			
Flow Control			
CTS Flow	0 (NO) - 1 (YES)		NO
DSR Flow	0 (NO) - 1 (YES)		NO
DSR Sensitive	0 (NO) - 1 (YES)		NO
DTR Control	Inactive / Active / Permit send		Inactive
RTS Control	Inactive / Active / Permit send		Inactive
Time			
Tx Time Factor	0 -100 characters	0.5	1
Tx Time Constant	0 - 60000 ms	1 ms	0 ms
Message Modification			
Number of Zeros	0 - 255	1	0
Collisions			
Type of Collision	NO / DCD - ECHO		NO
Number of Retries	0 - 3	1	0
Minimum Retry Time	0 - 60000 ms	1 ms	0 ms
Maximum Retry Time	0 - 60000 ms	1 ms	0 ms

Remote Communications Ports 1, 2 and 3 Ethernet			
Setting	**Range**	**Step**	**Default**
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Enabling the Ethernet Port	NO / YES		YES
IP Address	ddd. ddd. ddd. ddd		192.168.1.151(PR1) 192.168.1.61(PR2) 192.168.1.71(PR3)
Net Mask	128.000.000.000 - 255.255.255.254		255.255.255.0
Port Number	0 - 65535	1	20000
Max. Time between Messages TCP	0 - 65 s	1	30
RX Car. Time	0 - 60000 ms	0.5 ms	1 ms
Communication fault indication time	0 - 600 s	0.1 s	60 s
Protocol 1 (2IRX-***-******-*M*)			
Protocol Selection	PROCOME DNP 3.0 MODBUS		PROCOME
Port Number	0 - 65535	1	32001
Protocol 2 (2IRX-***-******-*M*)			
Protocol Selection	PROCOME DNP 3.0 MODBUS		DNP 3.0
Port Number	0 - 65535	1	20000

Communications Protocols			
Setting	**Range**	**Step**	**Default**
PROCOME Protocol			
IED Address	0 - 254	1	0
Communications Password Enable	YES / NO		NO
Communications Password Timeout	1 - 10 min	1	10 min
Communications Password	8 characters		
DNP 3.0 Protocol			
IED Address	0 - 65519	1	1
T. Confirm Timeout	100 - 65535 ms	1	1000 ms
Max. Retries	0 - 65535	1	0
Enable Unsolicited	YES / NO		NO
Unsolicited Start Enable	YES / NO		
Unsolic. Master No.	0 - 65519	1	1
Unsolic. Grouping Time.	100 - 65535 ms	1	1000 ms
Sync Interval	0 - 120 min	1	0 min
Unsolicited Start Activation	YES / NO		
DNP 3.0 Revision	Standard ZIV / 2003		
DNP 3.0 Protocol: Measurements (16 Deadband Measurements Change)	0.01 - 100	0.01	100
DNP 3.0 Profile II Protocol: Measurements (16 Deadband Measurements Change)	0.0001 - 100	0.0001	100
Digital Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 1
Analog Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 2
Counters Changes Class (DNP 3.0 Profile II and Profile II Ethernet)	CLASS 1, CLASS 2, CLASS 3, NONE		CLASS 3
Validity Status for Digital Inputs (DNP 3.0 Profile II and Profile II Ethernet)	YES / NO		YES
32 Bits Measurements (DNP 3.0 Profile II and Profile II Ethernet)	YES / NO		YES
Counters (max. 20) (DNP 3.0 Profile II and Profile II Ethernet)	1 - 32767	1	1
MODBUS Protocol			
IED Address	0 - 247	1	1

Communications Protocols			
Setting	**Range**	**Step**	**Default**
IEC-61850 Protocol			
Goose			
Goose Channel	LAN 1 / LAN 2		LAN 2
Goose Out Enable	YES / NO		YES
IP			
IP Address	ddd.ddd.ddd.ddd		
DHCP Enable	YES / NO		NO
Default Gateway	ddd.ddd.ddd.ddd		
Network Mask	ddd.ddd.ddd.ddd		
DNS Address	ddd.ddd.ddd.ddd		
SNTP			
SNTP enable	YES / NO		NO
Broadcast Synchronizing Enable	YES / NO		NO
Unicast Synchronizing Enable	YES / NO		NO
IP Address of Main SNTP Server	ddd.ddd.ddd.ddd		
IP Address of Secondary SNTP Server	ddd.ddd.ddd.ddd		
Time Delay of Unicast Validation	10 - 1000000 s	1 s	30 s
Time Delay of Unicast Error	10 - 1000000 s	1 s	30 s
Number of Connection Retries	1 - 10	1	3
Synchronizing Period	10 - 1000000 s	1 s	10 s
Period between Retries	10 - 1000000 s	1 s	10 s
Time Delay of Broadcast Validation	0 - 1000000 s	1 s	0 s
Time Delay of Broadcast Error	0 - 1000000 s	1 s	0 s
Maximum Synchronizing Time Difference	0 - 1000000 s	1 s	0 s
Ignore Synchronizing Leap Indicator	YES / NO		NO
Calculation of Synchronizing Status	Time Delay Leap Indicator		Time Delay
Ethernet (*)			
Redundancy Mode	No Redundancy Bondng Redund. PRP Redund.		No Redundancy
Channel Status Time	1 - 60 s	1 s	5 s
Bonding			
Link Check Interval	25 - 500 ms	25 ms	100 ms
PRP			
Supervision Frame Send Interval	0 - 30000 ms	500 ms	2000 ms
LSB of Destination MAC for Supervision Frames	0 - 255	1	0

(*) 2IRX-*6*-******* Models.**

- **Communications: HMI Access**

0 - CONFIGURATION	0 - NOMINAL VALUES	**0 - PORTS**
1 - OPERATIONS	1 - PASSWORDS	**1 - PROTOCOLS**
2 - ACTIVATE GROUP	**2 - COMMUNICATIONS**	
2 - CHANGE SETTINGS	3 - TIME AND DATE	
3 - INFORMATION	4 - DISPLAY CONTROLS	
	5 - DISP. LIGHT. T.OUT	
	6 - COMMAND BUTTONS	

Ports / CAN Ports

0 - PORTS	**0 - CAN**	**0 - BAUDRATE**
1 - PROTOCOLS	1 - LOCAL PORT	**1 - COMMS FAIL IND. TIME**
	2 - REMOTE PORT 1	
	3 - REMOTE PORT 2	
	4 - IRIG-B	

Ports / Local Port

0 - PORTS	0 - CAN	**0 - BAUDRATE**
1 - PROTOCOLS	**1 - LOCAL PORT**	**1 - STOP BITS**
	2 - REMOTE PORT 1	**2 - PARITY**
	3 - REMOTE PORT 2	**3 - RX TIME BTW. CHAR**
	4 - IRIG-B	**4 - COMMS FAIL IND. TIME**

Ports / Remote Ports 1 and 2

0 - PORTS	0 - CAN	**0 - PROTOCOL SELECT.**
1 - PROTOCOLS	1 - LOCAL PORT	**1 - BAUDRATE**
	2 - REMOTE PORT 1	**2 - STOP BITS**
	3 - REMOTE PORT 2	**3 - PARITY**
	4 - IRIG-B	**4 - RX TIME BTW. CHAR**
		5 - COMMS FAIL IND. TIME
		6 - ADVANCED SETTINGS

0 - PROTOCOL SELECT.	
1 - BAUDRATE	
2 - STOP BITS	
3 - PARITY	**0 - OPERATING MODE**
4 - RX TIME BTW. CHAR	**1 - TIME**
5 - COMMS FAIL IND. TIME	**2 - MESSAGE MODIF.**
6 - ADVANCED SETTINGS	**3 - COLLITIONS**

0 - OPERATING MODE	**0 - TX TIME FACTOR**
1 - TIME	**1 - TX TIMEOUT CONST.**
2 - MESSAGE MODIF.	**2 - STOP BYTES 485**
3 - COLLITIONS	

0 - OPERATING MODE	
1 - TIME	
2 - MESSAGE MODIF.	**0 - NUMBER OF ZEROS**
3 - COLLITIONS	

0 - OPERATING MODE	**0 - COLLISION TYPE**
1 - TIME	**1 - MAX RETRIES**
2 - MESSAGE MODIF.	**2 - MIN RETRY TIME**
3 - COLLITIONS	**3 - MAX RETRY TIME**

Ports / Ethernet Remote Ports 1, 2 and 3

0 - PORTS	0 - LOCAL PORT	
1 - PROTOCOLS	**1 - REMOTE PORT 1**	
	2 - REMOTE PORT 2	**0 - PROTOCOL SELECT**
	3 - REMOTE PORT 3	**1 - UART**
	4 - IRIG-B	**2 - ETHERNET**

0 - PROTOCOL SELECT	**0 - BAUDRATE**
1 - UART	**1 - STOP BITS**
2 - ETHERNET	**2 - PARITY**
	3 - RX TIME BTW. CHAR
	4 - COMMS FAIL IND.TIME
	5 - ADVANCED SETTINGS

0 - BAUDRATE	
1 - STOP BITS	
2 - PARITY	**0 - OPERATING MODE**
3 - RX TIME BTW. CHAR	**1 - TIME**
4 - COMMS FAIL IND. TIME	**2 - MESSAGE MODIF.**
5 - ADVANCED SETTINGS	**3 - COLLITIONS**

0 - PROTOCOL SELECT.	**0 - ETHERNET PORT**
1 - UART	**1 - IP ADDRESS**
2 - ETHERNET	**2 - SUBNET MASK**
	3 - PORT NUMBER
	4 - KEEPALIVE TIME
	5 - RX TIME BTW. CHAR
	6 - COMMS FAIL IND.TIME

Ports / Ethernet Remote Ports 1, 2 and 3 (2IRX-***-******-*M*)

0 - PORTS	0 - LOCAL PORT	**0 - ETHERNET PORT**
1 - PROTOCOLS	**1 - REMOTE PORT 1**	**1 - IP ADDRESS**
	2 - IRIG-B	**2 - SUBNET MASK**
		3 - KEEPALIVE TIME
		4 - RX TIME BTW. CHAR
		5 - COMMS FAIL IND.TIME
		6 - PROTOCOL 1
		7 - PROTOCOL 2

0 - ETHERNET PORT	
1 - IP ADDRESS	
2 - SUBNET MASK	
3 - KEEPALIVE TIME	
4 - RX TIME BTW. CHAR	
5 - COMMS FAIL IND.TIME	
6 - PROTOCOL 1	**0 - PROTOCOL SELECT**
7 - PROTOCOL 2	**1 - PORT NUMBER**

0 - ETHERNET PORT	
1 - IP ADDRESS	
2 - SUBNET MASK	
3 - KEEPALIVE TIME	
4 - RX TIME BTW. CHAR	
5 - COMMS FAIL IND.TIME	
6 - PROTOCOL 1	**0 - PROTOCOL SELECT**
7 - PROTOCOL 2	**1 - PORT NUMBER**

Ports / IRIG-B

0 - PORTS	0 - CAN	
1 - PROTOCOLS	1 - LOCAL PORT	
	2 - REMOTE PORT 1	
	3 - REMOTE PORT 2	
	4 - IRIG-B	**0 - IRIG-B TIME TYPE**

Protocols / Procome Protocol

0 - PORTS	**0 - PROCOME PROTOCOL**	**0 - UNIT NUMBER**
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	**1 - COMMS PASSW. ENABLE**
	2 - MODBUS PROTOCOL	**2 - COMMS PASSW. TIMEOUT**
	3 - IEC 61850	**3 - COMMS PASSW.**
	4 - TCP/IP	

Protocols / DNP 3.0 Protocol

0 - PORTS	0 - PROCOME PROTOCOL	**0 - RELAY NUMBER**
1 - PROTOCOLS	**1 - DNP 3.0 PROTOCOL**	**1 - T. CONFIRM TIMEOUT**
	2 - MODBUS PROTOCOL	**2 - MAX RETRIES**
	3 - IEC 61850	**3 - HAB. UNSOLICITED**
	4 - TCP/IP	**4 - UNSOL. PICKUP ACT.**
		5 - UNSOLIC. MASTER NO.
		6 - UNSOL. GROUPING TIME
		7 - SYNCR. INTERVAL
		8 - BINARY CLASS
		9 - ANALOG CLASS
		10 - COUNTER CLASS
		11 - BINARY STATUS
		12 - 32 BIT ANALOG INP.
		13 - MEASURES
		14 - COUNTERS

Protocols / Modbus Protocol

0 - PORTS	0 - PROCOME PROTOCOL	
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	
	2 - MODBUS PROTOCOL	**0 - UNIT NUMBER**
	3 - IEC 61850	
	4 - TCP/IP	

Protocols / IEC 61850 Protocol

0 - PORTS	0 - PROCOME PROTOCOL	
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	
	2 - MODBUS PROTOCOL	**0 - GOOSE CHANNEL**
	3 - IEC 61850	**1 - ENBLGOOSEOUT**
	4 - TCP/IP	

Protocols / TCP/IP Protocol

0 - PORTS	0 - PROCOME PROTOCOL	
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	
	2 - MODBUS PROTOCOL	**0 - LAN 1**
	3 - IEC 61850	**1 - LAN 2**
	4 - TCP/IP	**2 - SNTP**

0 - PROCOME PROTOCOL		**0 - IP ADDRESS**
1 - DNP 3.0 PROTOCOL		**1 - ENABLE DHCP**
2 - MODBUS PROTOCOL	**0 - LAN 1**	**2 - DEFAULT GATEWAY**
3 - IEC 61850	**1 - LAN 2**	**3 - NETWORK MASK**
4 - TCP/IP	2 - SNTP	**4 - DNS ADDRESS**

0 - PROCOME PROTOCOL		**0 - ENABLESNTP**
1 - DNP 3.0 PROTOCOL		**1 - ENBL_BROADCASTSNTP**
2 - MODBUS PROTOCOL	0 - LAN 1	**2 - ENBL_UNICASTSNTP**
3 - IEC 61850	1 - LAN 2	**3 - MAINSNTPSRV**
4 - TCP/IP	**2 - SNTP**	**4 - BACKUPSNTPSRV**
		5 - UNICAST VALID TIME
		6 - UNICAST ERROR TIME
		7 - RETRY ATTEMPTS
		8 - SYNC PERIOD
		9 - RETRY PERIOD
		10 - BRDCST VALID TIME
		11 - BRDCST ERROR TIME
		12 - MAX TIME DIF
		13 - SNTP_IGNORELEAPIND
		14 - SNTP_SYNCSTATECALC

Protocols / IEC 61850 Protocol (2IRX-*6*-*********)

0 - PORTS	0 - PROCOME PROTOCOL	**0 - ETHERNET**
1 - PROTOCOLS	1 - DNP 3.0 PROTOCOL	**1 - IP**
	2 - MODBUS PROTOCOL	**2 - GOOSE**
	3 - IEC 61850	**3 - SNTP**

0 - ETHERNET	**0 - REDUNDANCY MODE**
1 - IP	**1 - CHANNEL LIVE TIME**
2 - GOOSE	**2 - BONDING**
3 - SNTP	**3 - PRP**

0 - ETHERNET	0 - REDUNDANCY MODE	
1 - IP	1 - CHANNEL LIVE TIME	
2 - GOOSE	**2 - BONDING**	**0 - LINK CHK INTERVAL**
3 - SNTP	3 - PRP	

0 - ETHERNET	0 - REDUNDANCY MODE	
1 - IP	1 - CHANNEL LIVE TIME	
2 - GOOSE	2 - BONDING	**0 - SUPERV TX INTERVAL**
3 - SNTP	**3 - PRP**	**1 - SUP LSB DEST MAC**

0 - ETHERNET		**0 - IP ADDRESS**
1 - IP	**0 - LAN 1**	**1 - ENABLE DHCP**
2 - GOOSE	**1 - LAN 2**	**2 - DEFAULT GATEWAY**
3 - SNTP		**3 - NETWORK MASK**
		4 - DNS ADDRESS

0 - ETHERNET	
1 - IP	**0 - GOOSE CHANNEL**
2 - GOOSE	**1 - ENBLGOOSEOUT**
3 - SNTP	

0 - ETHERNET	**0 - ENABLESNTP**
1 - IP	**1 - ENBL_BROADCASTSNTP**
2 - GOOSE	**2 - ENBL_UNICASTSNTP**
3 - SNTP	**3 - MAINSNTPSRV**
	4 - BACKUPSNTPSRV
	5 - UNICAST VALID TIME
	6 - UNICAST ERROR TIME
	7 - RETRY ATTEMPTS
	8 - SYNC PERIOD
	9 - RETRY PERIOD
	10 - BRDCST VALID TIME
	11 - BRDCST ERROR TIME
	12 - MAX TIME DIF
	13 - SNTP_IGNORELEAPIND
	14 - SNTP_SYNCSTATECALC

3.33.8 Communications Test

In order to proceed with the communications testing the relay must be supplied with the nominal voltage. Then the “In Service” LED must light up.

3.33.8.a PROCOME Protocol Test

The testing shall be performed through the three communications ports (one front and two rear [P1 and P2] ports), which must be set as follows:

Baud rate	38,400 bauds
Stop bits	1
Parity	1 (even)

All ports shall be assigned the PROCOME protocol in order to use the ***ZivercomPlus***® communications program in all of them.

Connect with the relay through the front port via a male DB9 cable. Synchronize the time through the ***ZivercomPlus***® program. Disconnect the relay and wait for two minutes. Then, supply power to the relay again and connect with the relay through both rear ports. Finally set the ***ZivercomPlus***® program to cyclic and check that the time updates properly with both P1 and P2 connected.

3.33.8.b DNP v3.0 Protocol Tests

The main objects to test are:

1	0	Binary Input – All variations
1	1	Binary Input

The relay is asked about the state in that instant of the IED's status contact input signals (digital inputs, digital outputs, logic signals) configured to be sent via DNP v3.0.

2	0	Binary Input Change – All variations
2	1	Binary Input Change without Time
2	2	Binary Input Change with Time
2	3	Binary Input Change with Relative Time

The relay is asked about the control changes generated by the status contact input signals configured to be sent via DNP v3.0. They can be all the changes, without time, with time or with relative time.

10	0	Binary Outputs – All variations

The relay is asked about the state of the writings of outputs configured in the relay.

12	1	Control Relay Output Block

The operations sent through communications are tested on the IED.

20	0	Binary Counter – All variations
20	1	32-bit Binary Counter
21	0	Frozen Counter – All variations
21	1	32-bit Frozen Counter
22	0	Counter Change Event – All variations

A request is made for the value of the counters included in the IED's logic. These counters can be 32-bits binary or frozen counters. A request is also made for the changes generated by the value of these counters.

30	0	Analog Input – All variations
30	2	16-Bit Analog Input

A request is made for the value of the IED's analog inputs at that precise moment.

32	0	Analog Change Event – All variations
32	4	16-Bit Analog Change Event with Time

A request is made for the control changes generated by the variation in the value of the IED's analog channels.

40	0	Analog Output Status – All variations

The relay is asked about the state at that precise moment of the value of the IED's analog outputs.

41	2	16-Bit Analog Output Block

The relay is asked about the state at that precise moment of the value of the IED's 16-bit analog outputs.

50	1	Time and Date

The IED's date and time are synchronized.

52	2	Time Delay Fine

The relay is asked about the communications delay time. It is measured from the time the relay receives the first bit of the first byte of the question until the transmission of the first bit of the first byte of the IED's response.

60	1	Class 0 Data
60	2	Class 1 Data
60	3	Class 2 Data
60	4	Class 3 Data

The relay is asked about the various data defined in the relay as Class 0, Class 1, Class 2 and Class 3.

Within these requests, the IED's generation and sending of Unsolicited Messages for each of the different kinds of data is tested.

-

80	1	Internal Indications

The IED's Internal Indication bit (IIN1-7 bit Device Restart) is reset.

--	--	No Object (Cold Start)

When the IED receives a “Cold Load Pickup” object, it must answer with a message object “Time Delay Fine” and with a reset of the internal indication bit IIN1-7 (Device Restart).

--	--	No Object (Warm Start)

When the IED receives a “Warm Load Pickup” object, it must answer with a message object “Time Delay Fine” and with a reset of the internal indication bit IIN1-7 (Device Restart).

--	--	No Object (Delay Measurement)

The IED must answer with a communications object “Time Delay Fine.”

The Broadcast addresses are tested and the indications corresponding to “All Stations” with each of them.

3.34 Integrated Simulator

3.34.1 Description

The **IRX** IED is provided with a special test and simulation mode of the implemented units which allows to upload an external oscillogram through any of the communication ports used by the PROCOME protocol. Oscillograms captured by the equipment itself or by other equipment can be used. In the latter case, an external program will prepare the oscillogram for this purpose (adaptation of the sampling frequency and scale).

Once an oscillogram is sent through the ***ZivercomPlus***® program, the equipment enters into **Oscillogram Simulation Mode**, from which it can exit through an activation pulse of the **Oscillogram Simulation Cancellation** input. The simulation will only commence when, with the equipment in oscillogram simulation mode, one of the following two conditions is fulfilled:

- Reception of an activation pulse of the **Oscillogram Simulation Start** input, provided that the **Trigger Enable Via Digital Signal** setting is set at **YES**.
- The time of the IED reaches the time set in the uploaded oscillogram, provided that the **Time Trigger Enable** setting is set at **YES**.

Once the simulation is complete, the equipment exits the oscillography simulation mode after 5 seconds. To return to this mode, without having to upload a new oscillogram, if the relay already has one (it always considers the last oscillogram, either collected by it or previously uploaded through communications), it is only necessary to activate the **Start Oscillogram Simulation Mode** input.

With the start of the simulation, the relay suspends the capture of samples from the analog-digital converter and carries out a reading, from the memory, of the samples contained in the oscillogram, operating with samples read in the same manner as those captured.

The oscillogram storage operates in normal mode, such that the waveforms captured can be compared with those read.

Given that the simulation function is also considered for use with equipment already installed, as part of the maintenance practices, it may be necessary to impede the real actuation of the relay over its physical environment; for this reason, it is possible to disable the following resources through setting:

- **Physical Digital Inputs**: when the **Digital Input Simulation** setting is set at **YES**, the equipment ignores the state of the physical digital inputs, which are substituted by the logical signals of the oscillogram configured as digital inputs.
- **Switching Outputs**: when the **Trip and Close Contact Operation Enable** setting is set at **NO**, the equipment ceases to act on the switching outputs.
- **Auxiliary Outputs**: when the **Auxiliary Output Operation Enable** setting is set at **NO**, the equipment ceases to act on the auxiliary outputs.

3.34.2 Integrated Simulator Settings

Integrated Simulator			
Setting	**Range**	**Step**	**Default**
Trigger enable via digital signal	YES / NO		NO
Time trigger enable	YES / NO		NO
Digital input simulation	YES / NO		NO
Trip and close contact operation enable	YES / NO		NO
Auxiliary output operation enable	YES / NO		NO

3.34.3 Digital Inputs of the Integrated Simulator

Table 3.34-1: Digital Inputs of the Integrated Simulator		
Name	**Description**	**Function**
INST_MODE_SIM	Oscillogram simulation mode start input	Activation of this input takes the equipment to the oscillogram simulation mode.
IN_ST_SIM_OSC	Oscillogram simulation start input	Activation of this input starts simulation.
INCNCL_SIMOSC	Oscillogram simulation cancellation input	Activation of this input removes the equipment from the oscillogram simulation mode state.

3.34.4 Auxiliary Outputs of the Integrated Simulator

Table 3.34-2: Auxiliary Outputs of the Integrated Simulator		
Name	**Description**	**Function**
FILE_LOADED	File uploaded	An oscillogram is received to carry out simulation.
MODE_SIM_OSC	Oscillogram simulation mode	The equipment is in oscillogram simulation mode.
PU_SIM_OSC	Simulation picked up	The equipment has started a simulation.

3.35 Fault Locator

3.35.1 Fault Locator Settings

3.35.1.a Line Impedance

The settable electrical parameters of the line are: **Positive Sequence Magnitude**, **Positive Sequence Angle, Zero Sequence Angle** and **K0 Factor**, where all values are secondary ohms.

The **K0 Factor** setting allows you to define the zero sequence compensation factor (**Z_0 = k_0 x Z_1**).

3.35.1.b 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.

3.35.1.c Configuration of the Fault Locator

- **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, kilometres 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.

- **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 **Indication Duration** 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 **Indication Duration** 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.

- **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 **Minimum Zero Sequence Current 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 **Inside Line**, information is available for faults located inside the defined length for the protected line.

With the option **Inside and Outside**, information is available for any fault independent of the location being inside or outside of the defined length.

t is important to consider the setting **Pickup Report** described in section 3.24.6.

With the option **Inside Line** is possible to consider the pickup of the units. In any case all the faults are detected

The option Inside and Outside requires to set 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 report.

3.35.2 Phase Selector

The Fault Locator uses the **Phase Selector** (see 3.4) to determine the type of fault. Then the algorithm for each type of fault determines the distance to the fault.

3.35.3 Location of Faults with 2 VTs and 3VTs

To locate faults, it is necessary to set the line parameters (impedances of positive and zero sequences) to secondary values. Line impedance in primary ohms becomes secondary ohms as follows:

$$\Omega_{SECONDARY} = \Omega_{PRIMARY} \cdot (PCTR/VTR)$$

where

PCTR is the transformation ratio of the phase currents and
VTR is the transformation ratio of the voltages

When the IED is configured for 3 voltage transformers, these parameters are sufficient to calculate the distance to the fault. Depending on the **Locator Units** selected, the **Line Length** setting will be used or not. It will be taken into account when **Line Length Units** have been selected instead of **%**.

When the IED is configured for 2 voltage transformers (phase-to-phase voltages), it is also necessary to set the **Zero Sequence Impedance of the Local Source**; its magnitude is also set in secondary ohms. This way, the zero sequence voltage that flows through the fault can be calculated.

3.35.4 Configuration of the Fault Locator

As indicated in section 3.36.1, the Fault Locator has two settings for sending the distance through remote communications (in the control profile):

Indication Duration: 1 - 120 min

If the **Permanent Indication** setting is **NO**, the locator takes the **Indication Duration** 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.

Also as stated in section 3.36.1, 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.

3.35.5 Location Information

- **From Display**

The indication of the distance to the fault can be set to be offered either in line length units (kilometres 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. When the fault is unknown, however, the distance will be filled in with asterisks and the type of fault will be 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.

With the ***ZivercomPlus***® 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

To create a profile like that of figure 3.36.3, 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

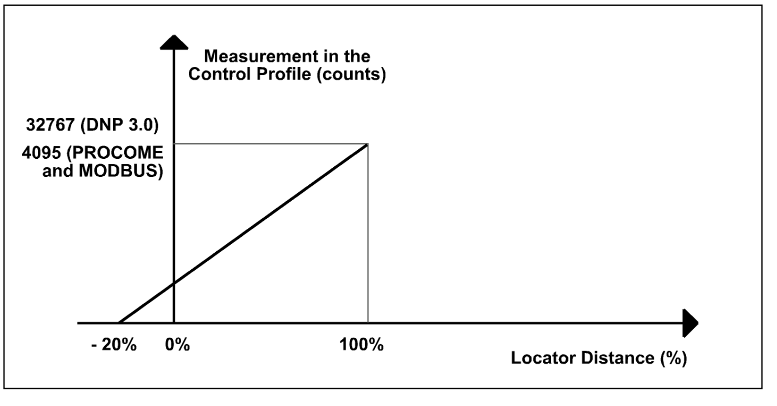


Figure 3.35.1 Scale of the Locator Measurements in the Control Profile.

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 **Indication Duration**.

There is another input to the fault locator module, the **Restore the Distance to the Fault** 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.

3.35.6 Fault Locator Settings

Capacitive Transformer			
Setting	**Range**	**Step**	**Default**
Capacitive VT	YES / NO		NO

Length and Units			
Setting	**Range**	**Step**	**Default**
Line length	0.1 - 1000	0.01	100
Line length unit	0:Km 1: Miles		Km
Locator unit	0: Length units 1: % of Length		% of Length

Line Impedance			
Setting	**Range**	**Step**	**Default**
Positive Sequence Magnitude	0.01 - 250 Ω	0.01 Ω	0.01 Ω
Positive Sequence Angle	15 - 90º	1º	75º
Z1 K0 Factor	1 - 20	0.01	1
Zero Sequence Angle	15º - 90º	1º	75º

Local Source Impedance			
Setting	**Range**	**Step**	**Default**
Zero Sequence Magnitude	0.01 - 50 Ω	0.01 Ω	1.25 Ω
Zero Sequence Angle	25º - 90º	1º	75º

Indication			
Setting	**Range**	**Step**	**Default**
Permanent Indication	YES / NO		NO
Time Indication	1 - 120 min	1 min	5 min
Zero Sequence Min. Value	0 - 500 A	0.01 A	0 A
Indication zones	0: Internal Faults 1: Internal and External		0: Internal Faults

- **Fault Locator: HMI Access**

0 - CONFIGURATION	0 - GENERAL	0 - SOBREINTENSIDAD
1 - OPERATIONS	**1 - PROTECTION**	...
2 - ACTIVATE GROUP	2 - RECLOSER	**17 - LOCALIZADOR**
3 - CHANGE SETTINGS	3 - LOGIC	...
4 - INFORMATION	...	

0 - OVERCURRENT	**0 - LENGTH AND UNITS**
...	**1 - LINE IMPEDANCE**
17 - FAULT LOCATOR	**2 - LOCAL SOURCE Z**
...	**3 - INDICATION**

Length and Units

0 - LENGTH AND UNITS	**0 - LINE LENGTH**
1 - LINE IMPEDANCE	**1 - LENGTH UNITS**
2 - LOCAL SOURCE Z	**2 - LOCATOR UNITS**
3 - INDICATION	

Line Impedance

0 - LENGTH AND UNITS	**0 - POS. SEQ. MAGNITUDE**
1 - LINE IMPEDANCE	**1 - POS. SEQ. ANGLE**
2 - LOCAL SOURCE Z	**2 - ZERO SEQ. ANGLE**
3 - INDICATION	**3 - Z1 K0 FACTOR**

Local Source Impedance

0 - LENGTH AND UNITS	**0 - ZERO SEQ. MAGNITUDE**
1 - LINE IMPEDANCE	**1 - ZERO SEQ. ANGLE**
2 - LOCAL SOURCE Z	
3 - INDICATION	

Indication

0 - LENGTH AND UNITS	**0 - PERMANENT INDICATION**
1 - LINE IMPEDANCE	**1 - TIME INDICATION**
2 - LOCAL SOURCE Z	**2 - ZERO SEQ. MIN VALUE**
3 - INDICATION	**3 - INDICATION ZONE**

3.36 Current Transformers Dimensioning

3.36.1 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.

3.36.2 CT Dimensioning According to Different Standards

3.36.2.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.

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:

$$Ktf = \frac{w \cdot T1 \cdot T2}{T1 - T2} \cdot \cos\theta \cdot (e^{\frac{-t}{T1}} - e^{\frac{-t}{T2}}) + \sin\theta \cdot e^{\frac{-t}{T2}} - \sin(wt + \theta)$$ (3.36.1), 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).

3.36.2.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.

3.36.2.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 3.36.1).

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.

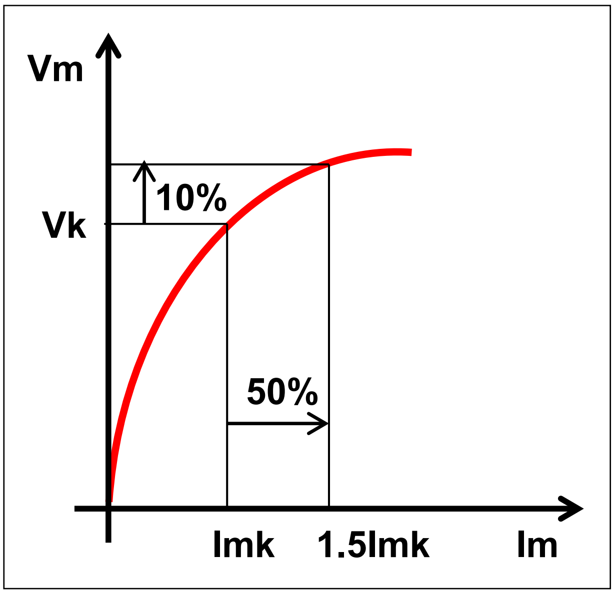


Figure 3.36.1 Knee Point Voltage Definition.

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

3.36.3 CT Dimensioning for Different Protection Functions

Table 3.36-1 includes general parameters to be considered for the calculation of CT dimensioning factors.

Table 3.36-2 includes the saturation free times (for Ktf calculation) and current values (for Kssc calculation) that must be used for CT dimensioning.

Table 3.36-1: 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 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 2).	(s)

Table 3.36-2: 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. f = 50 Hz	t (s) f = 60 Hz	IF (fault current to calculate Kssc)
87T/87B/87L	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	$10x10^{-3}$ (s)	$8.3x10^{-3}$ (s)	$IF = IF_{pickup50}$ (instantaneous overcurrent unit pickup in primary value). $IFpickup50 \approx 0.7 \cdot (IF_2)$ 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% (IF0%)
	Internal fault at 0% of the line	$8.4x10^{-3}$ (s)	$7 x10^{-3}$ (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)	$IF = IF_{80\%}$

3.36.3.a Remanence Factor

If close onto fault conditions may occur, a remanence factor should be considered.

A recommended value may be Kr=50%--> Krem=2

3.36.3.b Ktf Factor

The following tables include different ktf values calculated according to the formula (3.36e formula (3.36.1). 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/87B/87L	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	2.91	2.81	2.3	2.3
	≤ 0.02	3.25	3.17	2.6	2.5
	≤ 0.03	3.38	3.33	2.7	2.6
	≤ 0.04	3.46	3.42	2.7	2.7
	≤ 0.05	3.51	3.47	2.7	2.7
	≤ 0.08	3.58	3.56	2.8	2.8
	≤ 0.1	3.61	3.59	2.8	2.8
	≤ 0.2	3.66	3.65	2.8	2.8
	≤ 0.3	3.68	3.67	2.8	2.8

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.

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

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

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

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

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

Chapter 4.

Maintenance and Troubleshooting

4.1 Alarm Codes

4.1.1 Introduction

IRX models notify the occurrence of alarms by 3 routes:

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

4.1.2 Activation of Signal and Alarm Generation Event

The IED has 2 digital 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.

4.1.3 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 its processing to any of the communications protocols for transmission. Next Table shows the possible causes of alarm coded by alarm magnitude, together with their level of severity.

Table 4.1-1: Alarm Status Magnitude and Severity Level

Alarm	Value	Severity
Error read settings	0x00000001	CRITICAL
Non-calibrated relay	0x00000010	NON-CRITICAL
Protection operation error	0x00000020	CRITICAL
Error write settings	0x00000040	CRITICAL
Non-critical error in A/D converter	0x00000080	NON-CRITICAL
Critical error in A/D converter	0x00000100	CRITICAL
Loss of content in non-volatile RAM	0x00000200	NON-CRITICAL
Error in internal clock operation	0x00000400	NON-CRITICAL
Digital I/O Operation Error	0x00002000	CRITICAL
Error read/write from FLASH	0x00008000	CRITICAL
Error lack of VCC	0x00080000	CRITICAL
Error IEC 61850	0x00100000	NON-CRITICAL
Error signals	0x00200000	CRITICAL
Error in configuration	0x00800000	NON-CRITICAL
Program error	0x01000000	CRITICAL
Communications Port Error	0x10000000	NON-CRITICAL

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

4.1.4 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.

4.1.5 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 or Traps counter increment.

4.1.6 Common Repairs

Table 4.1-2: Overall Problems		
Relay does not go on	- Check the power supply matches the nameplate data and the external wiring diagram. - Check the alarm output status.	- Increase relay power supply. - If the alarm output is not activated and the relay is communicating, then the problem rests probably on the front panel or cable connected to the front panel.
Digital input does not activate	- Check the polarity. - Check AC voltage. - Check input activation on the screen. - Check supervision input configuration.	- Check the external wiring. - Check the digital inputs and cable outputs (50 pins).
Digital output is not operating	- Remove the external wiring. - Activate the digital output and check the impedance between terminals. - Check the activation of the digital output on the screen.	- Check varistor condition. - Change the relay with the damaged contact. - If the output is not operating check the digital inputs and cable outputs (50 pins). - Check the output configuration in the logic.
Analog input loss	- Check the presence of voltage / current at the analog signal input.	- Calibrate the relay again.

Table 4.1-2: Overall Problems		
No communications through front port	- Compare relay communications settings with laptop PC settings (both must coincide). - Check the communications cable PIN 2 at one end is connected to PIN 3 at the other end. PIN 5 is connected to PIN 5 at the other end. - Communicate through another serial port.	- Can communicate with other ZIV relays? - Test the communications with any other laptop PC. - Check the front panel cable (50 pins).
No communications through rear port	- Check protocol communications and configuration.	- Change the communications port.

4.2 Troubleshooting

4.2.1 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.

4.2.2 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 4.1, Alarm Codes.

The alarms generated by the self-checking module are divided in two levels, critical and non-critical alarms (table located in Chapter 4.1, 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.

4.2.3 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 4.2-1: 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 taking into account the external connection drawing of the device	In the device is in service status and the “ready” LED and display are not switched on, the problem is located in the frontal card of the relay or in the internal cables. If the device is in alarm status the problem is located in the power supply module or in the internal cables. In both situations contact your supplier and the Quality Department of ZIV.

4.2.4 In Service / Alarm Contact

Table 4.2-2: In Service / Alarm Contact		
Test	**Check**	**Actions**
1	Access through the MMI or with the communication program (*Zivercomplus*®) 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 MMI and verify if it is a critical alarm taking into account the table located in the Chapter 4.1, Alarm Codes.	Contact your supplier and the Quality Department of ZIV.

4.2.5 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 4.2-3: 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.
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 of 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 of 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.

Table 4.2-3: 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 of 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 of 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 of the Quality Department of ZIV.
	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 4.1, Alarm Codes.	Contact your supplier of the Quality Department of ZIV.

- **Non IEC61850 Devices**

Table 4.2-4: Error Messages during Power Up – Non 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 4.1, Alarm Codes.	Contact your supplier of the Quality Department of ZIV.

4.2.6 Error Messages when the Relay is in Normal Operation

Table 4.2-5: Error Messages when the Relay is in Normal Operation		
Test	**Check**	**Actions**
1	If there is an error message in the MMI, check which kind of error it is according to the table that appears in Chapter 4.1, Alarm Codes.	Contact your supplier of the Quality Department of ZIV.

4.2.7 Errors while Communicating

Table 4.2-6: Errors while Communicating

Test	Check	Actions
1	If a communication error takes place when trying to communicate with *Zivercomplus®* 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 USB cable and you have all the drivers installed. - That the communication parameters of the device and the ones set in *Zivercomplus®* fit. Click two times in the screen of *Zivercomplus®* 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.
2	If a communication error takes place when trying to communicate with *Zivercomplus®* program through the frontal port with the following message: Cannot locate the identifier corresponding profile: XXXX.	Close *Zivercomplus®* program, update the database and run again *Zivercomplus®* in order to communicate with the relay.
3	If a communication error takes place when trying to communicate with *Zivercomplus®* program through the serial rear ports of the relay.	Verify: - That you are using a crossed cable (5-5, 2-3). - That the communication parameters of the device and the ones set in *Zivercomplus®* fit. - That the protocol of the rear port has been set to PROCOME. Click two times in the screen of *Zivercomplus®* 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 *Zivercomplus®* program through the Ethernet serial rear ports or the LAN ports of the relay.	Verify: - The IP address of the relay is the same one set in *Zivercomplus®*. - That the TCP port set in *Zivercomplus®* is 32001. - That the LAN parameter selected in *Zivercomplus®* is 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.

Table 4.2-6: Errors while Communicating

Test	Check	Actions
5	Errors when communicating in Modbus and DNP3 through the serial remote ports.	Verify: - That you are using a crossed cable. - That the communication parameters of the device and the ones set in Zivercomplus fit. - That the rear port in the relay has been set with the appropriate protocol. - That the control configuration of the relay has the addresses requested by the client. If you cannot communicate, verify the correct behavior of the port trying to communicate in PROCOME with *Zivercomplus*®. 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 and DNP3 through the serial Ethernet ports.	Verify: - The IP address of the relay is the same one set in *Zivercomplus*®. - That the TCP port fits. - The rear port is set with the appropriate protocol. - That the control configuration of the relay has the addresses requested by the client. - That the IP address of the PC/client belongs to the same 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 *Zivercomplus*®. If it works, check again the initial points. If it does not work, contact your supplier and the Quality Department of ZIV.
7	Errors when communicating in Modbus and DNP3 through the IEC61850 LAN ports.	Verify: - That the model supports DNP3 and MODBUS through the LAN IEC61850 ports as defined in the model selection. - The IP address of the relay is the same one set in the PC/client. - That the TCP port fits. - The rear port is set with the appropriate protocol. - That the control configuration of the relay has the addresses requested by the client. - That the IP address of the PC/client belongs to the same family address of the one set in the relay and the network masks are correct. - That the number of instances of each protocol have not been exceeded. - That there is no IEC61850 error in HMI of the relay (press ▲•). If you cannot communicate, verify the correct behavior of the port trying to communicate in PROCOME with *Zivercomplus*®. If it works, check again the initial points. If it does not work, contact your supplier and the Quality Department of ZIV.

4.2.8 Error in Digital Inputs

Table 4.2-7: Error in Digital Inputs		
Test	**Check**	**Actions**
1	Verify with a multimeter 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 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 *Zivercomplus®* 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 2.1, 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 of the relay. In any case contact your supplier and the Quality Department of ZIV.

4.2.9 Error in Digital Outputs

Table 4.2-8: Error in Digital Outputs		
Test	**Check**	**Actions**
1	If the output contacts are not operating.	Verify the control logic and the signals that activate the outputs. If it is correct, make the necessary actions in order to execute the control logic and give the closing command. Verify if the output is changing the status in the HMI 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.
2	If the TRIP contacts are not operating when there is a trip condition indicated in the HMI.	Verify that the protection unit is not taking into account the status of the breaker or other kind of factors. If the tripping condition is being complied but the trip contacts are not closed after verifying them with a multimeter and the external connection wiring diagram, contact your supplier and the Quality Department of ZIV.
3	If the CLOSE contacts are not operating when the relay gives a reclosing command.	Repeat the action to generate a new reclosing command, verifying that the command is generated in the events of the relay and the close contact is not closing (with a multimeter and the external connection wiring diagram). If the DO is not activating, contact your supplier and the Quality Department of ZIV.

4.2.10 Error in Input Transducers

Table 4.2-9: Error in Input Transducers

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 (front label of the relay and model selection).	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.

4.2.11 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 (external connection wiring diagram).
- 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.

4.2.12 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 numerical code inside brackets [xx] in the line which is located between the firmware model and the version and checksum. If so, collect the available information of the relay (events, logs, fault reports, disturbance recorder files, etc.) and contact your supplier and the Quality Department of ZIV.

A. PROCOME 3.0 Protocol

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**

A.2 Control Data

- **Control Metering (MEA-s)**

Configurable through the ***Zivercom***®: 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 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 neutral currents: **1.2 A** sends 4095 counts.
- Line-to-neutral and sequence voltages and harmonics: **(Rated value V / √3) + 20%** sends 4095 counts.
- Phase-to-phase 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 ***Zivercom***® 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.

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 ***Zivercom***®: 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 ***Zivercom***®: 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 ***Zivercom***®: 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 ***Zivercom***®: Any input or output logic signal from the protection modules or generated by the programmable logic.

B. DNP V3.00 Device Profiles Document

DNP V3.0 DEVICE PROFILE DOCUMENT This document must be accompanied by: **Implementation Table** and **Point List**.
Vendor Name: **ZIV Aplicaciones y Tecnología S.A.**
Device Name: **IRX**

Highest DNP Level Supported: For Requests 2 For Responses 2	Device Function: ☐ 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): Transmitted ____292____ Received ____292____	Maximum Application Fragment Size (octets): Transmitted _2048_ (if >2048, must be configurable) Received __249__(must be <= 249)
Maximum Data Link Re-tries: ☒ None ☐ Fixed at ______________ ☐ Configurable, range ___ to _____	Maximum Application Layer Re-tries: ☐ 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?
____

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.

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

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	

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

7	6	5	4	3	2	1	0
	Index Size			Qualifier Code			

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

IMPLEMENTATION TABLE

OBJECT			REQUEST (IRX parse)		RESPONSE (IRX 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

OBJECT			REQUEST (IRX parse)		RESPONSE (IRX 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 20,21	6,7,8 6	129,130	28	D
60	3	Class 2 Data	1 20,21	6,7,8 6	129,130	28	D
60	4	Class 3 Data	1 20,21	6,7,8 6	129,130	28	D
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.

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.**

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	

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.

Additional assign with *ZIVercomPlus*⑧:

Index	Description
16	***Configure by ZIVercomPlus⑧ 256 points***
17	***Configure by ZIVercomPlus⑧ 256 points***
18	***Configure by ZIVercomPlus⑧ 256 points***
19	***Configure by ZIVercomPlus⑧ 256 points***
20	***Configure by ZIVercomPlus⑧ 256 points***
21	***Configure by ZIVercomPlus⑧ 256 points***
22	***Configure by ZIVercomPlus⑧ 256 points***
23	***Configure by ZIVercomPlus⑧ 256 points***
24	***Configure by ZIVercomPlus⑧ 256 points***
25	***Configure by ZIVercomPlus⑧ 256 points***
26	***Configure by ZIVercomPlus⑧ 256 points***
27	***Configure by ZIVercomPlus⑧ 256 points***
....	***Configure by ZIVercomPlus⑧ 256 points***
62	***Configure by ZIVercomPlus⑧ 256 points***
63	***Configure by ZIVercomPlus⑧ 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**

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.

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.**

() 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.

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 %	

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**

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

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

DNP Protocol Configuration

- <u>Relay Number</u> (**RTU Address**):
  Remote Terminal Unit Address. Addresses 0xFFF0 to 0xFFFF are reserved as *Broadcast Addresses*.
- <u>T Confirm Timeout</u> **(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.
- <u>Max Retries</u> **(N7 Retries)** :
  Number of retries of the Application Layer after timeout while waiting for Confirmation.
- <u>Enable Unsolicited</u> **(Enable Unsolicited Reporting)** :
  Enables or disables Unsolicited reporting.
- <u>Enable Unsol. after Restart</u> :
  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.
- <u>Unsolic. Master No</u>. (**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.
- <u>Unsol. Grouping Time</u> **(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.
- <u>Synchronization Interval</u>
  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.
- <u>DNP 3.0 Rev</u>.
  Certification revision **STANDARD ZIV** or **2003** (DNP3-2003 Intelligent Electronic Device (IED) Certification Procedure Subset Level 2 Version 2.3 29-Sept-03)
- <u>Binary Changes CLASS</u>.
  Selection to send Binary Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- <u>Analog Changes CLASS</u>.
  Selection to send Analog Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- <u>Counter Changes CLASS</u>.
  Selection to send Counter Changes as CLASS 1 CLASS 2 CLASS 3 or None.
- <u>Binary Status</u> .
  Send Binary with status otherwise without status
- <u>32 Bits Analog Input</u> .
  Send Analog All Variations and Analog Change Event Binary Changes with 32 bits otherwise with 16 bits

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 .

DNP V3.00 Profile for 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: **IRX**

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?

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.

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

<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>

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

7	6	5	4	3	2	1	0
		Index Size		Qualifier Code			

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

IMPLEMENTATION TABLE

OBJECT			REQUEST (IRX parse)		RESPONSE (IRX 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

OBJECT			REQUEST (IRX parse)		RESPONSE (IRX 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 20,21	6,7,8 6	129,130	28	D
60	3	Class 2 Data	1 20,21	6,7,8 6	129,130	28	D
60	4	Class 3 Data	1 20,21	6,7,8 6	129,130	28	D
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.

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.**

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	

CONTROL RELAY OUTPUT BLOCK (OBJECT 12)		
Index	**Description**	
14	*Configure by ZIVercomPlus⑧* 256 points	
15	*Configure by ZIVercomPlus⑧* 256 points	
16	*Configure by ZIVercomPlus⑧* 256 points	
17	*Configure by ZIVercomPlus⑧* 256 points	
...	*Configure by ZIVercomPlus⑧* 256 points	
253	*Configure by ZIVercomPlus⑧* 256 points	
254	*Configure by ZIVercomPlus⑧* 256 points	
255	*Configure by ZIVercomPlus⑧* 256 points	

ANALOG INPUT (OBJECT 30) -> Assigned to Class 0. ANALOG INPUT CHANGE (OBJECT 32) -> Assign to Class		
Index	**Description**	**Deadband**
0	*Configure by ZIVercomPlus⑧* 256 points	Deadband_1.
1	*Configure by ZIVercomPlus⑧* 256 points	Deadband_2.
2	*Configure by ZIVercomPlus⑧* 256 points	Deadband_3.
3	*Configure by ZIVercomPlus⑧* 256 points	Deadband_4.
4	*Configure by ZIVercomPlus⑧* 256 points	Deadband_5.
5	*Configure by ZIVercomPlus⑧* 256 points	Deadband_6.
6	*Configure by ZIVercomPlus⑧* 256 points	Deadband_7.
7	*Configure by ZIVercomPlus⑧* 256 points	Deadband_8.
8	*Configure by ZIVercomPlus⑧* 256 points	Deadband_9.
9	*Configure by ZIVercomPlus⑧* 256 points	Deadband_10.
10	*Configure by ZIVercomPlus⑧* 256 points	Deadband_11.
11	*Configure by ZIVercomPlus⑧* 256 points	Deadband_12.
12	*Configure by ZIVercomPlus⑧* 256 points	Deadband_13.
13	*Configure by ZIVercomPlus⑧* 256 points	Deadband_14.
14	*Configure by ZIVercomPlus⑧* 256 points	Deadband_15.
15	*Configure by ZIVercomPlus⑧* 256 points	Deadband_16.

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**

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.

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.**

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.

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 %	

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.**

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

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.

C. MODBUS RTU Documentation Address Map

C.1 Preliminary Information

This a reference document for implementing the MODBUS RTU protocol in the **IRX** IED.

This document provides a detailed MODBUS address map (input status, coil status, input registers and force single coil) and their equivalent in the **IRX** 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 IRX

The MODBUS coil status address map for the **IRX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	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 ***ZivercomPlus***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.3 Function 02: Read Input Status

C.3.1 Modbus Address Map for IRX

The MODBUS input status address map for the **IRX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	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 ***ZivercomPlus***® 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 IRX

The MODBUS read holding registers address map for the **IRX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	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 ***ZivercomPlus***®: 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 ***ZivercomPlus***® program.

Non-configured addresses will be considered illegal and will return exception code 02 (Illegal Data Address).

C.5 Function 04: Read Input Registers

C.5.1 Modbus Address Map for IRX

The MODBUS read input registers address map for the **IRX** relay will be:

Address	Description
Configurable through the *ZivercomPlus*®	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 values**. Some typical values are:

- Phase and sequence currents and harmonics: **Rated value I_{PHASE} + 20**% sends 32767 counts.
- Ground and synchronization currents: **Rated value I_{GROUND} + 20%** sends 32767 counts.
- Sensitive ground and directional ungrounded neutral currents: **1.2 A** sends 32767 counts.
- Line-to-neutral and sequence voltages and harmonics: **(Rated value V / √3) + 20%** sends 32767 counts.
- Phase-to-phase and polarization voltages: **Rated value V + 20%** sends 32767 counts.
- Powers: 3 x 1.4 x Rated value I_{PHASE} x Rated value / √3 sends 32767 counts.
- Power factor: from **-1** to **1** sends from -32767 to 32767 counts.
- Frequency: from **0 Hz** to **1.2 x $Frequency_{RATED}$** (50Hz / 60Hz) sends 32767 counts.
- Thermal value: **240%** sends 32767 counts.
- Distance to the fault:
  - Percentage value: **±100%** sends ±32767 counts (range from -100% to 100%).
  - Value in kilometers: with the "**length of the line**," it sends ±32767 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 ±32767 counts (range from 0 km to the length of the line set in miles. It can also send negative values).

With the ***ZivercomPlus***® 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 (32767) 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.

The expression that allows defining this full-scale value is the following:

- -When the Nominal flag is enabled,

$$CommunicationsMeasurement = \frac{Measurement - Offset}{Nominal} \times \frac{32767}{Limit}$$

- -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 ***ZivercomPlus®*** 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 IRX

The MODBUS force single coil address map of the **IRX** relay will be:

Address	Description
Configurable through the *ZivercomPlus®*	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 ***ZivercomPlus®*** 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).

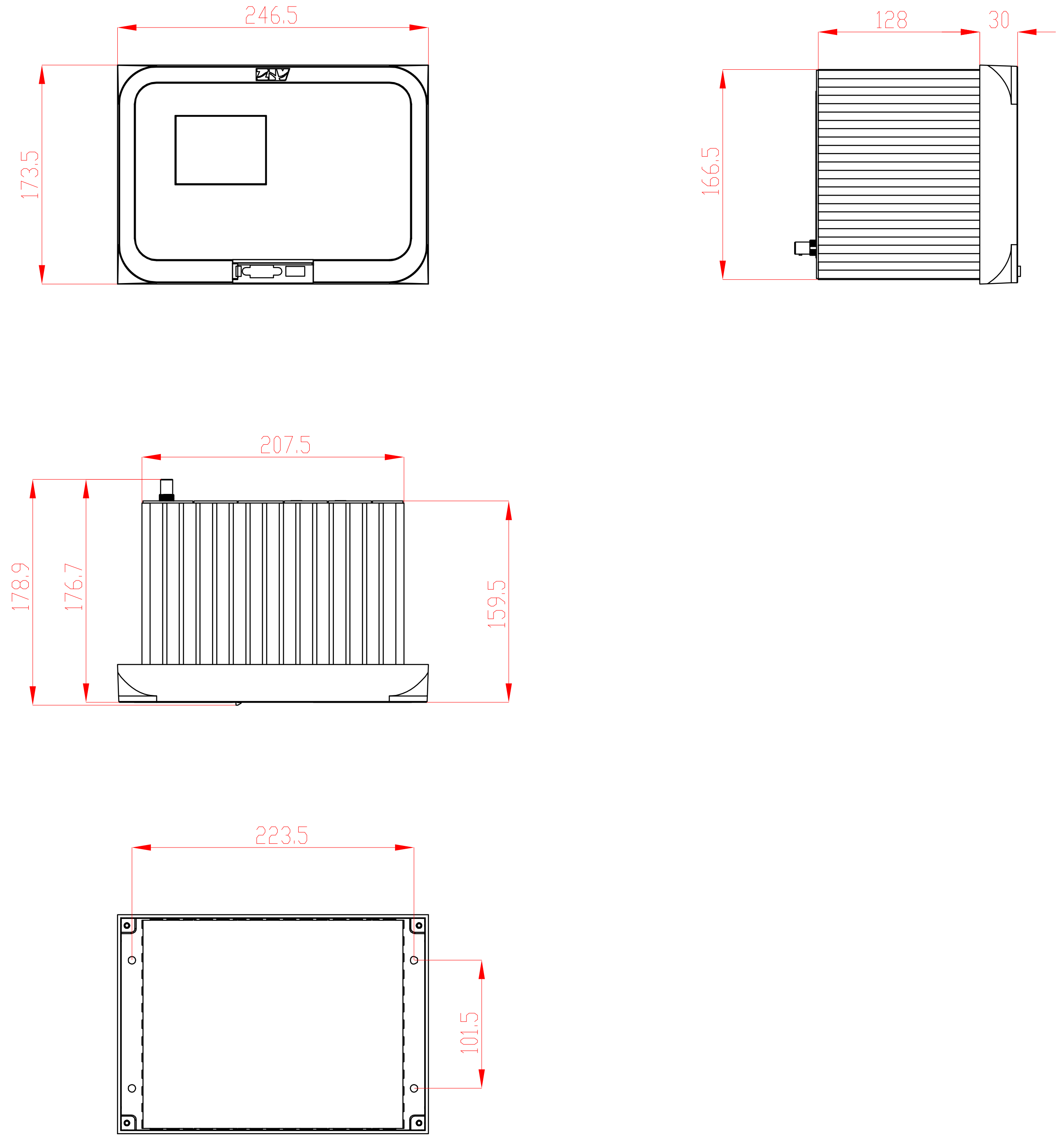
D. Schemes and Drawings

Dimension and Drill Hole Schemes

2IRX (6U x 1/2 19" rack)	>>4BF0102/0001

External Connection Schemes

2IRX-A-***100**	>>3RX0170/0004 (generic)
2IRX-A-***000**	>>3RX0170/0010 (generic)
2IRX-B	>>3RX0170/0006 (generic)
2IRX-B-***2*****	>>3RX0170/0013 (generic)
2IRX-B-*A******	>>3RX0170/0018 (generic)
2IRX-B-****F1**	>>3RX0170/0022 (generic)



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5		6		7	
8		9		10	
11		12		13	
14		15		16	

ZIV Aplicaciones y Tecnologia S.A.

TITULO: DIMENSIONES

PROYECTO: CAJA 2IRX-B(100)

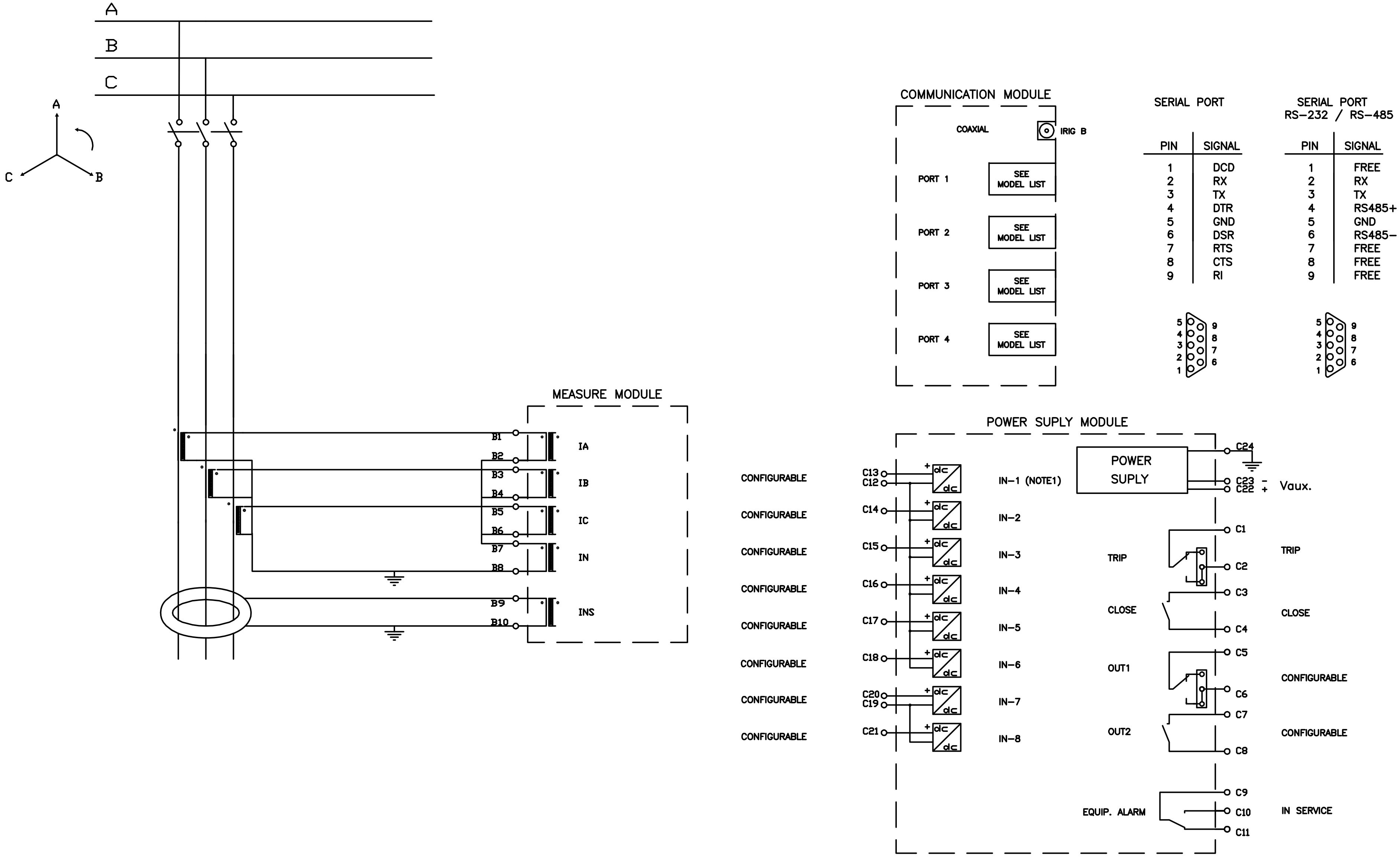
Rev. 0
Rev. 1 10/2/09

NUMERO: 4BF0102/0001

	Fecha	Nombre
Dibujado	29/01/08	J.C.S.
Aprobado	29/01/08	P.A.

Hoja: 1

Continua en Hoja:



SERIAL PORT

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

SERIAL PORT RS-232 / RS-485

PIN	SIGNAL
1	FREE
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	FREE
8	FREE
9	FREE

SERIAL PORT RJ45

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

SERIAL PORT CAN

PIN	SIGNAL
1	H
2	L
3	GND

NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

REVISIONS	0	CD0904140	1		2		3		4	
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11	12		13		14		15		16	

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TITLE: EXTERNAL CONNECTIONS 2IRX-A (100)

PROJECT: IRX

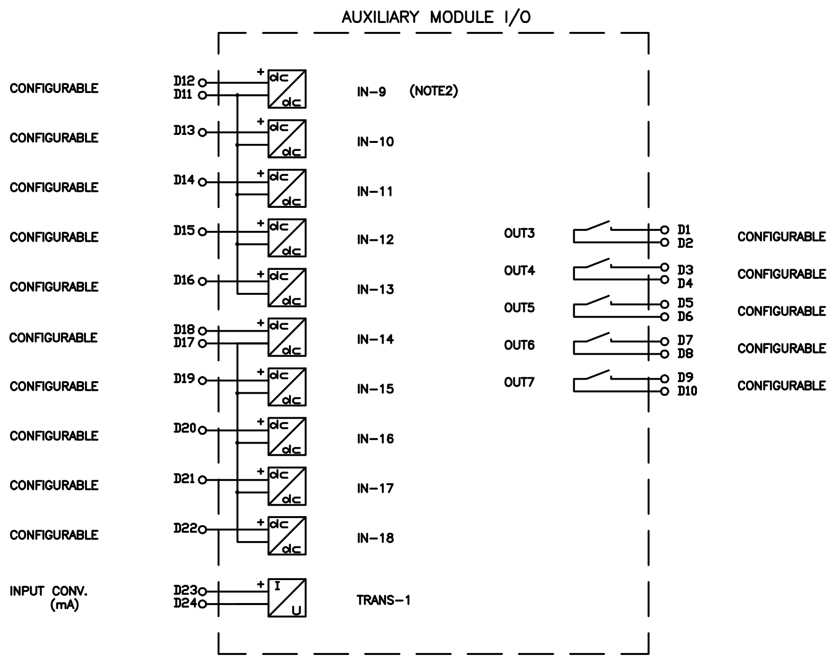
Rev.0

NUMBER: 3RX0170/0004

	Date	Name
Drawn	18/05/09	J.C.S.
Approved	18/05/09	J.M.Y.

Sheet: 1

Continued on Sheed: 2



NOTE 2: TERMINAL D12 SHOULD BE CONNECTED WHEN ANY OF THE INPUTS IN10, IN11, IN12 OR IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

"WARNING"
This document contains trade secret information of Z I V S.A. Unauthorized disclosure is strictly prohibited and may result in serious legal consequences.

REVISIONS	0	CD0904140	1		2		3		4	
5	6		7		8		9		10	
11	12		13		14		15		16	

Z I V Aplicaciones y Tecnologia S.A.

TITLE: EXTERNAL CONNECTIONS 2IRX-A (100)

PROJECT: IRX

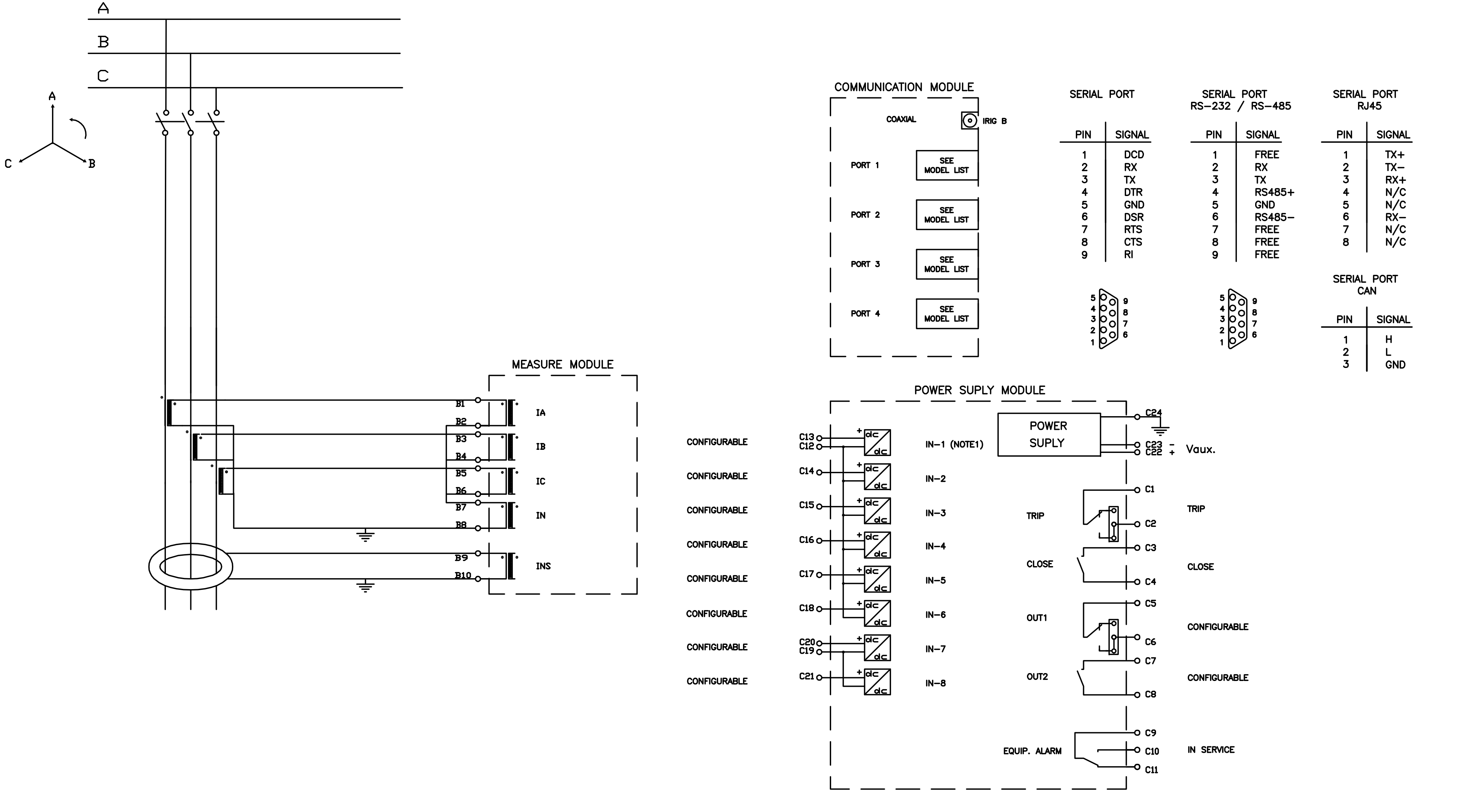
Rev.0

NUMBER: 3RX0170/0004

	Date	Name
Drawn	18/05/09	J.C.S.
Approved	18/05/09	J.M.Y.

Sheet: 2

Continued on Sheed:



NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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11	12		13		14		15		16	

Z I V Aplicaciones y Tecnologia S.L.

TITLE: EXTERNAL CONNECTIONS 2IRX-A (000)

PROJECT: IRX

Rev.0

NUMBER: 3RX0170/0010

	Date	Name
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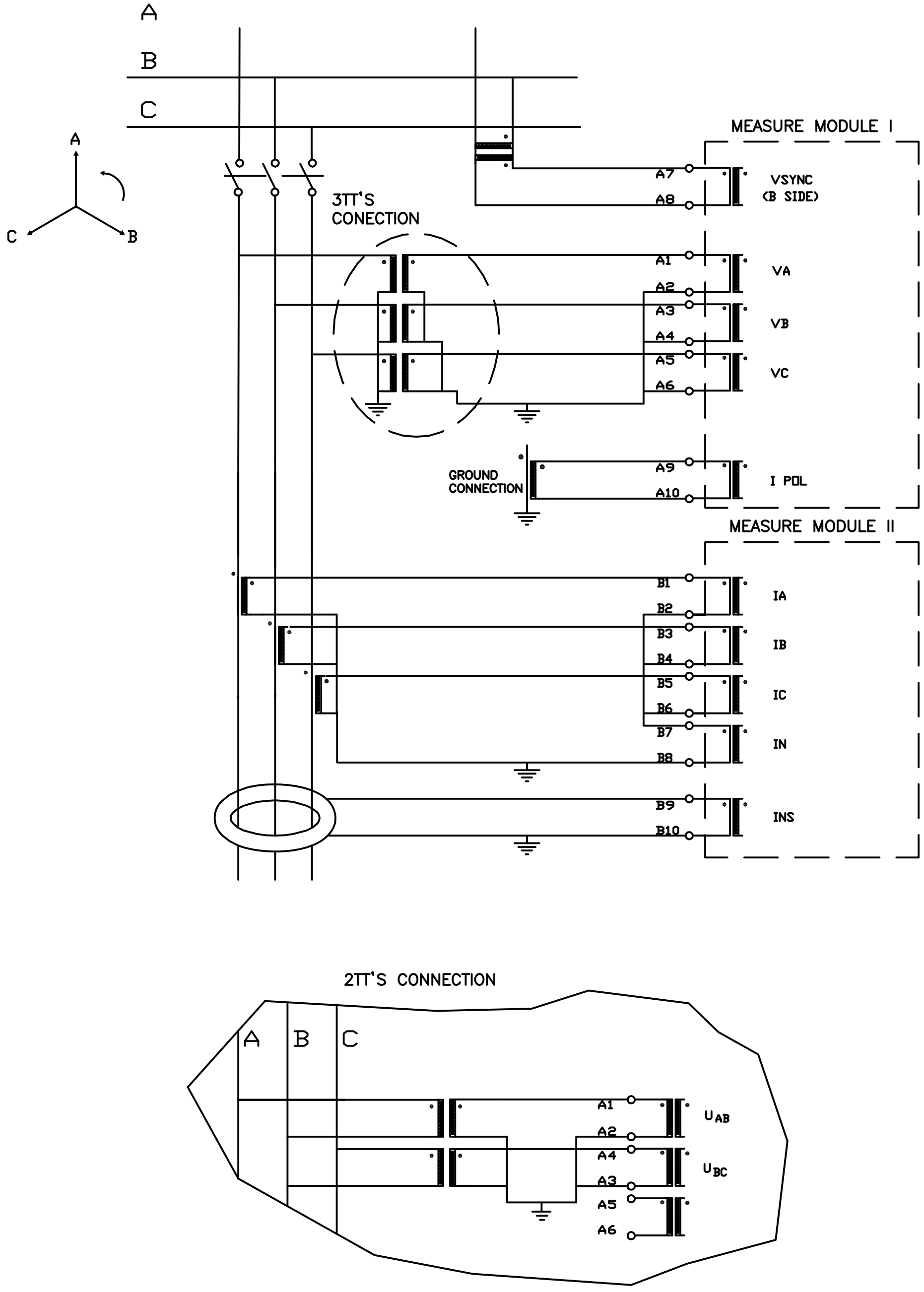
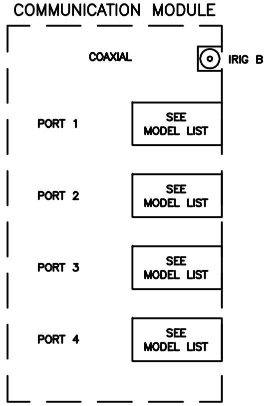
Approved	22/10/09	J.M.Y.

Sheet: 1

Continued on Sheed:





SERIAL PORT

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

SERIAL PORT RS-232 / RS-485

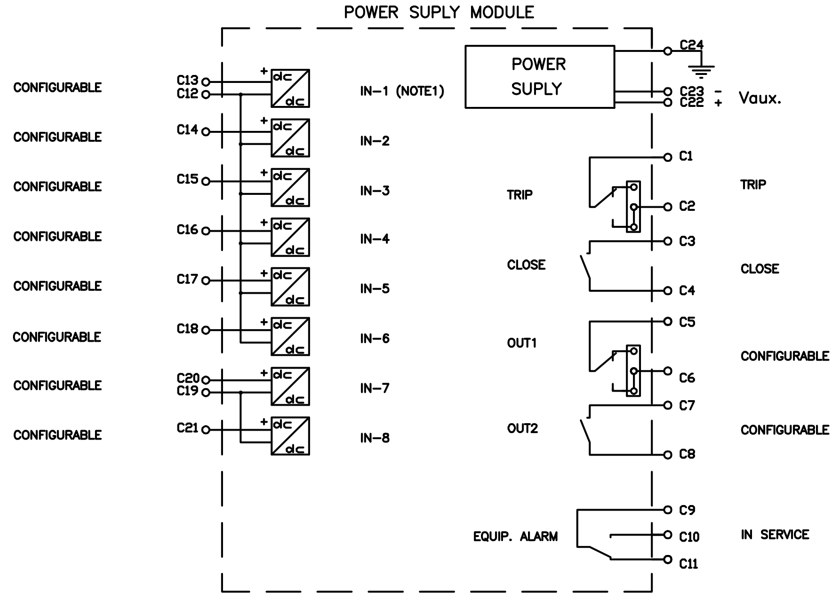
PIN	SIGNAL
1	FREE
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	FREE
8	FREE
9	FREE

SERIAL PORT RJ45

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

SERIAL PORT CAN

PIN	SIGNAL
1	H
2	L
3	GND



NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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11	12		13	14	15	16

Z I V Aplicaciones y Tecnologia S.A.

TITLE: EXTERNAL CONNECTIONS 2IRX-B (100)

PROJECT: IRX

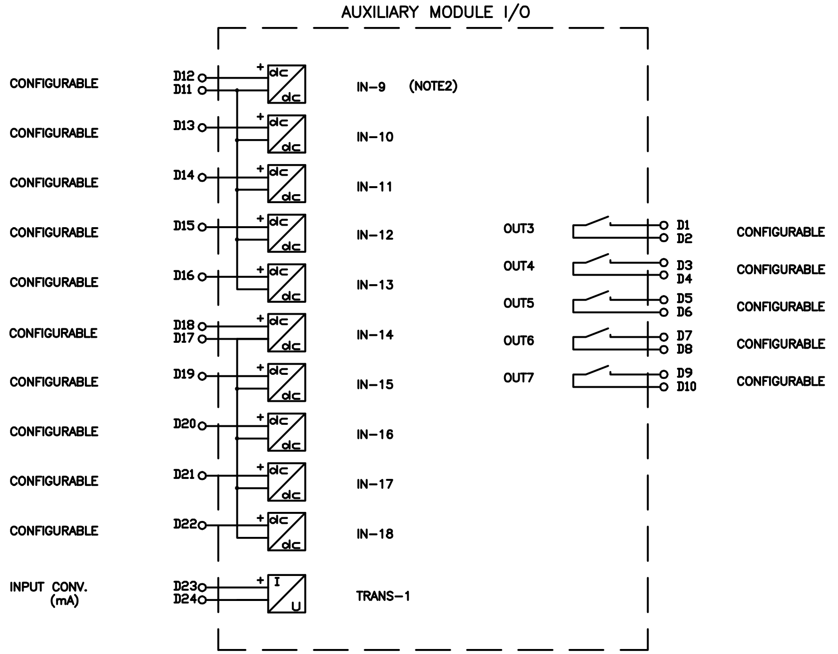
Rev.0

NUMBER: 3RX0170/0006

	Date	Name
Drawn	18/05/09	J.C.S.
Approved	18/05/09	J.M.Y.

Sheet: 1

Continued on Sheed: 2



NOTE 2: TERMINAL D12 SHOULD BE CONNECTED WHEN ANY OF THE INPUTS IN10, IN11, IN12 OR IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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Z I V Aplicaciones y Tecnología S.A.

TITLE: EXTERNAL CONNECTIONS 2IRX-B (100)

PROJECT: IRX

Rev.0

NUMBER: 3RX0170/0006

	Date	Name
Drawn	18/05/09	J.C.S.
Approved	18/05/09	J.M.Y.

Sheet: 2

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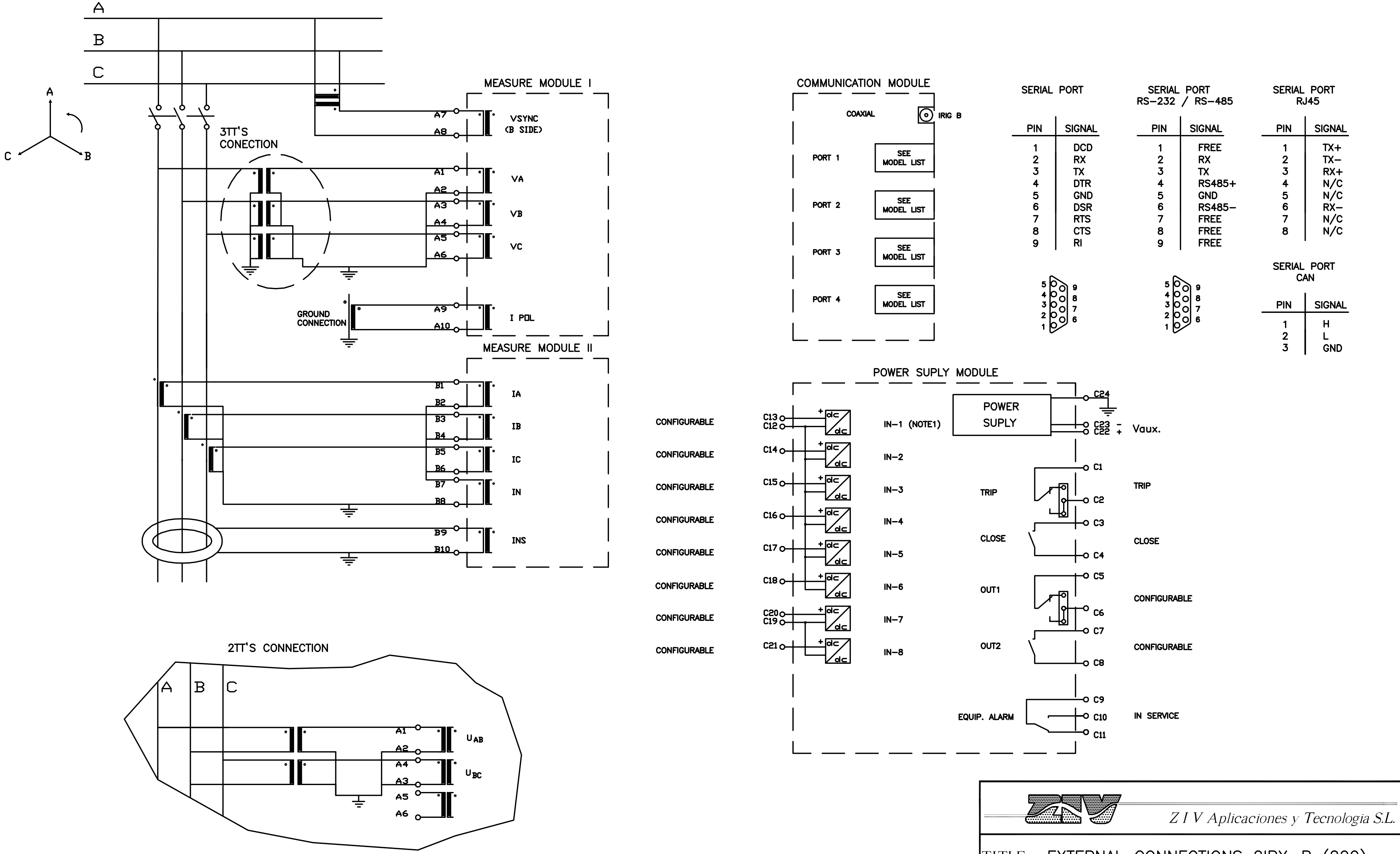

NOTE 1: TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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Z I V Aplicaciones y Tecnologia S.L.

TITLE: EXTERNAL CONNECTIONS 2IRX−B (200)

PROJECT: IRX

Rev.0

NUMBER: 3RX0170/0013

	Date	Name
Drawn	24/06/10	J.C.S.
Approved	24/06/10	J.M.Y.

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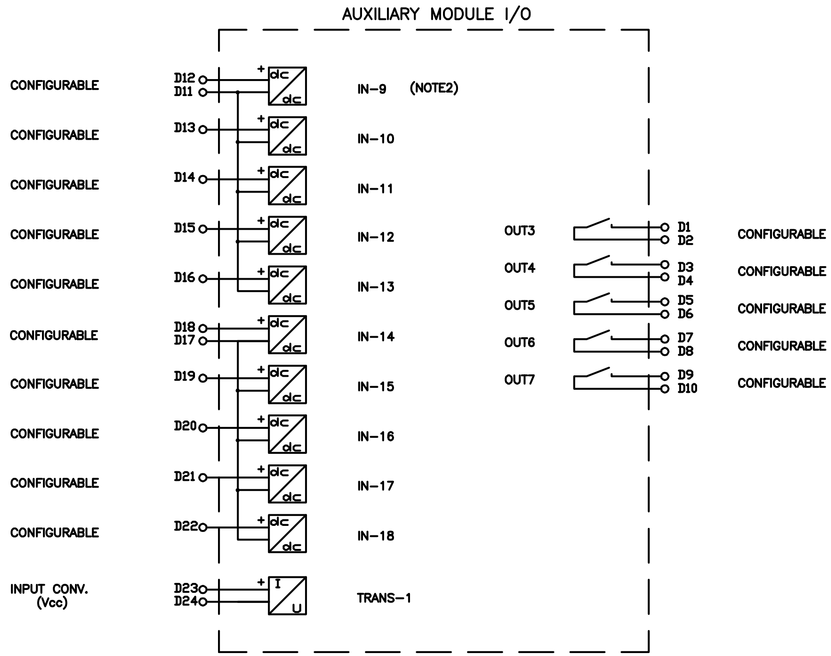

NOTE 2: TERMINAL D12 SHOULD BE CONNECTED WHEN ANY OF THE INPUTS IN10, IN11, IN12 OR IN13 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION.

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Z I V Aplicaciones y Tecnologia S.L.

TITLE: EXTERNAL CONNECTIONS 2IRX-B (200)

PROJECT: IRX

Rev.0

NUMBER: 3RX0170/0013

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Drawn	24/06/10	J.C.S.
Approved	24/06/10	J.M.Y.

Sheet: 2

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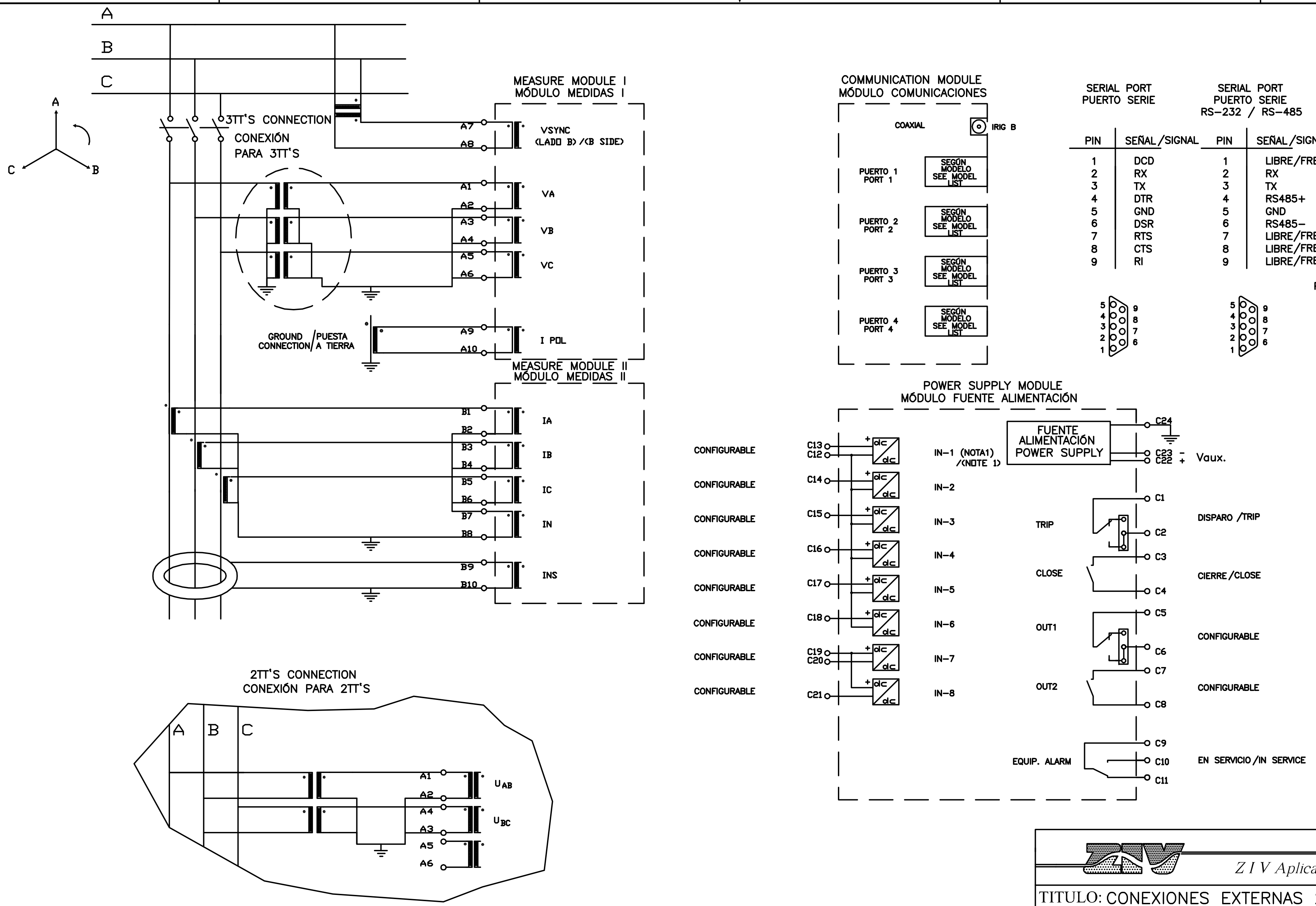

SERIAL PORT
PUERTO SERIE

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

SERIAL PORT
PUERTO SERIE
RJ45

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

PUERTO SERIE/SERIAL PORT
CAN

PIN	SEÑAL/SIGNAL
1	H
2	L
3	GND

NOTA 1: LA BORNA C13 DEBERA CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS (IN2, IN3) PARA LA FUNCION DE VIGILANCIA DE BOBINAS DE INTERRUPTOR

NOTE 1: THE TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION

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Z I V Aplicaciones y Tecnologia

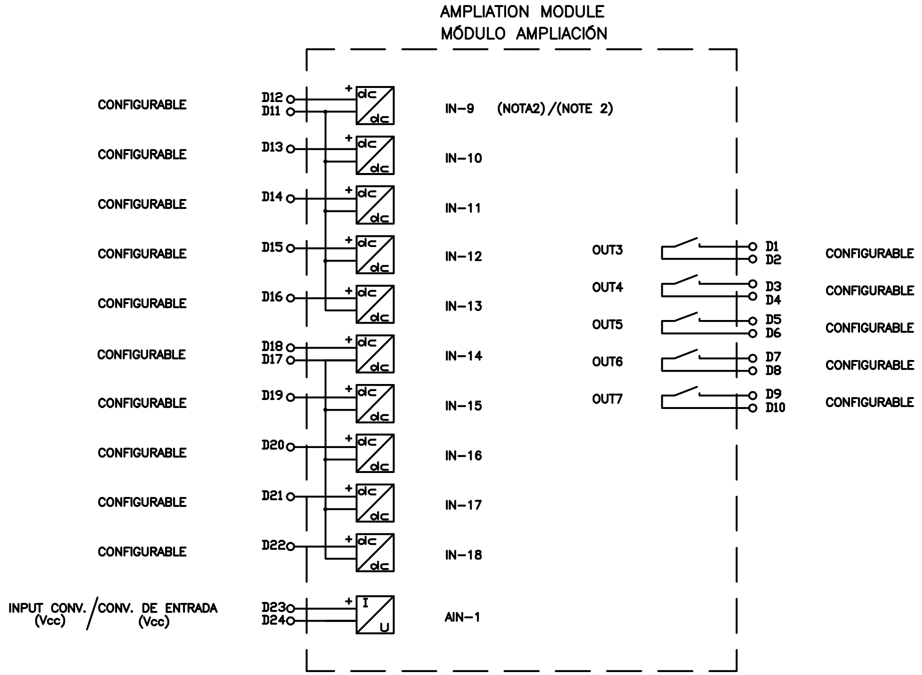
TITULO: CONEXIONES EXTERNAS 2IRX-B (2E*)
TITLE: EXTERNAL CONNECTIONS 2IRX-B (2E)*

PROYECTO / *PROJECT:* IRX /*IRX*

Rev.0

NUM.: 3RX0170/0018

	Fecha / *Date*	Nombre / *Name*	
Dibujado / *Drawn*	08/07/11	D.A.R.	Hoja / *Sheet:* 1
Aprobado / *Approved*	08/07/11	P.A.	Continua en Hoja: *Continued on sheet:* 2



NOTA 2: LA BORNA D12 DEBERA CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS (IN10,IN11,IN12,IN13) PARA LA FUNCION DE VIGILANCIA DE BOBINAS DE INTERRUPTOR

NOTE 2: THE TERMINAL D12 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS (IN10,IN11,IN12,IN13) ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION

REV.	0	CD1107105	1		2		3		4	
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Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS 2IRX-B (2E*)
TITLE: EXTERNAL CONNECTIONS 2IRX-B (2E)*

PROYECTO / *PROJECT:* IRX /*IRX*

Rev.0

NUM.: 3RX0170/0018

	Fecha / *Date*	Nombre / *Name*	
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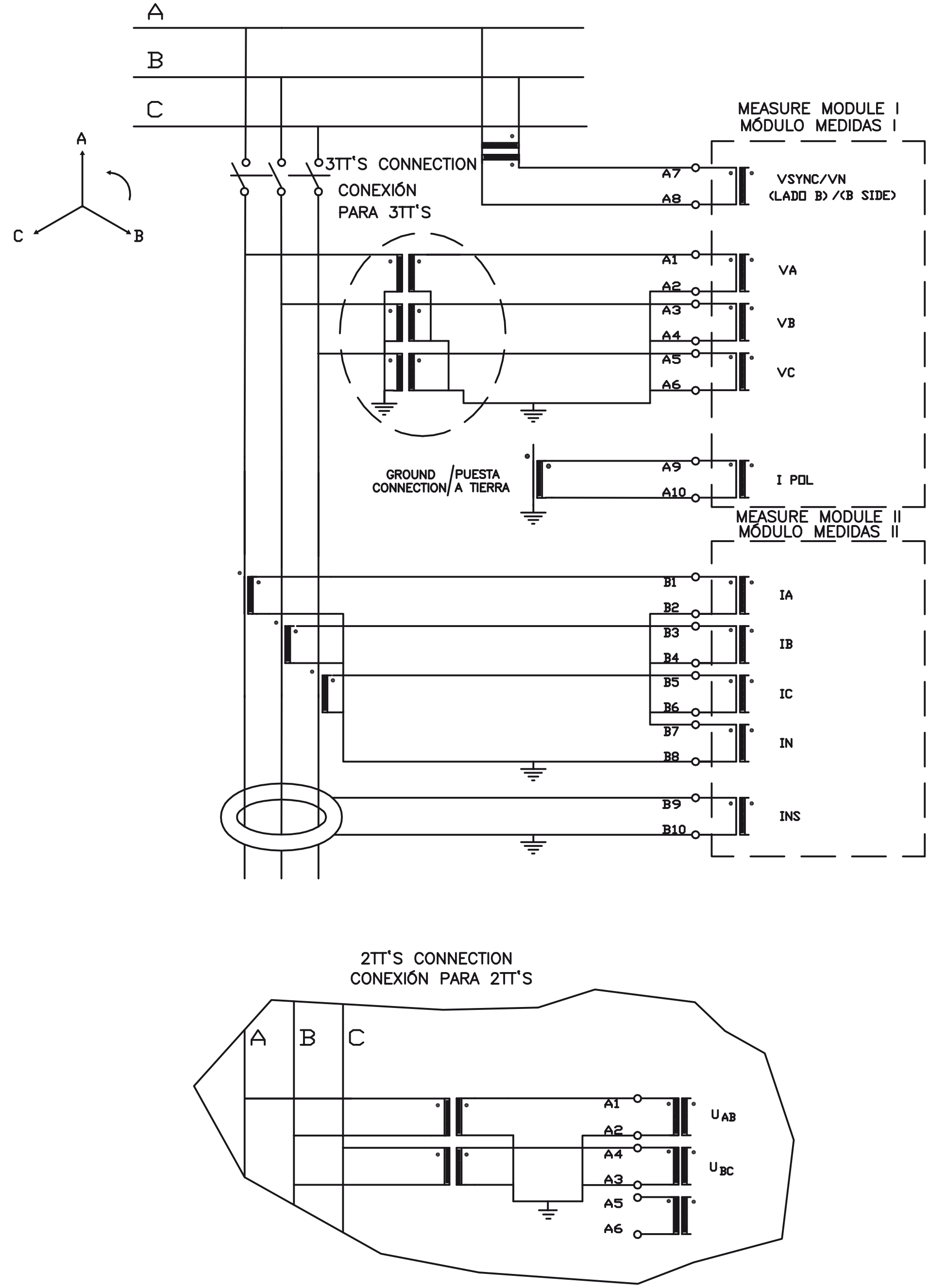
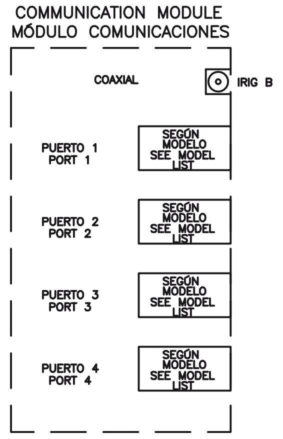
Aprobado / *Approved*	08/07/11	P.A.	Continua en Hoja: / *Continued on sheet:* –





SERIAL PORT / PUERTO SERIE

PIN	SEÑAL/SIGNAL
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

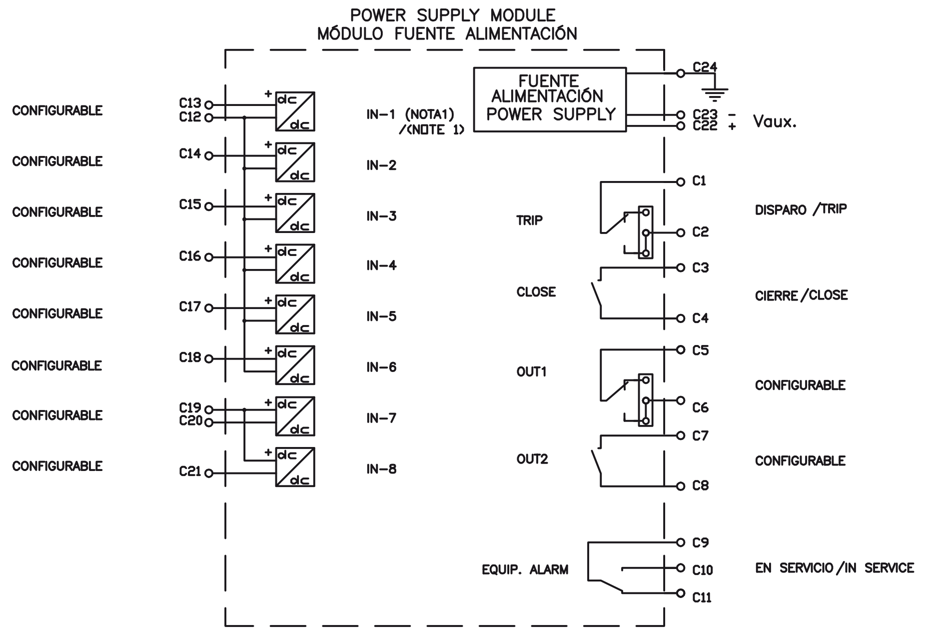
PIN	SEÑAL/SIGNAL
1	LIBRE/FREE
2	RX
3	TX
4	RS485+
5	GND
6	RS485-
7	LIBRE/FREE
8	LIBRE/FREE
9	LIBRE/FREE

SERIAL PORT / PUERTO SERIE RJ45

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

PUERTO SERIE/SERIAL PORT CAN

PIN	SEÑAL/SIGNAL
1	H
2	L
3	GND



NOTA 1: LA BORNA C13 DEBERA CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS (IN2, IN3) PARA LA FUNCION DE VIGILANCIA DE BOBINAS DE INTERRUPTOR

NOTE 1: THE TERMINAL C13 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS IN2 OR IN3 ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION

REV.	0	CD1404117	1	2	3	4
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TITULO: CONEXIONES EXTERNAS 2IRX-B (1F1)
TITLE: EXTERNAL CONNECTIONS 2IRX-B (1F1)

PROYECTO / *PROJECT:* IRX /*IRX*

Rev.0

NUM.: 3RX0170/0022

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	30/04/14	J.M.S.
Aprobado / *Approved*	30/04/14	P.A.

Hoja / *Sheet:* 1
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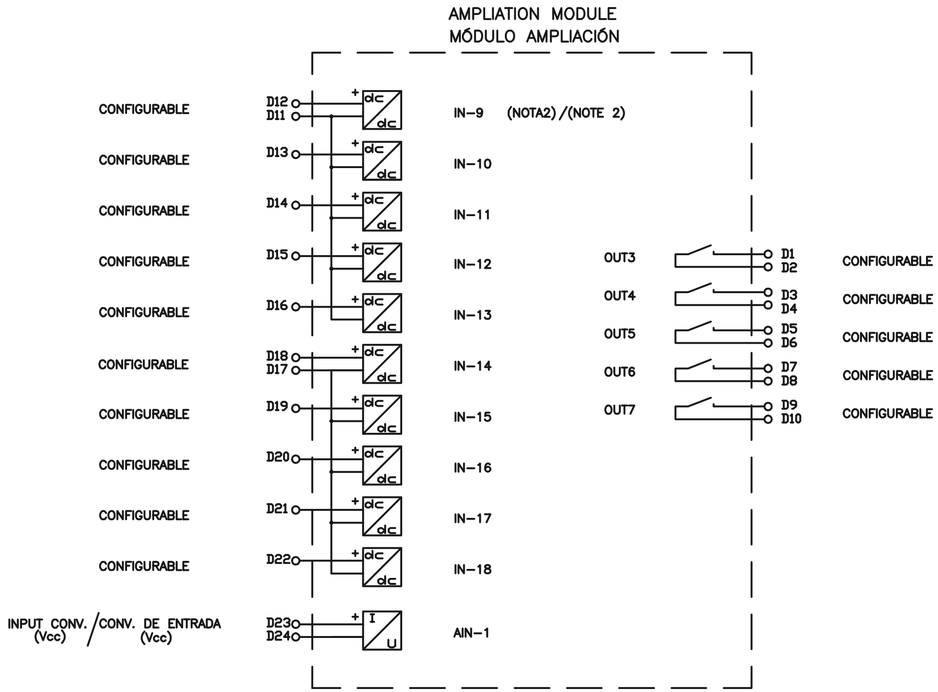

NOTA 2: LA BORNA D12 DEBERA CONECTARSE A POSITIVO SIEMPRE QUE SE USE ALGUNA DE LAS ENTRADAS (IN10,IN11,IN12,IN13) PARA LA FUNCION DE VIGILANCIA DE BOBINAS DE INTERRUPTOR

NOTE 2: THE TERMINAL D12 SHOULD BE CONNECTED TO POSITIVE WHEN ANY OF THE INPUTS (IN10,IN11,IN12,IN13) ARE BEING USED FOR THE BREAKER COIL SUPERVISION FUNCTION

REV.	0	CD1404117	1	2	3	4
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TITULO: CONEXIONES EXTERNAS 2IRX-B (1F1)
TITLE: EXTERNAL CONNECTIONS 2IRX-B (1F1)

PROYECTO / *PROJECT:* IRX /*IRX*

Rev.0

NUM.: 3RX0170/0022

	Fecha / *Date*	Nombre / *Name*
Dibujado / *Drawn*	30/04/14	J.M.S.
Aprobado / *Approved*	30/04/14	P.A.

Hoja / *Sheet:* 2
Continua en Hoja: / *Continued on sheet:* –

E. List of Illustrations and Tables

E.1 List of Illustrations

E.2 List of tables

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