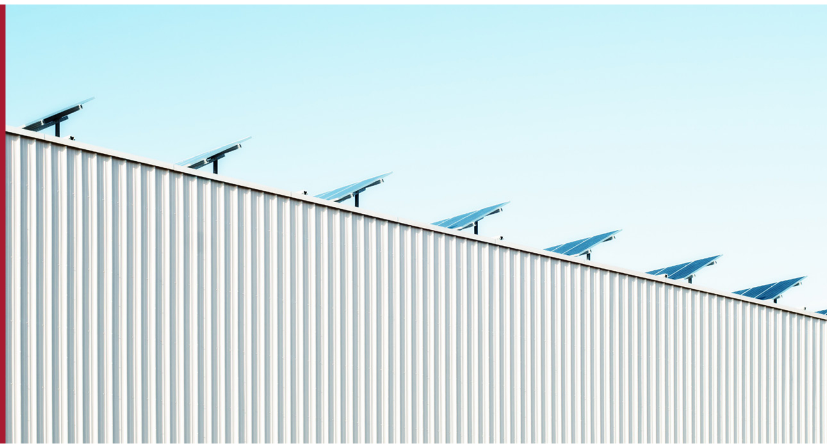

2TCA-E

Automation and Control for Modular Assemblies

Instructions Manual for **2TCA-E** Models
M2TCAE2001Iv03

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Chapter 1.

Description and Start-Up

1.1 Introduction

This instruction manual provides a technical and functional description of the device **2TCA-E,** which is a combination of a remote terminal unit (RTU), a medium voltage supervision system and a control and automation system specially adapted to be used in modular assemblies and secondary substations. The manual may be used as technical reference in engineering, installation, commissioning, and normal operation of the relay since the manual contains operating and handling instructions apart from descriptions relative to technical data, function lists, logic diagrams, input and output signals, parameter settings and detail explanation of every function.

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

1.1.1 Relay Overview and Applications

The IED generally called **2TCA-E** integrates all functions required to cover the complete protection of modular assemblies. These IEDs use the most advanced digital technology based on a powerful microprocessor that incorporate a Directional Fault Passage Detector based on directional overcurrent protection functions, presence of voltage and absence of voltage.

The **2TCA-E** systems are applicable in secondary substations and overhead line switchgear, where a supervision of the parameters of the Medium Voltage network is required (measurement of voltages, currents and powers), detection and communication towards the control center of the existence of faults both between phases and between phase and ground, with indication of the directionality of the same, automatic isolation of the faulted sections and control from the dispatch of the opening and closing of the switchgears or breakers of the bay. It is also possible to supervise various alarms specific to the center, such as fire detectors, floods, intrusion, battery status, etc.

2TCA-E systems have been specially designed to implement automation solutions for modular assemblies.

Their communications interface includes secure access systems (SSH, HTTPS) and supports different protocols including the communications standard IEC60870-5-104, as well as the SNTP synchronization protocol, LDAP authentication protocol, web server and web page.

1.1.2 Symbols

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

	**WARNING:** **Hazards that may derived into personal injuries or damage to the equipment. Refer to the Instructions Manual.**
	**WARNING:** **Electrical risk hazard**
	**Grounding**
	**Protection Ground Terminal**

1.1.3 Relay Family Features

Automation, protection and control devices of **2TCA-E** family are provided with the state-of-the-art digital technology based on powerful microprocessors so that all measurements acquisition tasks and breaker supervision tasks are digitally processed within a modular design.

Relay analog inputs capture currents and voltages transmitted by sensors adapting them to internal processing level of the relay. **2TCA-E** device has a maximum of 39 analog inputs that can be combined depending on the selected configuration to obtain a device with 3 or 6 channel of voltage and up to a maximum of 20 current channels. Analog measurements are processed by an analog digital converter included in the analog input board which sends the digital samples to the microcontroller.

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

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

2TCA-E family has two USB frontal ports (1 A type A and 1 B type) to carry out management tasks and three Ethernet ports, a local one located in the front part of the device and another two ones in the rear side for remote communications.

1.1.3.a Hardware Design

The main components are:

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

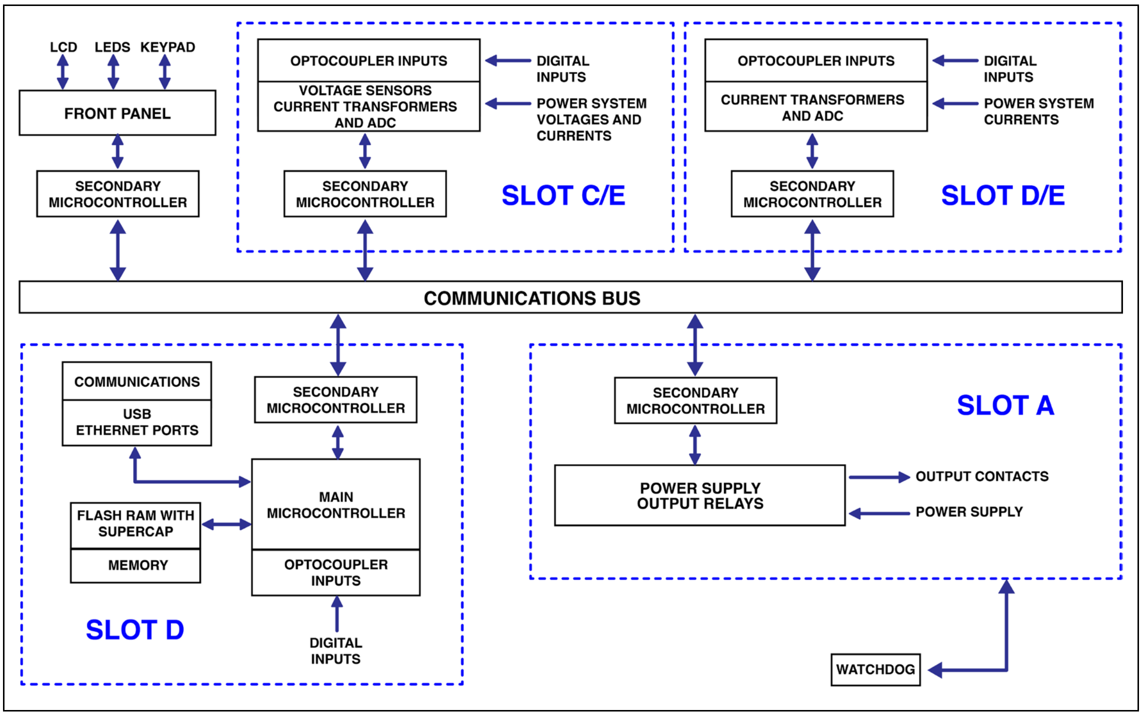


Figure 1.1.1 General HW Design.

1.1.3.b Measurement Processing

2TCA-E devices provide accurate measurement with high resolution in a broad dynamic range thanks to the high sampling frequency and the powerful measurement function they operate with.

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

After the measurement transformers, the relay is provided with a signal adapting stage together with analog low pass filter (antialiasing filter+ filter to strengthen the relay electromagnetic disturbance response). The A / D converter has an initial sampling frequency of 1 MHz. After applying a digital antialiasing filter, the A / D converter will generate, with a 24 bit resolution, an output frequency of 4800 Hz, in accordance with IEC 61869-9. The microcontroller included in each analog board performs two consecutive resamplings: the first, at 4800 Hz, to correct the magnitude and angle error introduced by the measurement chain (measurement transformers, analog filters, etc). The second, at 80 samples / cycle

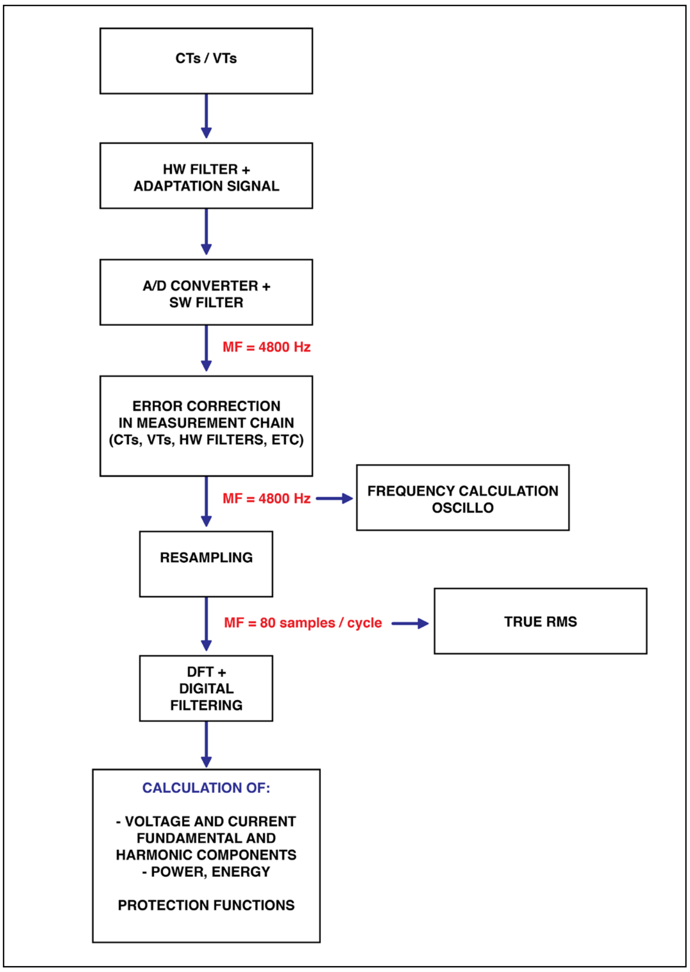


Figure 1.1.2 Measurement Processing.

1.1.3.c Memory and Internal Clock

2TCA-E devices include two different types of storage memory. All the relevant data will remain in non-volatile flash memory:

- Protection settings.
- Control logic.
- Fault reports.
- Oscillography.

In the non-volatile NVRAM memory the following information will be stored:

- Events.
- Memorized LEDs.

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

1.1.4 Functional Diagram

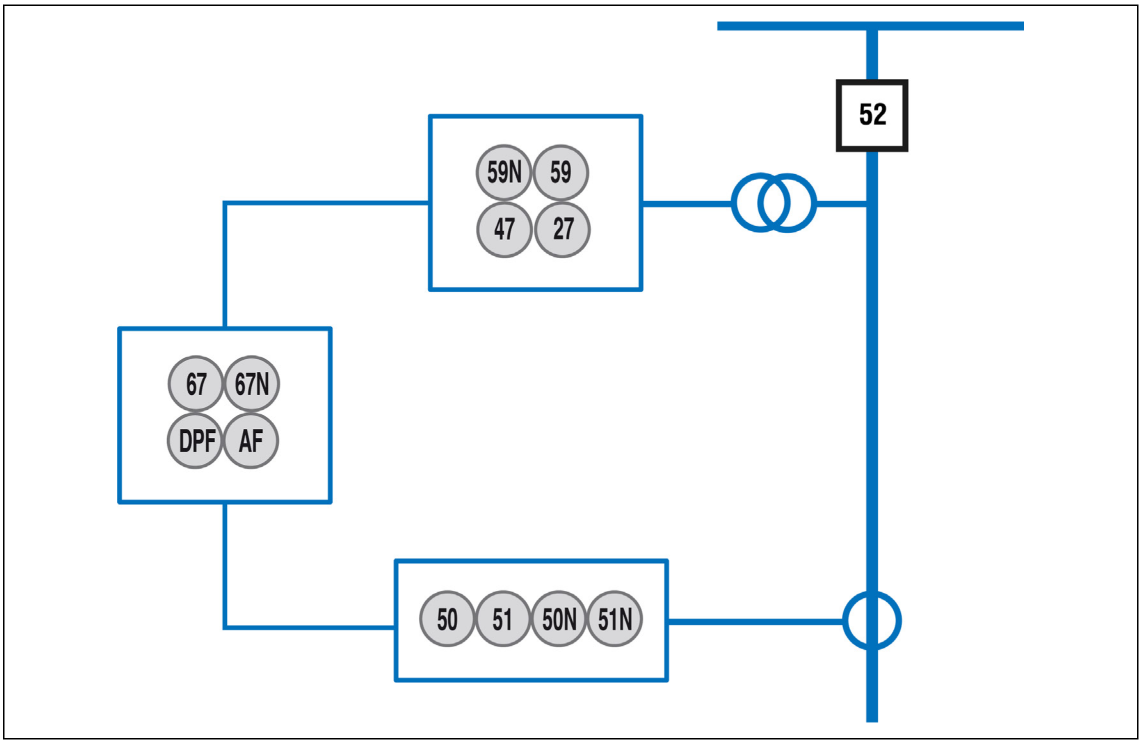


Figure 1.1.3 Functional Diagram per protected line.

1.2 Model Selection

1.2.1 Model Selection

2TCA	E	-	3						0	2	-				
1-2-3-4	5		6	7	8	9	10	11	12	13		14	15	16	17

5	**Function**			
	E	RTU+DPF		
6	**User Interface**			
	3	No display + L/R		
7	**Analog Channel Sensors / Measurement Class**			
	B	Current convention sensors and voltage sensors - Class 0.5	**C**	Smart RTU: CT + VT sensors according to IEC 61869
8	**Auxiliary Power Supply**			
	2	48 VDC	**3**	Smart RTU: 24 VDC
9	**Digital Inptus Voltage**			
	1	48 VDC	**4**	Smart RTU: 24 VDC
10	**Communications interface**			
	2	Frontal Ethernet for local connection + 2 x Rear Ethernet for remote communication.	**3**	Smart RTU: Frontal Ethernet + 2 x Rear Ethernet + 2 x Rear RS 485.
11	**Input and Output Channels. Slot Selection**			
	A	3LxP: 48xDI (groups of 8DIs) + 16DO + 3V + 12C	**G**	Smart RTU 2L1T: 32xDI (groups of 8DIs) + 16DO + 3V + 8I
	B	5LxP: 64xDI (groups of 8DIs) + 16DO + 3V + 20C		
	C	4LE: 64xDI (groups of 8DIs) + 16DO + 6V + 16C	**H**	Smart RTU 3L1T/2L2T/4L: 48xDI (groups of 8DIs) + 16DO + 3V + 12I
12	**Memory extension**			
	0	NO		
13	**Enclosure**			
	2	1/2 rack		
14	**Spare**			
	E	Default.	**F**	Smart RTU: Correction factors for VT/CT sensors + Control logic through e-NET Tool + Open phase unit + Inrush restraint + New fault indication automatism.
15	**Telecommunication Profile**			
	0	Iberdrola	**2**	Smart RTU: SEC
	1	GNF		
16	**Master Protocols**			
	0	None	**3**	Smart RTU: Serial MODBUS up to 3 IEDs
17	**Finish**			
	--	None	**L**	Conformal coated circuit boards.

1.2.1.a Definition of Slots

SLOT: Each of the vertical provisions of the equipment. See Chapter 1.4, Physical Description and Chapter 1.8, Schemes and Drawings. 6 SLOTs for 1/2 rack equipment.

Possible provisions of the different Slots:

Rack	1/2					
Slots	A	B	C	D	E	F
Power Supply	X					
Digital Inputs			X	X	X	X
Digital Outputs	X					
V / I analogue channels			X		X	
I analogue channels				X	X	
CPU						X

1.2.2 Protection Functions according to Model

ANSI	Functions	UNITS
50	Phase Instantaneous Overcurrent	3
51	Phase Time Overcurrent	3
50N	Neutral Instantaneous Overcurrent	1
51N	Neutral Time Overcurrent	1
51Ns	Sensitive Neutral Time Overcurrent	1
67	Phase Directional	1
67N	Neutral Direction	1
	Harmonic Blocking	1
27	Phase Undervoltage (Voltage Absence)	3
59	Phase Overvoltage (Voltage Presence)	3
52	Breaker Supervision	1
	Fault Passage Detector	1
	Fault Isolation Automatism	1
	Open Phase (depending on model selection: Smart RTU)	1
	Inrush Restraint (depending on model selection: Smart RTU)	1

- **Analog Channels**

Model	Analog channels
2TCAE-XXXXXAXXXXX	VA, VB, VC, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN
2TCAE-XXXXXBXXXXX	VA, VB, VC, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN
2TCAE-XXXXXCXXXXX	VA, VB, VC, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN, VA, VB, VC, IA, IB, IC, IN
2TCAE-XXXXXGXXXXX	VA, VB, VC, IA, IB, IC, IN, IA, IB, IC, IN
2TCAE-XXXXXHXXXXX	VA, VB, VC, IA, IB, IC, IN, IA, IB, IC, IN, IA, IB, IC, IN

1.3 Technical Data

1.3.1 Power Supply Voltage

The terminals have a type of auxiliary power supply with the following voltage range:

48 VDC (+30%, -20%)
24 VDC (+10%, -10%)

Note: in case of power supply failure, a maximum interruption of 100 ms is allowed for 24VDC input.

1.3.2 Power Supply Burden

Powered up at nominal voltage	**6W**

Note: burden is measured with:
- One digital output activated.
- Device is communicating.
- Injecting current of 1A and a voltage of $2\sqrt{3}$ in the equipment of 48VDC and one of 230V in the equipment powered at 12VDC.
- All the functions are in active status.

1.3.3 Current Analog Inputs

The family provides two different types of current analog channels selectable by model:

Phase and Neutral Currents

Frequency range	**50 Hz**, **60 Hz**
Nominal value	**In** = **1 A**
Measurement range	**0** - **10A** x **In**
Thermal withstand capability	**4 A** x **In** (continuously)
	10 A x **In** (for 10 s)
	100 A x **In** (for 1 s)
Current circuit burden	**<0.05 VA**

Phase and Neutral Currents Smart RTU	
Frequency range	**50 Hz**, **60 Hz**
Nominal value	**Vn** = **225m V**
Measurement range	**0** - **7 V**
Thermal withstand capability	**6 V** (continuously) **22.5 V** (for 1 s)
Input impedance	**2 MΩ** // **< 50 pF**

1.3.4 Voltage Analog Inputs

Nominal Value	**Un = 2/√3** or **3.25/√3 VCA** (selectable in the IED)
Thermal withstand capability	**6 VCA** (continuously) **10 VCA** (for 10s)
Input impedance	**20 MΩ** // **< 300 pF or 2 MΩ** // **< 50 pF** (selectable in the IED)

1.3.5 Frequency

Operating Range	**50** - **60 Hz**

1.3.6 Measurement Accuracy

Measured Currents	
Phases and ground	**±0.5%** or **±1 mA** (the greater) or **±0.5%** from **10%** to **400%Vn** and **±1%** from **2.5%** to **10%Vn** (selectable in the IED)
Angles	**±0.25º** or **±0.5º** from **10%** to **400%Vn** and **±1º** from **2%** to **10%Vn** (selectable in the IED)
Measured voltages	
Phase-Ground	**±1% or ±5 mV** (the greater) or **±0.5%** from **20%** to **190%Vn** and **±1%** from **2%** to **20%Vn** (selectable in the IED)
Angles	**±0.25º** or **±0.33º** from **20%** to **190%Vn** and **±0.67º** from **2%** to **20%Vn** (selectable in the IED)

Note: Signal Processing

Sampling function adjustment of analog input signals is made by means of zero pass count of one of the measured signals (Cosine filter of Clark alpha component voltage, difference between channels or direct magnitude of the channel) 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 80 samples per cycle. The frequency value is saved for later use in Protection and Control tasks.

Zero passage detection is carried out depending on the number of channels the IED has:

- **IEDs with three channels: the Vclark cosine signal ((2VA - VB – VC)/3) is used, and when the value of the combination of Vclark and Vcosine drops below the disable voltage setting, the frequency measurement becomes impossible**
- **IEDs with two channels: the magnitude calculated as the difference between both channels is used.**
- **IEDs with one channel: the magnitude of the channel itself with no additional calculations is used.**

Upon losing this voltage, the following will be carried out:

- **The last valid frequency is kept for two seconds.**
- **After two seconds, the frequency measurement goes to zero.**

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

1.3.7 Accuracy of the Pickup and Reset of the Overcurrent Elements

Overcurrent Elements	
Pickup of phases, neutral, ground and sensitive ground (static test)	**±3 %** or **±10mA** of the theoretical value (the greater)
Reset of phases, neutral, ground and sensitive ground	**±3 %** or **±10mA** of the theoretical value (the greater) **1.5 cycles** for 50Hz and 60Hz

Note: the pickup of the overcurrent units will take place at 1.05 times the pickup setting.

Measuring times

Mode	Measuring times	
	50Hz	60Hz
Fixed time	±1 % of the setting or ±25 ms (the greater)	
Inverse curve	Class 2 (E = 2) or ±35ms (the greater) (UNE 21-136, IEC 255-4) (for measured currents of 100mA or greater)	

1.3.8 Repeatability

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

1.3.9 Accuracy of the Pickup and Reset of the Voltage Elements

Overvoltage and Undervoltage Units

Pickup (static test)	**±2 %** or **±10 mV** of the theoretical value (the greater)
Reset	**1.5 cycles** for 50 and 60Hz

Measuring times

Mode	Measuring times	
	50Hz	60Hz
Fixed time	±1 % of the setting or ±25 ms (the greater)	

1.3.10 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

1.3.11 Digital Inputs

Inputs with polarity (all the Inputs are DC).

V nominal	V MAX	Burden	V ON	V OFF
24 VDC	48 VDC	<2.3mA	16VDC	10VDC
48 VDC	62.4 VDC	<5mA	20VDC	13VDC

1.3.12 Auxiliary Outputs

All the contacts of the equipment have the same physical characteristics and all of them are configurable by setting:

I DC maximum limit (with resistive load)	**30 A** (1 s)
I DC continuous service (with resistive load)	**8 A**
Close	**2000 W**
Breaking capability (with resistive load)	**75 W** - max. 8 A - (48 VDC)
	1000 VA
Break (L/R = 0.04 s)	**40 W** at **48 VDC**
Switching voltage	**70 VDC / 50 VAC**
Momentary close time trip contacts remain closed	**100 ms**

1.3.13 Communications Link

Local Communications Port
ETHERNET (RJ45)
USB type B 1.1 (admits cables for USB 1.1 and USB 2.0)

Remote Communications Port
Two ETHERNET (RJ45) ports

RJ45 Port Signals

Used signals	**Pin 1 - TX+**
	Pin 2 - TX-
	Pin 3 - RX+
	Pin 4 - N/C
	Pin 5 - N/C
	Pin 6 - RX-
	Pin 7 - N/C
	Pin 8 - N/C

1.4 Physical Description

1.4.1 General

The equipments are made up of the following modules:

- Processor module and HMI.
- Analog inputs module.
- Power Supply.
- Digital inputs module.
- Digital outputs module.
- Communications module.

Next figures represent the external appearance of the IEDs. In the front panel the light signalling are mounted with their corresponding labels, the local/remote push buttons, and the front communication ports (ETHERNET, USB).

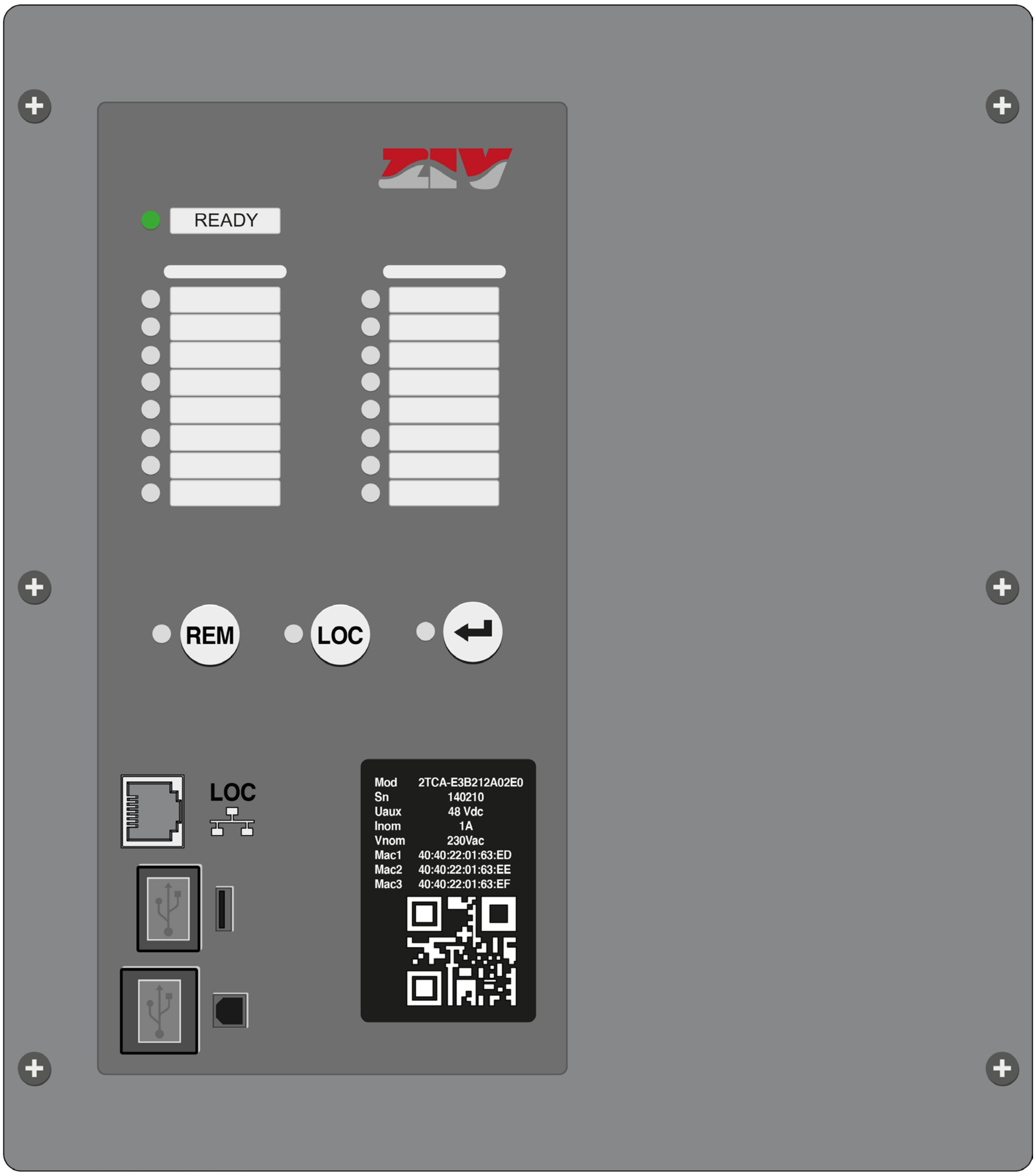


Figure 1.4.1 Front View of a 2TCA-E IED.

The modules are mounted vertically, constituting removable modules that do not require disassembling the front of the equipment. External connection is carried out by means of plug-in terminal blocks (supported on the bearing strip located at the back of each module) with pointed hubs.

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

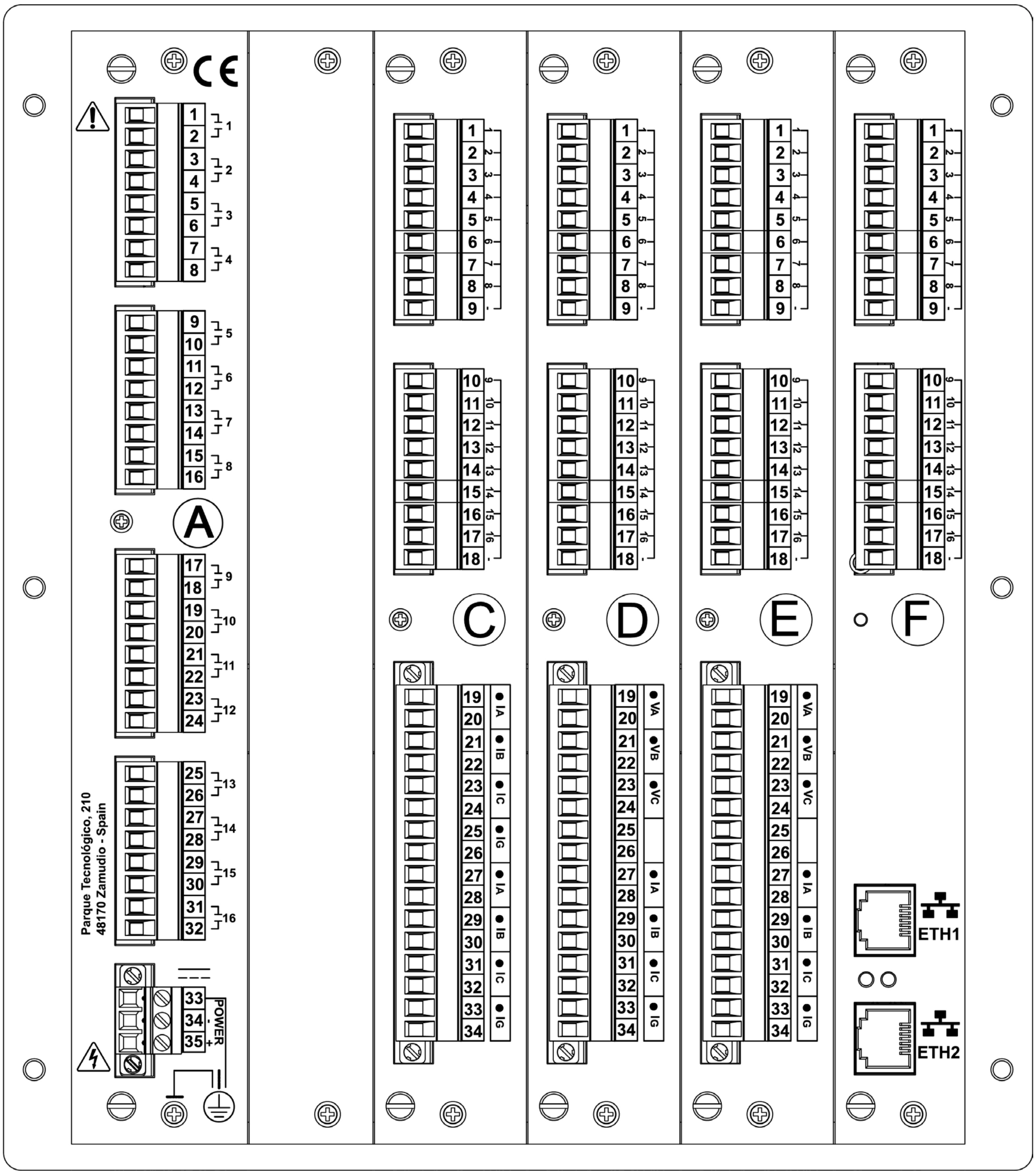


Figure 1.4.2 Rear View of a 2TCA-E IED.

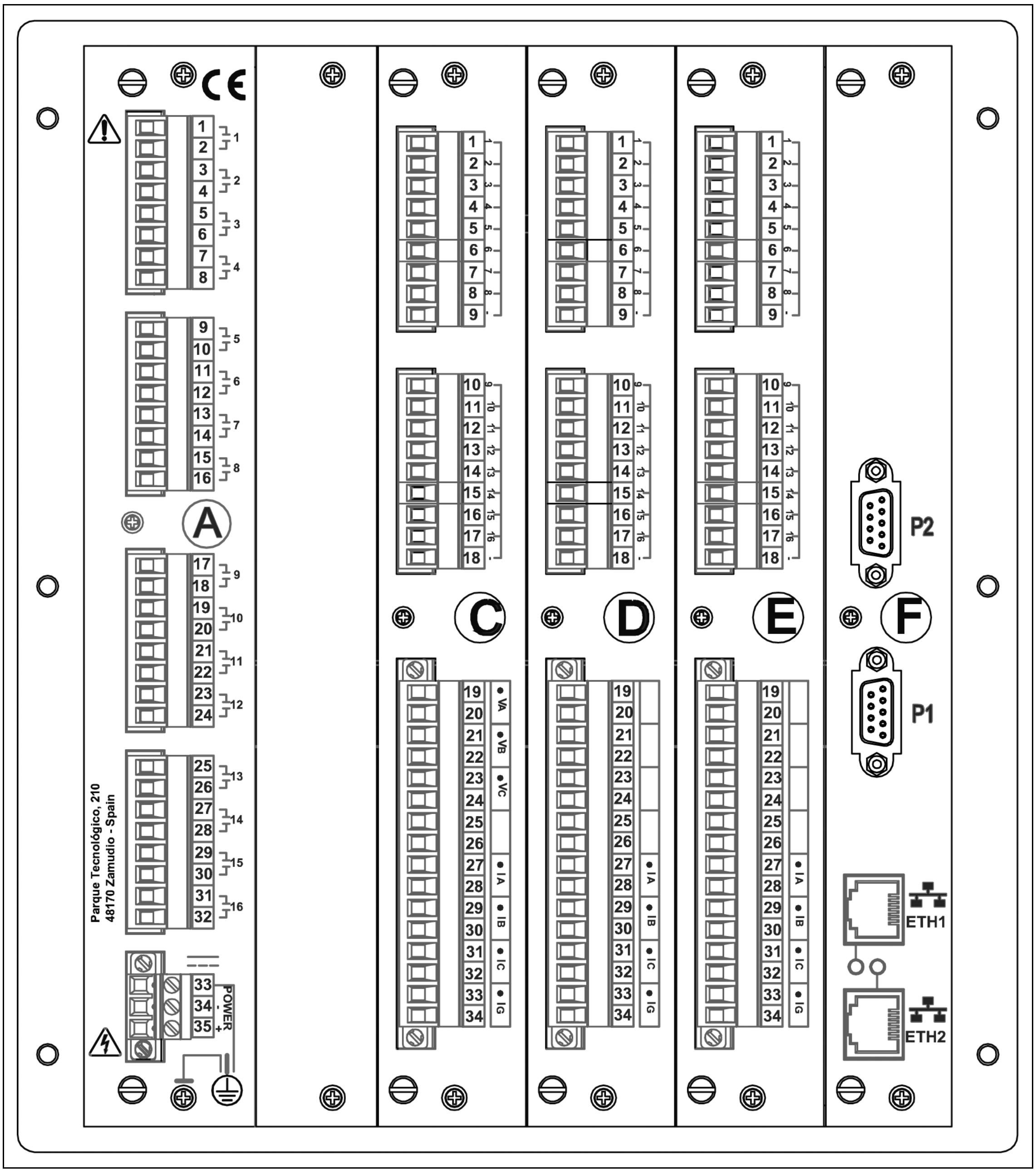


Figure 1.4.3 Rear View of a 2TCA-E (Smart RTU) IED.

1.4.2 Dimensions

Devices are mounted in panels (panel flush mounting) and are fixed with 4 M5 screws inserted by the front part of the IED. They are included in the package. This type of mounting allows a direct installation, fitting the device in the internal panel of the cabinets. Below is a detailed drawing of the holes to be made in the panel or door for correct installation.

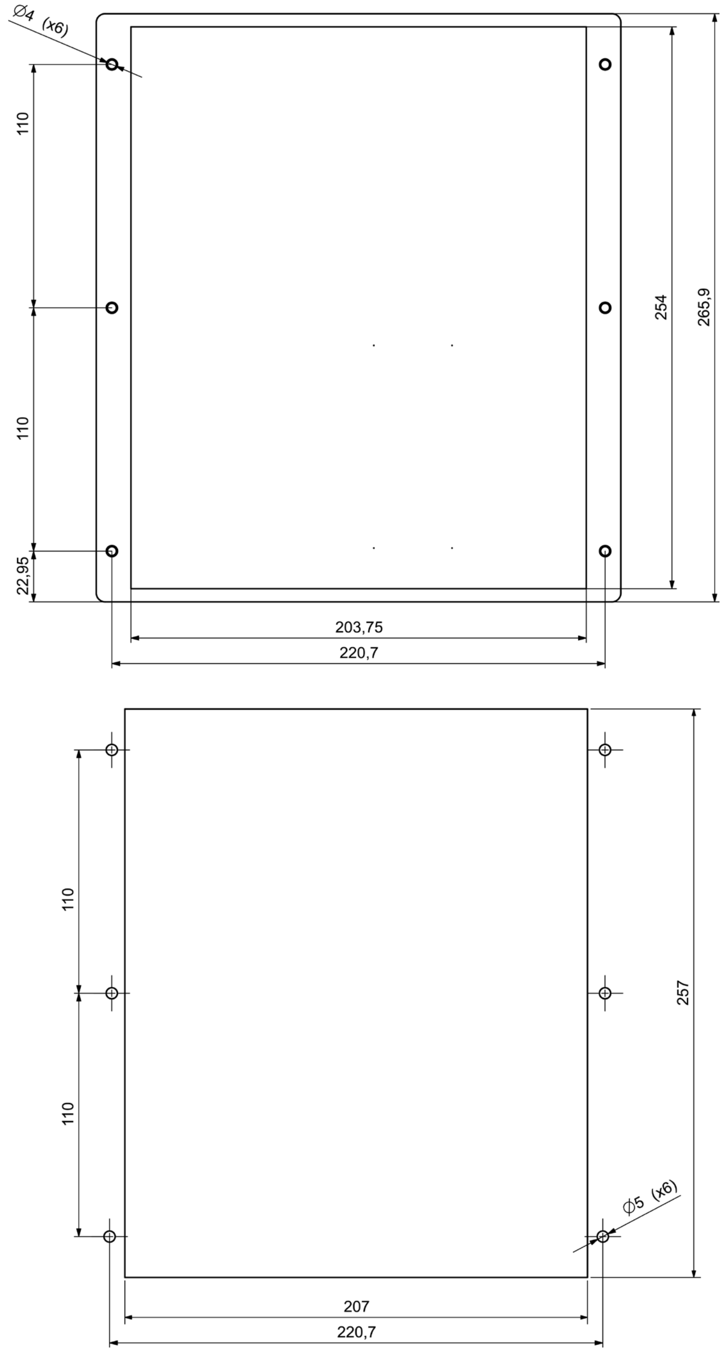


Figure 1.4.4 2TCA-E Installation Drawing.

1.4.3 Connection Elements

1.4.3.a Terminal Blocks

The number of slots of the relay depends on the device selected in the Model List (Chapter 1.2). Strips are arranged vertically as shown in figure. Terminal arrangement by columns is as follows:

- **SLOT A**: 4 terminal blocks of 8 terminals for digital outputs and one terminal block of 3 terminals for the auxiliary power supply.
- **SLOT B**: spare.
- **SLOT C/D/E**: 2 terminal blocks of 9 terminals for digital inputs and one terminal block of 16 terminals for analog inputs.
- **SLOT F**: depending on the model the IED will have 2 terminal blocks of 9 terminals for digital inputs and two ethernet ports or 4 communication ports, 2 ethernet and 2 RS232/485 ports.

The connectors are plug-in and not self-shorting. They admit a #13 AWG (2.5 mm^2) cable. It is recommended using pin terminals.

The slots are properly identified with a letter and in one side of the device there is a label which identifies every element.

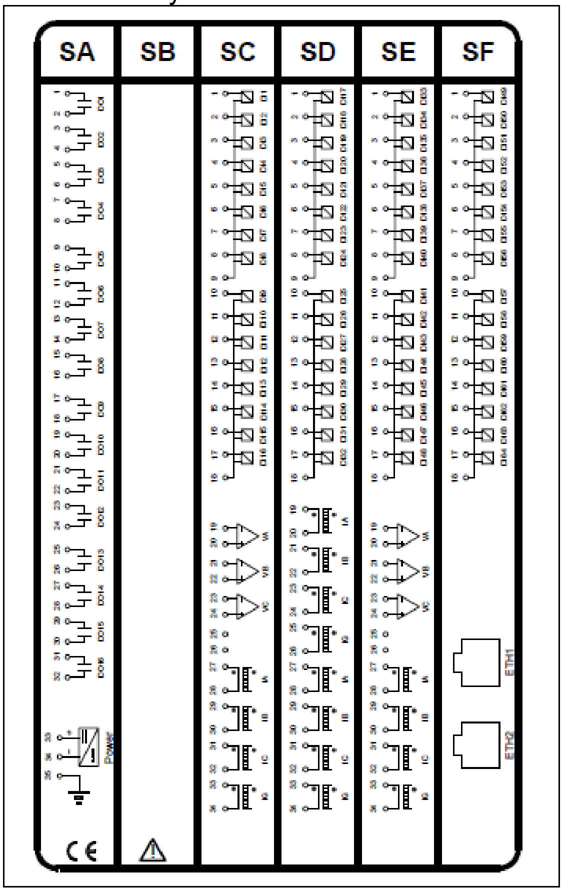


Figure 1.4.5 Example of label located in the side of the 2TCA-E.

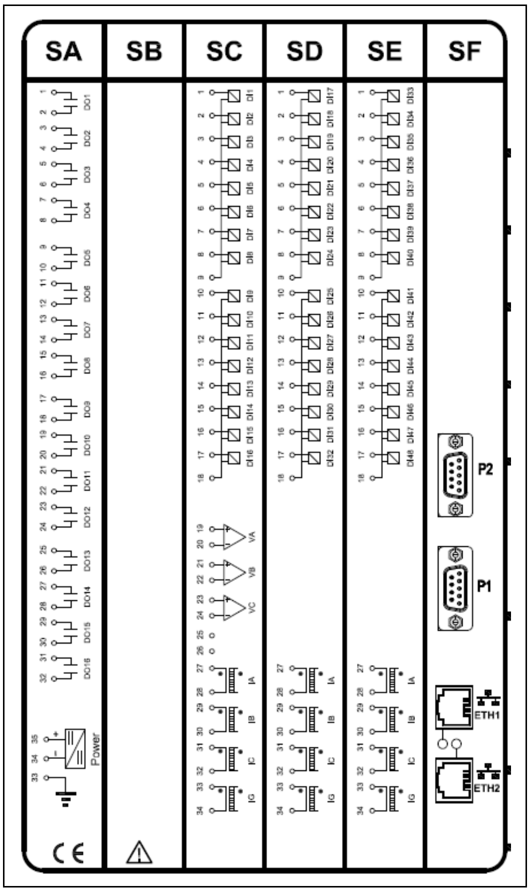


Figure 1.4.6 Example of label located in the side of the 2TCA-E (SmartRTU).

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


WARNING!

The IED's printed circuit board can be taken out. **WARNING: in models for convetional current sensors (no Smart RTU), the current connector is non self-shorting. Consequently, the CT secondaries must be short-circuited externally before board removal.**

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

1.4.3.c Internal Wiring

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

1.4.4 Local Interface

1.4.4.a Command Buttons and Operation Mode

The equipment has the following local commands that will be executed as long as they are followed by their confirmation:

	**Local Mode button** With this button the user can select the local mode
	**Remote Mode button** Remote mode selection button.
	**Confirmation button** After selecting the local or remote push button, the mode is confirmed after pressing this confirmation button.

The buttons have a light siganlling to show the status of the IED. The LED assigned to the confirmation button is disabled.

Once pressed a button, the corresponding LED starts flashing to indicate the user that is has been selected till the confirmation button is pressed and changes the status.

As an additional functionality, the device can restore the default setting using the confirmation button. The following sequence has to be executed: after a powering up and once the IED has executed the LED test carousel, press the confirmation button for 5 seconds and then all the LEDs will be switched on except the ready LED that will remain switched off. Once the IED has restored the configuration, the LEDs will switch off and the IED will keep on working normally. Once the IED is in operation the ready LED will flash in green and all the settings will be the default ones.

1.4.4.b LEDs

The relay includes 20 LEDs on the front, for have a fixed function and 16 are configurable.

- **Fixed function LED**

  - Ready: the LED on the upper right part of the relay with the greatest separation from the other LEDs is used to show the device status. It is a tricolor LED that will indicate the following conditions:
    - In operation: steady green.
    - Relay booting up: blinking green.
    - Relay in critical error (red).
  - 18 and 19 LEDs (red): they show the local or remote status of the device.
  - LED number 20: it is not in operation (disabled).

- **Configurable LEDs**

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

These LEDs are configured through protection settings being able to assign up to 6 input signals to an OR gate so that when any of these 6 variables is activated, the corresponding LED is activated and up to 6 input signals to an AND gate so that when all those 6 variables are activated, the corresponding LED is activated. Selected signals could be internal of the relay or user signals configured in the control logic configuration. Also, each LED will have three settings, ***Flashing***, ***Blinking*** and ***Memorizing*** so that they can be set separately for each LED in order that:

- ***Blink***: if the signals associated to the LED are inside this label, the LED will start blinking when any of the OR logic signals is activated or all the AND logic signals are activated, being activated and deactivated as a function of a pulse train of fixed duration.
- ***Flash***: if the signals associated to the LED are inside this label, the LED will remain on while any of the OR logic signals is activated or all the AND logic signals are activated.
- ***Memorized***: when the setting is set to **YES** and the signals assigned to the OR/AND logic are deactivated after one activation, the LED remains lit or blinking until a LEDs reset command is received.The reset command may be carried out through a digital input if the IED has been configured for that purpose.

In the control logic chapter is it described how the logic of the LEDs is configured.

1.4.5 Inputs and Outputs

Digital outputs are in the power supply module.

- **SLOT A**: 16 digital outputs.

Digital Inputs are grouped by SLOTs, being part of the CPU and analog modules in the model 2TCA-E or being part of the analog modules in the model **2TCA-E** (SmartRTU).

- **SLOT C/D/E/F**: 16 digital inputs per slot (**2TCA-E**). The Smart RTU model will not have digital inputs in Slot F.

The digital inputs and outputs can be configured through protection settings being able to assign up to 6 input signals to an OR gate so that when any of these 6 variables is activated, the corresponding input or output is activated and up to 6 input signals to an AND gate so that when all those 6 variables are activated, the corresponding input or output is activated. Selected signals could be internal of the relay or user signals configured in the control logic configuration.

1.4.5.a Digital Inputs

The digital inputs are divided in groups of 8 inputs. All of them can be configured with any signal that belongs to the protection of the device or the ones the user can define in the control configuration.

The filtering and operation of the digital inputs is performed at two levels and it is configurable according to the following options:

The first filtering level is used to remove the possible short-term activations and deactivations generated by contact rebounds. The device has 2 filters, each filter can be set according to the following settings:

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

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

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

The second filter level is used to avoid flood of status changes in the digital inputs send by the device to the control center. There is a functionality that detects these erroneous situations implementing an algorithm to block and unblock of the digital signals which works with the following settings:

- ***TACTDES***: ***Settable time window to disable a digital input due to excessvi number of changes*** (1 – 32.767 s): in order to prevent problems of a digital input under external or internal malfunction, a settable time window is established, in which the number of times the status of this digital input changes is monitored. If this number of changes exceeds a settable value, the digital input is disabled, and the last status is frozen.
- ***N_CAMB_D***: ***Number of maximum changes to block a digital input*** (0 - 255). If the number of changes of a digital input during the TACTDES time window is equal or greater than this setting, the digital input is disabled, and the status is frozen in the last value. The blocking quality bit is enabled (BL). Once blocked the digital input can be disabled by command or once the unblocking conditions are fulfilled. If the setting value is 0, the digital inputs will never be blocked.
- ***N_CAMB_A***: ***Number of maximum changes to unblock a digital input*** (0 - 255). Once one digital input has been disabled/blocked, it will be automatically unblocked again once the enabling conditions are fulfilled, this is, when the number of changes defined by this setting is equal or less than the number of changes detected in the TEACDES time window defined. In this case, the blocking quality bit (BL) will be deactivated.

Digital Inputs Settings			
Setting	**Range**	**Step**	**Default**
Time between samples Filter 1	1 - 10 ms	1 ms	2 ms
Time between samples Filter 2	1 - 10 ms	1 ms	2 ms
Number of samples with same value to validate Filter 1	1 - 10 samples	1	2
Number of samples with same value to validate Filter 2	1 - 10 samples	1	2
Filter assignation (one setting per DI)	0 = Filter 1 1 = Filter 2		Filter 1
Activation/deactivation time	1 - 32,767 s	1 s	10 s
Number of changes for deactivation	0 - 255	1	10
Number of changes for activation	0 - 255	1	10

- **Development of the Digital Input Settings on the WEB Page**

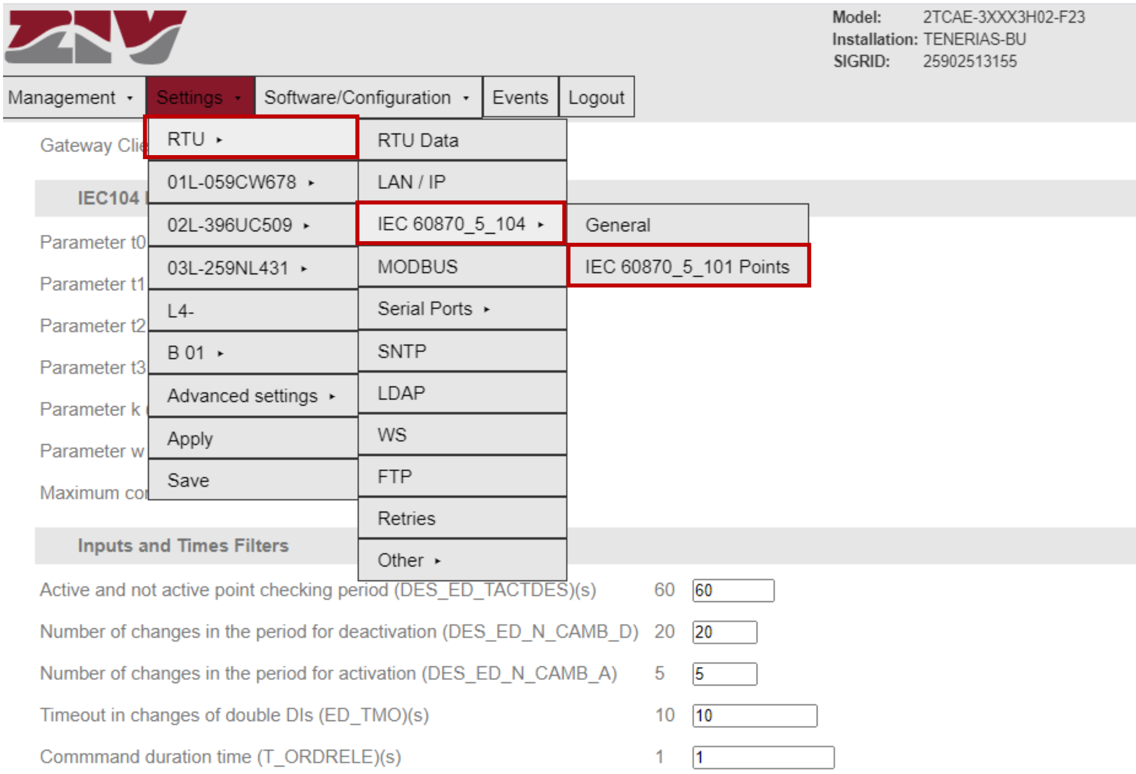


Figure 1.4.7 Menu of Digital Input Settings

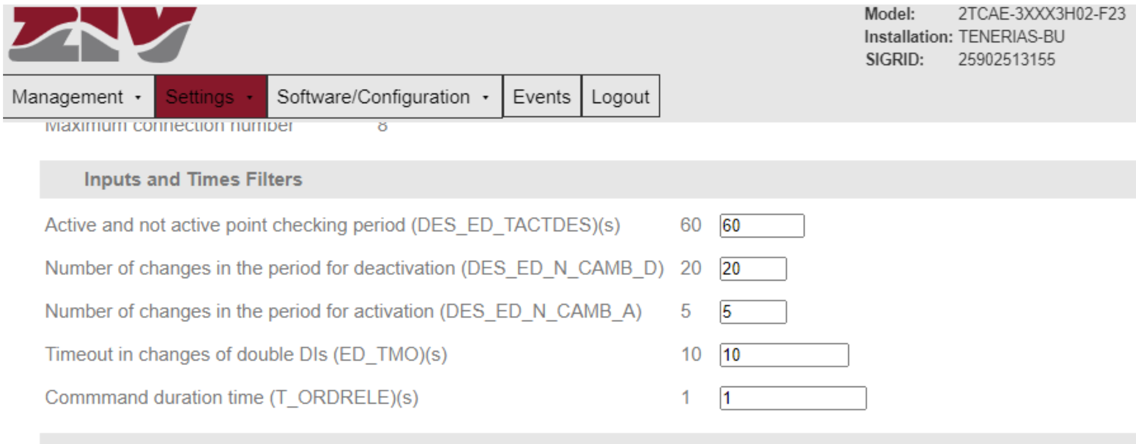


Figure 1.4.8 Excessive Number of Changes Filter (Digital Inputs).

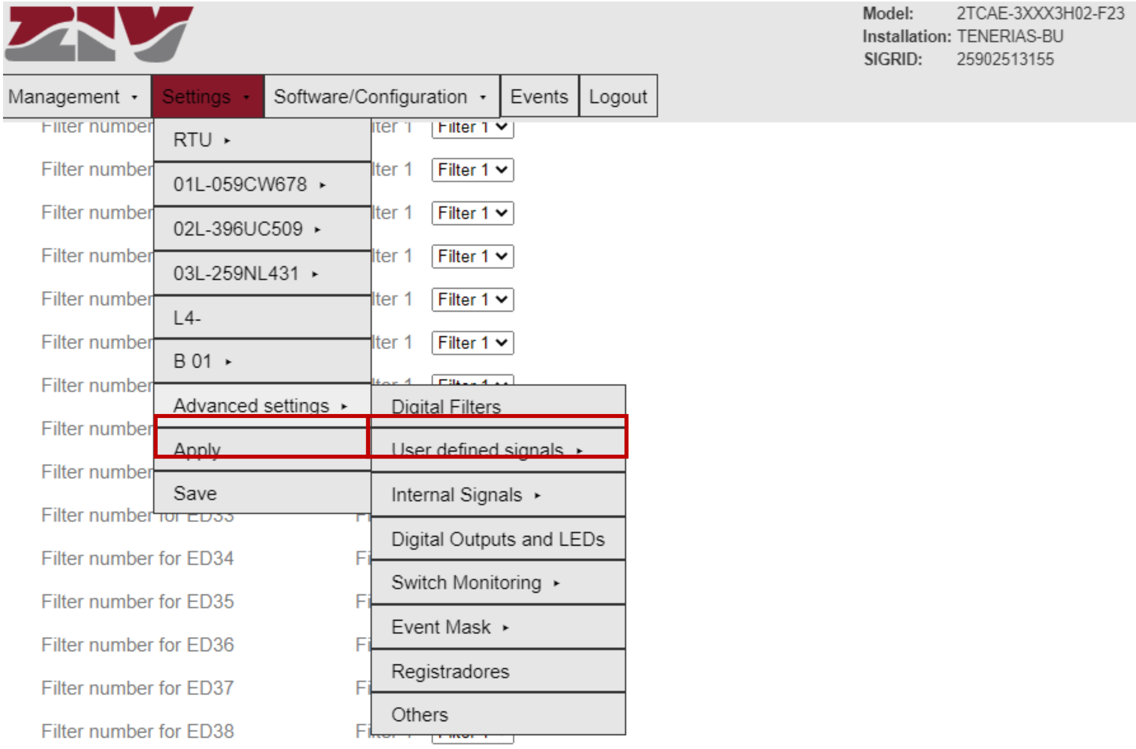


Figure 1.4.9 Menu of Anti-rebound Filter (Digital Inputs)Settings

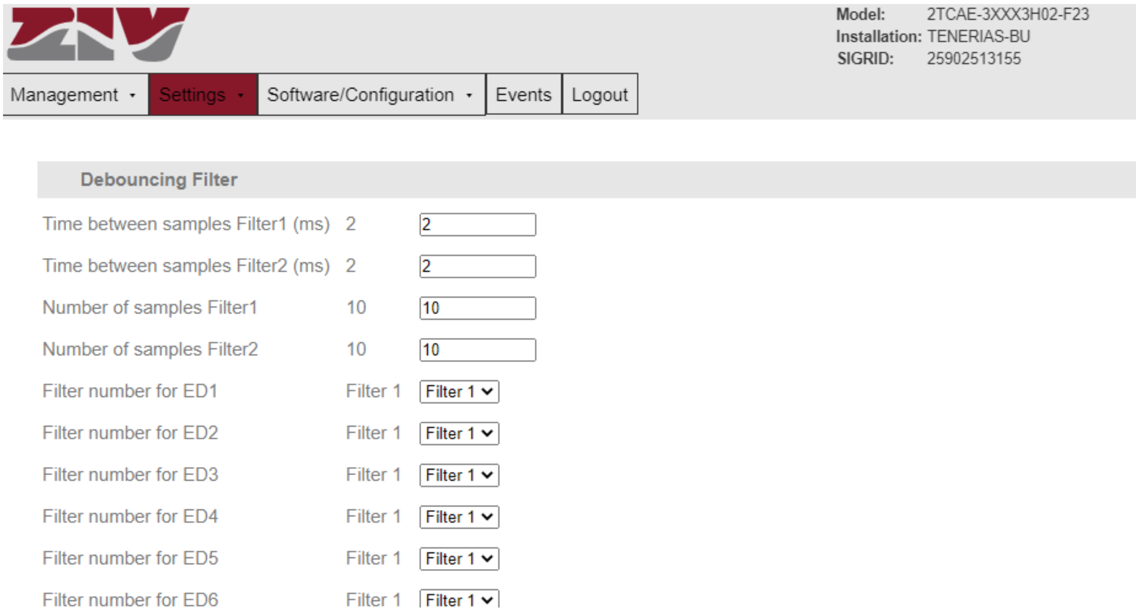


Figure 1.4.10 Anti-rebound Filter (Digital Inputs).

1.4.5.b Auxiliary Outputs

The device provides 16 configurable digital outputs. They can all be configured with any input or output signal of the pre-existing protection and control modules or defined by the user in the programmable logic.

Auxiliary outputs use normally open contacts.

The block diagram of the operation of the digital outputs is the following one. The configuration of the digital outputs is described in the control logic chapter.

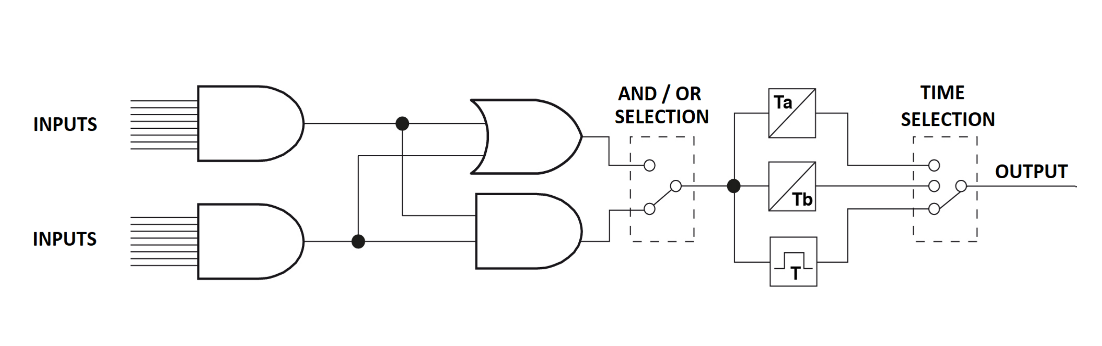


Figure 1.4.11 Block Diagram of the Logic Applicable for each Digital Output.

1.4.5.c Digital Inputs, Auxiliary Outputs and LEDs Test

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

- **Digital Inputs**

For the inputs test, exceed the rated voltage between the terminals corresponding to the inputs (marked in the external connections diagram), always taking the polarity of the contacts into account and activation levels.

Connect to the webserver and check the status of the digital inputs.

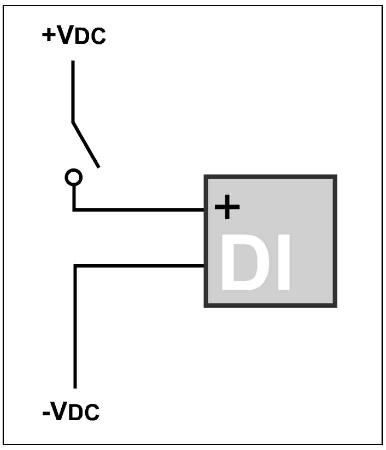


Figure 1.4.12 Digital Inputs Test.

- **Auxiliary Outputs**

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

- **LED Targets**

In order to check the LED indicators, activate them one by one. The easiest way to do so is configuring each LED to be activated with a digital input this way both the digital inputs and the LEDs can be checked.

1.4.6 Communications

The IEDs are provided with different types of communications ports depending on the selected Model, having several communications interfaces that allow remote communications to be established upstream with different control dispatches, downstream serial communications with different IEDs and local interconnections. The available interfaces are:

- 1 Front Local Port RJ45 type, with the following characteristics: through this Ethernet interface it is possible to access the system's Web Server.

- 1 Front Local Port USB-B type. Used only to access the service HMI via the command line.

- Up to 3 Rear Ports:
    - One LAN Interface: RJ45 type marked as ETH1. This port is used for remote connections and supports ethernet type communications (web services and IEC 60870-5-104). ETH2 LAN port is disabled and cannot be used.
    - P1 & P2 RS232 or RS485 electrical interface. Each port can be configured independently to communicate as master using MODBUS protocol.

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

Technical data for these communications links can be found in 1.3, Technical Data section. Information on model ports can be found in 1.2, Model Selection section.

1.4.6.a IP Addressing of Network Interfaces

The equipment has two network ports identified as ETH1 and LOC. The first one has two IP addresses corresponding to the remote addressing.

On the first of these remote IP addresses, the Dynamic IP option can be enabled so that an external DHCP server configures the main remote IP address of the unit. This option does not influence the second remote IP address or the local addressing of the ETH2 port.

The LOC port responds only to local accesses to the equipment and has its own local IP address. The default value is **100.0.0.1**.

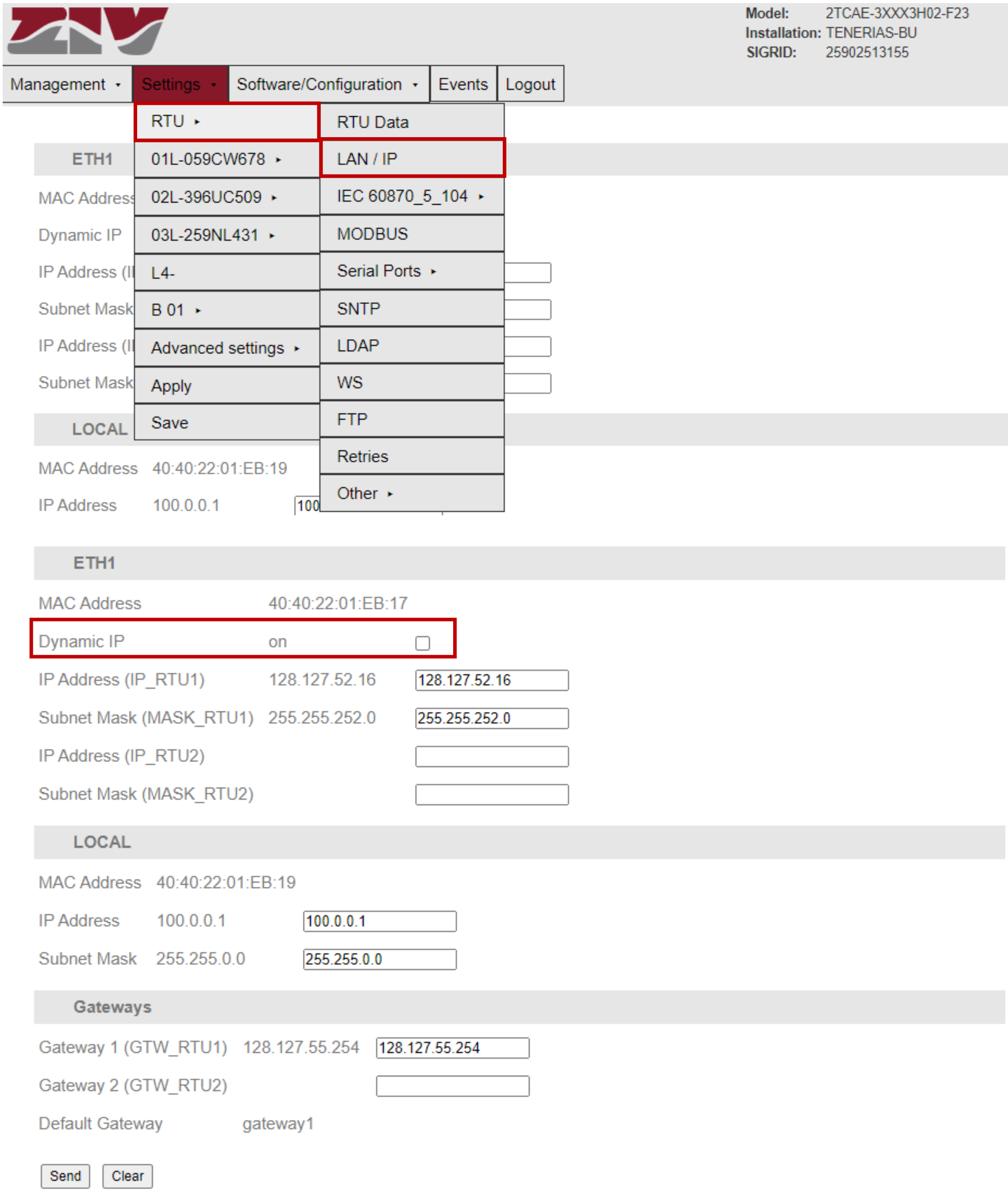
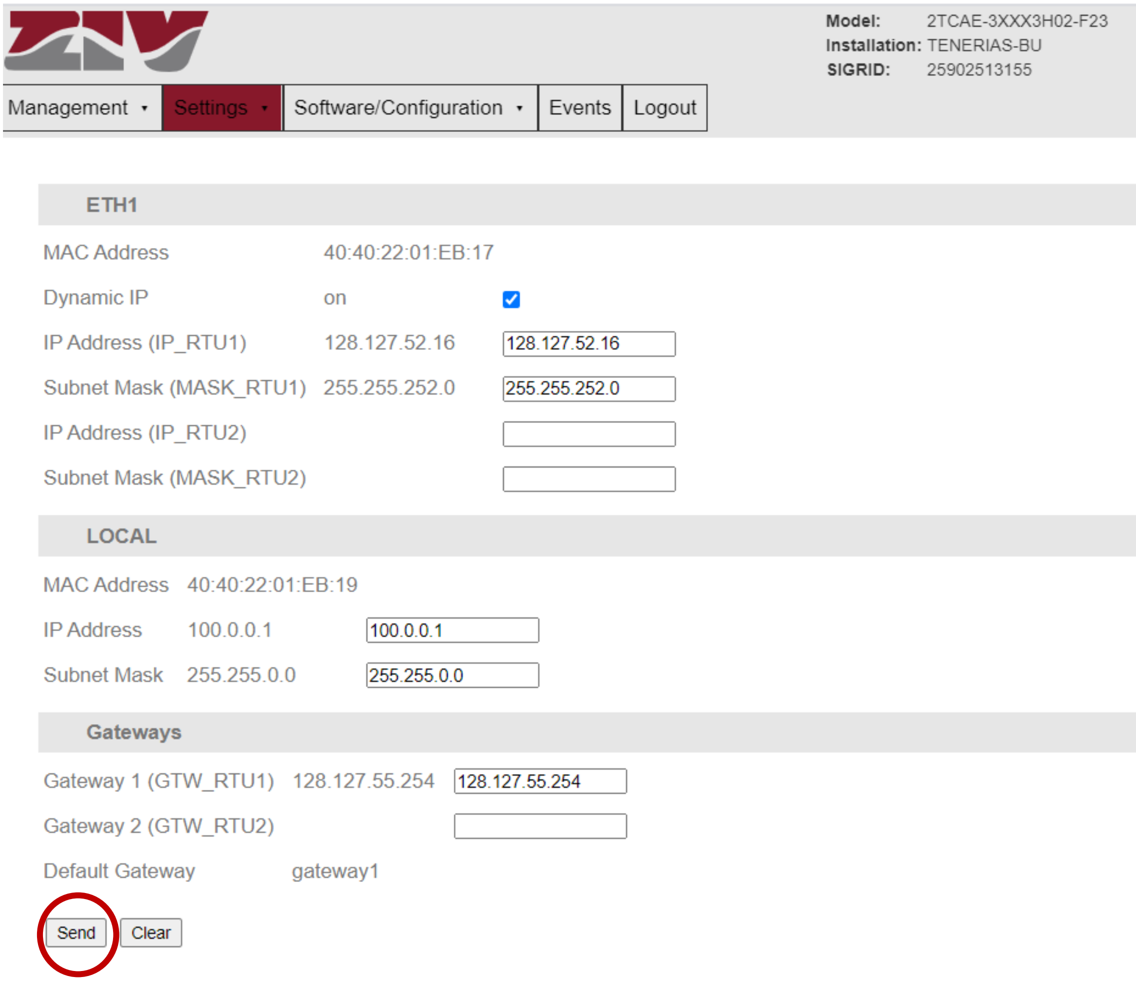


Figure 1.4.13 Dynamic IP Configuration.

- **IP Connectivity**

IP Addresses - LAN			
Setting	**Range**	**Step**	**Default**
Dynamic IP Enable (DHCP)	YES / NO		NO
Remote Port ETH 1			
IP #1 Address	ddd.ddd.ddd.ddd		200.0.0.1
IP #1 Subnet Mask	ddd.ddd.ddd.ddd		255.255.255.0
IP #2 Address	ddd.ddd.ddd.ddd		empty
IP #2 Subnet Mask	ddd.ddd.ddd.ddd		empty
Local Port ETH 2			
IP Address	ddd.ddd.ddd.ddd		100.0.0.1
Subnet Mask	ddd.ddd.ddd.ddd		255.255.255.0

Once the desired parameters have been set, press ***Send*** to send these settings to the **2TCA-E** unit.



1.4.6.b IEC 60870-5-104 Protocol

The **2TCA-E** equipment has two Ethernet communication ports (ETH1 and LOC) to communicate with one or more Telecontrol dispatches using the IEC 60870-5-104 protocol. This is a control protocol that defines the use of an open TCP/IP network, which transports the ASDUs of the IEC 60870-5-101 protocol.

The **2TCA-E** equipment acts as a Slave (*Controlled Station*) in the communication with the Telecontrol dispatch (*Controlling Station*) and implements a reduced set of all possible protocol ASDUs, as can be seen in the "Annex A" corresponding to the IEC 60870-5-104 Communications Profile.

In general, the parameters of the IEC 60870-5-104 Protocol will be adjustable in **the IEC 60870_5_104** option of the **Parameters** menu.

- **Protocol Settings**

IP Addresses

This section configures the two possible IP addresses assigned to the two Ethernet communication ports for the IEC 60870-5-104 protocol, as well as the subnet masks. For each Ethernet port (1 and 2), the following parameters will be configured, adjustable within the **LAN** option of the **Parameters** tab:

- **IP address**: IP address of the corresponding Ethernet port for the IEC 60870-5-104 protocol.
- **Subnet Mask**: Subnet mask of the corresponding Ethernet port for the IEC 60870-5-104 protocol.

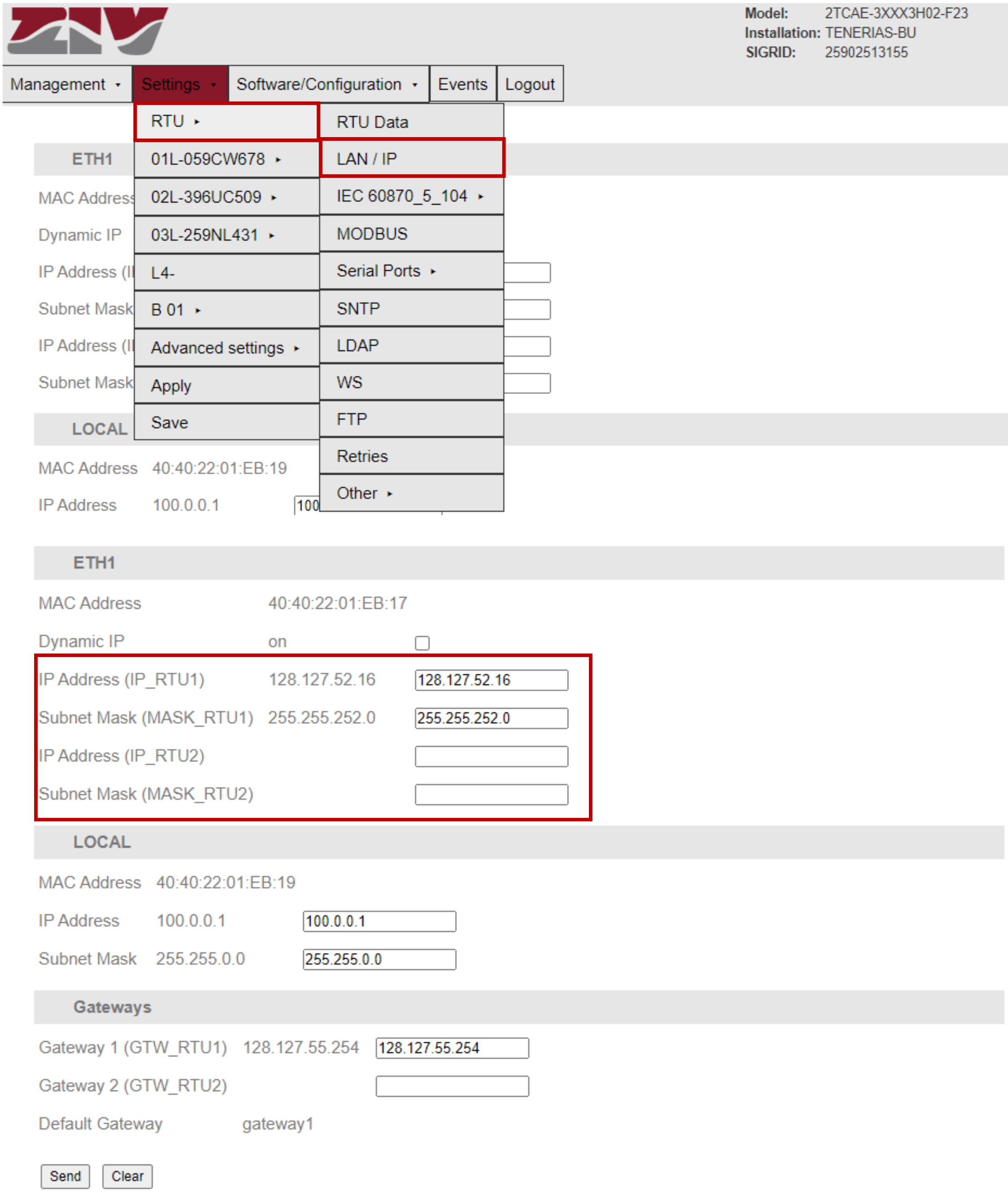


Figure 1.4.14 Example of Configuration of IEC 60870-5-104 Protocol IP Addresses.

Connections

This section configures the parameters related to the possible IEC 60870-5-104 connections supported by the **2TCA-E** equipment.

The **Maximum Number of Connections** parameter indicates the maximum number of simultaneous IEC 60870-5-104 client connections that the **2TCA-E** equipment can maintain. The following parameters can be configured for each of these connections:

- **Client IP**: IP address of the client that is connected to the **2TCA-E** unit. The **2TCA-E** unit will check the IP of the client that is connected to it by IEC 60870-5-104 and, if it coincides with the address of this parameter, the connection is accepted, being rejected otherwise. Special values of this parameter are the address **0.0.0.0** (meaning that connections from this client are not allowed) or **255.255.255.255** (connections from any client IP are allowed).

The following link layer parameters are set for all connections:

- **t0**: IEC 60870-5-104 connection establishment timeout. This time is counted and expires on the host. In the remote 2TCA-E Automation software, it is recorded at an informative level.
- **t1**: Timeout for sending or testing IEC 60870-5-104 frames.
- **t2**: Timeout for the recognition of IEC 60870-5-104 frames in case there are no data messages (t2 < t1).
- **t3**: Timeout for sending test frames in the case of a long waiting state (t3>t1).
- **k**: Maximum number of unrecognized transmitted frames.
- **w**: Maximum number of unrecognized frames received.

Connections			
Setting	**Range**	**Step**	**Default**
Maximum Number of Connections	1 - 8	1	8
IP Client	ddd.ddd.ddd.ddd		0.0.0.0
t0	1 – 255 s	1	30 s
t1	1 - 255 s	1	30 s
t2	1 - 255 s	1	10 s
t3	0 - 9999 s	1	60 s
k	1 - 32767	1	12
w	1 - 32767	1	8

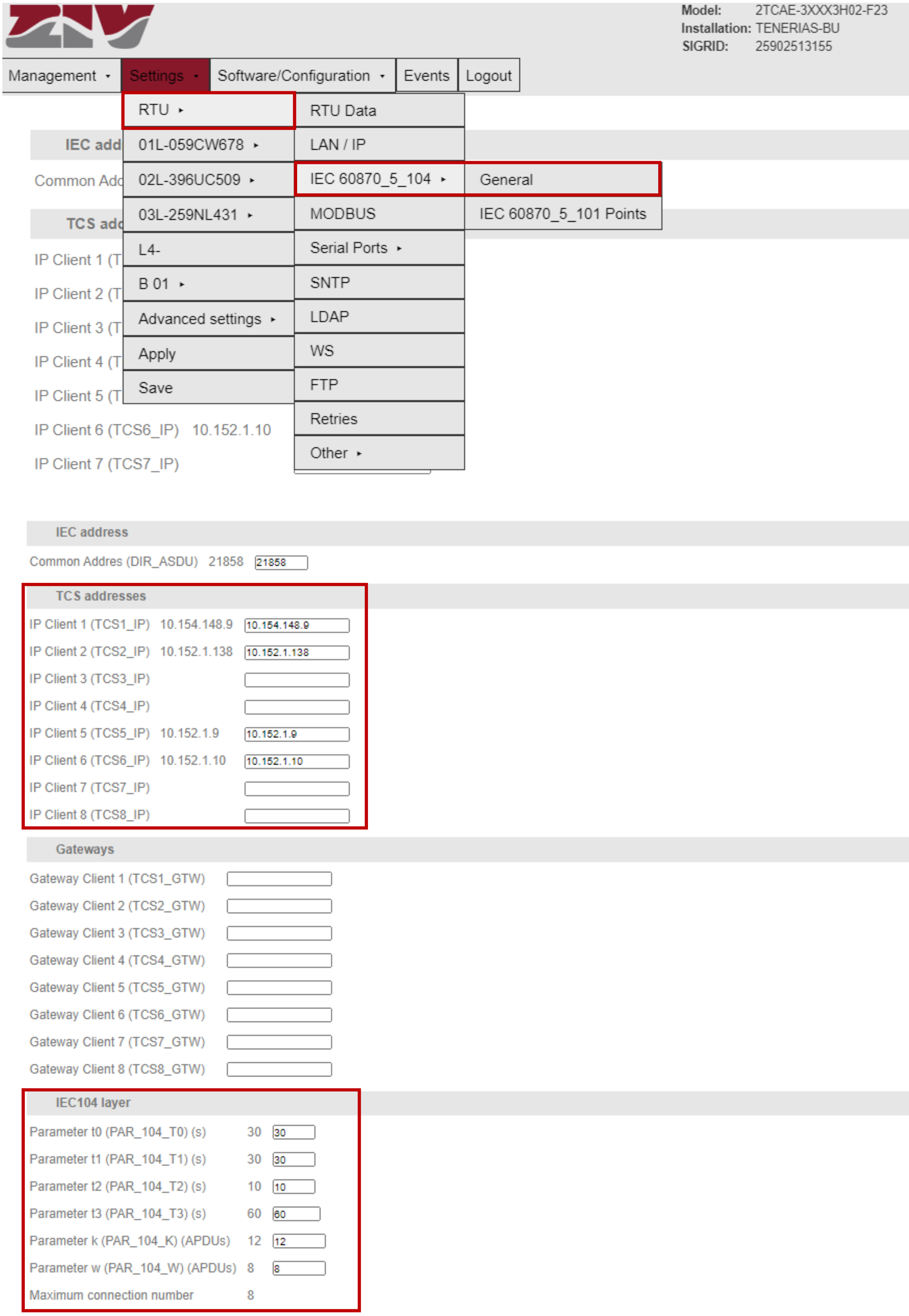


Figure 1.4.15 Example of Configuration of IEC 60870-5-104 Client Connections.

Routes

In this section, the Output Routes (Gateways) will be configured for each of the 8 possible IEC 60870-5-104 connections supported by the **2TCA-E** equipment. Therefore, for each of the 8 possible clients, the **Client Gateway** parameter will be configured, adjustable within the **Parameters → IEC 60870-5-104** menu:

- **Client Gateway #**: Gateway to be used for connection to the corresponding client (1-8). You can choose between the two possible Gateways that can be configured for the **2TCA-E** equipment (see **LAN (eth0) Gateways** of the same **Parameters** tab).

Routes			
Setting	**Range**	**Step**	**Default**
Client Gateway 1	ddd.ddd.ddd.ddd		empty
Client Gateway 2	ddd.ddd.ddd.ddd		empty
Client Gateway 3	ddd.ddd.ddd.ddd		empty
Client Gateway 4	ddd.ddd.ddd.ddd		empty
Client Gateway 5	ddd.ddd.ddd.ddd		empty
Client Gateway 6	ddd.ddd.ddd.ddd		empty
Client Gateway 7	ddd.ddd.ddd.ddd		empty
Client Gateway 8	ddd.ddd.ddd.ddd		empty

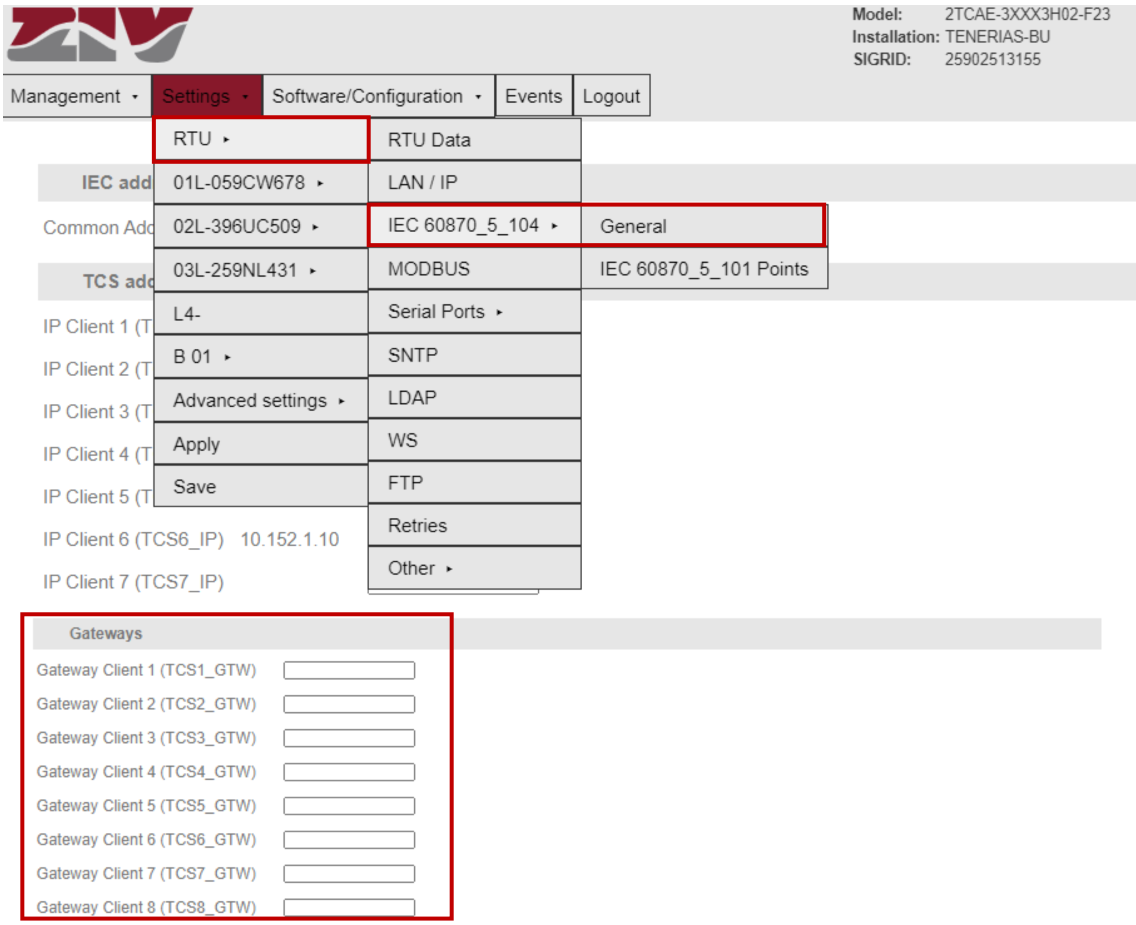


Figure 1.4.16 Example of Gateway Configuration for IEC 60870-5-104 Clients.

IEC Address

- **Direction of application layer**. Specifies the Common Address of ASDU of the **2TCA-E** equipment (acting as **RTU** or Controlled Station) in relation to the rest of the equipment that communicates with the same Controller Station.

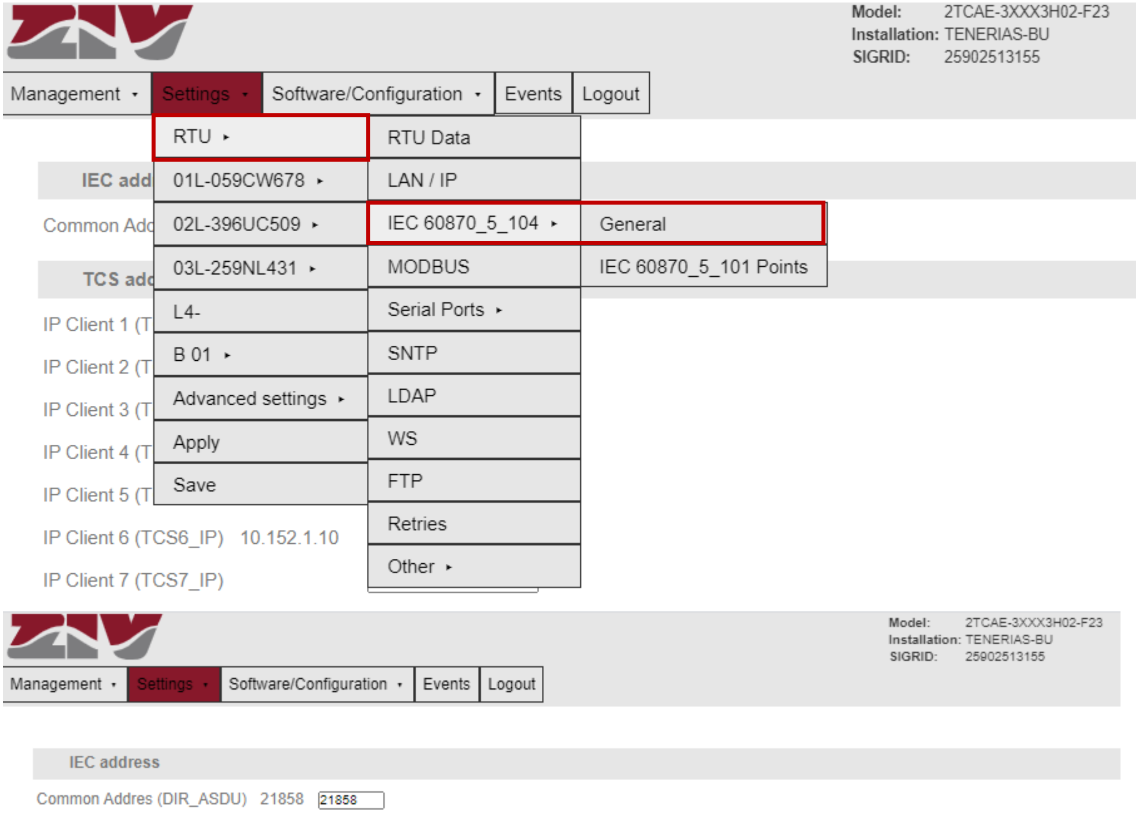


Figure 1.4.17 Example of Configuration of the IEC 60870-5-104 Application Address.

General

General Parameters of the IEC 60870-5-104 protocol will be configured in this section,

- **Maximum frame length**: This is the maximum number of bytes in the IEC 60870-5-104 frame (APDU).
- **Measurement exploration period**: This is the time of sampling values of analog measurements to treat them and evaluate if they have to be sent to the dispatch in case of exceeding the hysteresis or band value. A value of 0 implies that the **2TCA-E** equipment will process these measurements as quickly as it acquires them.
- **Deletion of the C2 queue reset link**: It indicates if the **2TCA-E** unit must delete (☑) or not (☐) the data of the class 2 queue when the IEC 60870-5-104 connection is established (it goes to STARTED state).
- **Length (ASDUs) queue C1**: Length in ASDUs (IEC 60870-5-101 frames) of the class 1 data queue. When the memory dedicated to the class 1 queue does not admit any more messages, the 2TCA-E equipment generates a full class 1 queue activation incident that is placed in the last position of the class 1 transmission queue to be sent to the Controller Station. From that moment on, the 2TCA-E equipment will stop the entry of incidents in this class 1 queue. The 2TCA-E unit will reset its IEC 60870-5-104 module when this class 1 queue has been emptied, that is, when it has sent the last event of a full class 1 queue.

- **Length (ASDUs) queue C2**: Length in ASDUs of the data class 2 sub queue. When this data sub queue is full, the entry of incidents in the queue is stopped until there is a free space.
- **Length (ASDUs) sub queue C2 command confirmation**: Length in ASDUs of the sub queue of class 2 commands confirmation. When the commands confirmation sub queue is full, the entry of incidents in the queue is stopped until there is a free space.
- **Command buffer length**: Length of the command buffer. It is the maximum number of pending commands of confirmation that the **2TCA-E** equipment is able to process. Once this buffer is full, the **2TCA-E** equipment will start rejecting orders from the controller station.
- **Request buffer length**: Request buffer length. It is the maximum number of unprocessed commands (data requests) that the **2TCA-E** equipment is able to store. Once this buffer is filled, the **2TCA-E** equipment will start rejecting requests from the Controller Station.
- **Period of periodic change**: It is the time in minutes of generation of a change of state and spontaneous transmission of the point of the system **Periodic Change** that is explained later. If it is configured with the value 0, it means that the generation of this change is deactivated.

General			
Setting	**Range**	**Step**	**Default**
Maximum frame length	23 - 255 bytes	1	255 bytes
Measurement exploration period	0 -	60 s	1
Deletion of the C2 queue reset link	YES / NO		YES
Length (ASDUs) queue C1	0 - 100	1	1
Length (ASDUs) queue C2	0 - 100	1	25
Length (ASDUs) sub queue C2 command confirmation	0 - 30	1	5
Command buffer length	0 - 10	1	3
Request buffer length	0 - 20	1	10
Period of periodic change	0 - 1440 min	1	1440 min

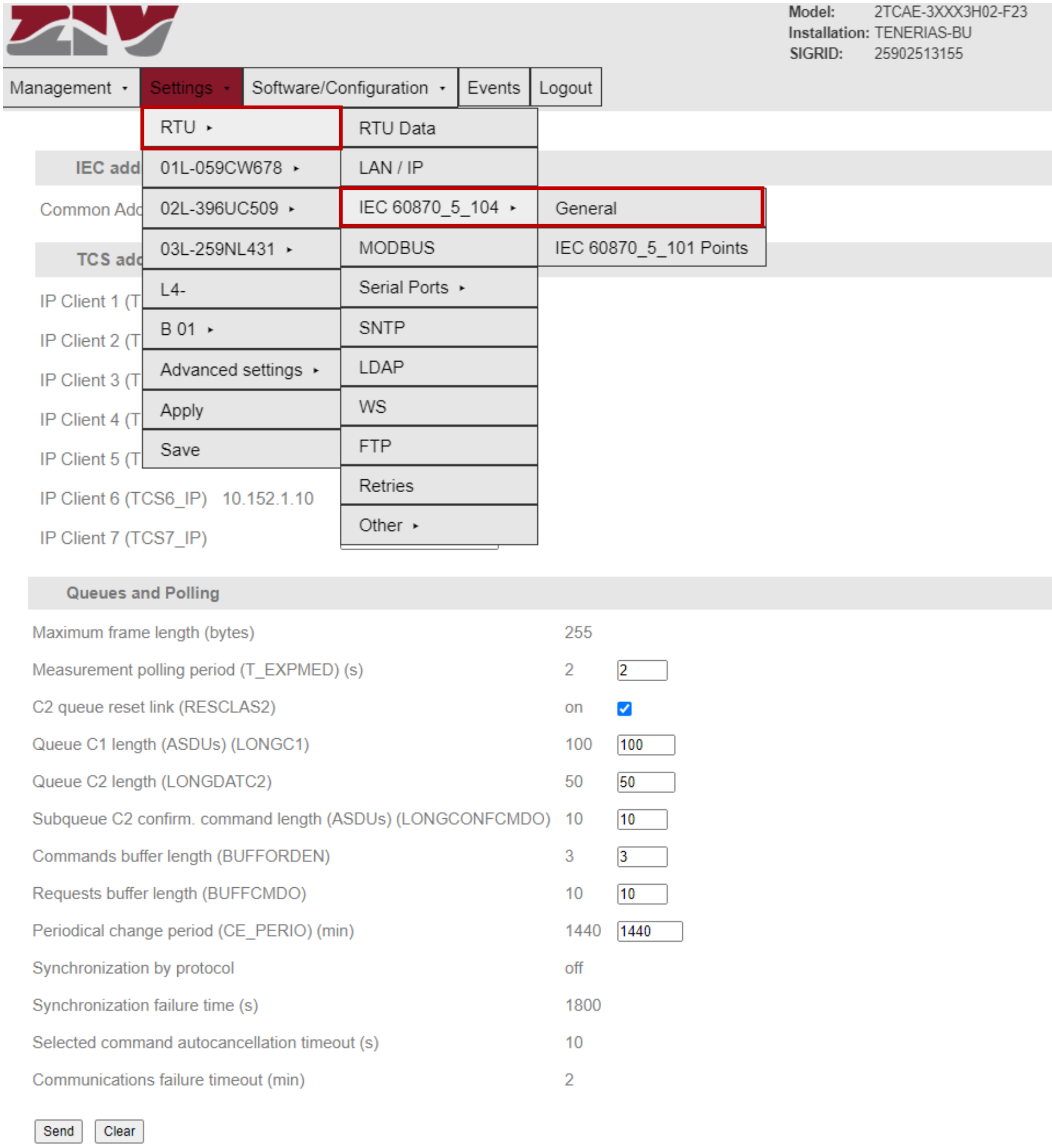


Figure 1.4.18 Example of General Configuration of IEC 60870-5-104 Application Address.

IEC 60870_5_101: System Points

In this section the Information Object Addresses (IOAs) of the System Points will be configured.

- **Queue full to 100%**. IOA Address of the System Point that indicates that the class 1 queue has been filled to 100%.
- **Queue full at X%**. IOA address of the System Point indicating that the class 1 queue has been filled to X%. This point is not used in the **2TCA-E** equipment and will always be sent with status 0.
- **Active file transfer**. IOA address of the System Point indicating that there is a file transfer in progress. This point is not used in the **2TCA-E** unit and will always be sent with status 0.
- **Periodic change**. IOA address of the System Point corresponding to the periodic and spontaneous change. This point will change status each time the time period indicated by the **Period of periodic change** parameter previously explained has elapsed.
- **Synchronized RTU**. IOA address of the System Point that indicates if the **2TCA-E** unit is synchronized by the time synchronization source. This point will take the status 0 when it is not synchronized and 1 when it is synchronized.
- **Synchronization source**. IOA address of the System Point that indicates the active time synchronization source. This point will always take the status 1, since the **2TCA-E** equipment will always be synchronized by an external synchronization source (SNTP), not using an ASDU of the IEC 60870-5-104 protocol (ASDU 103).

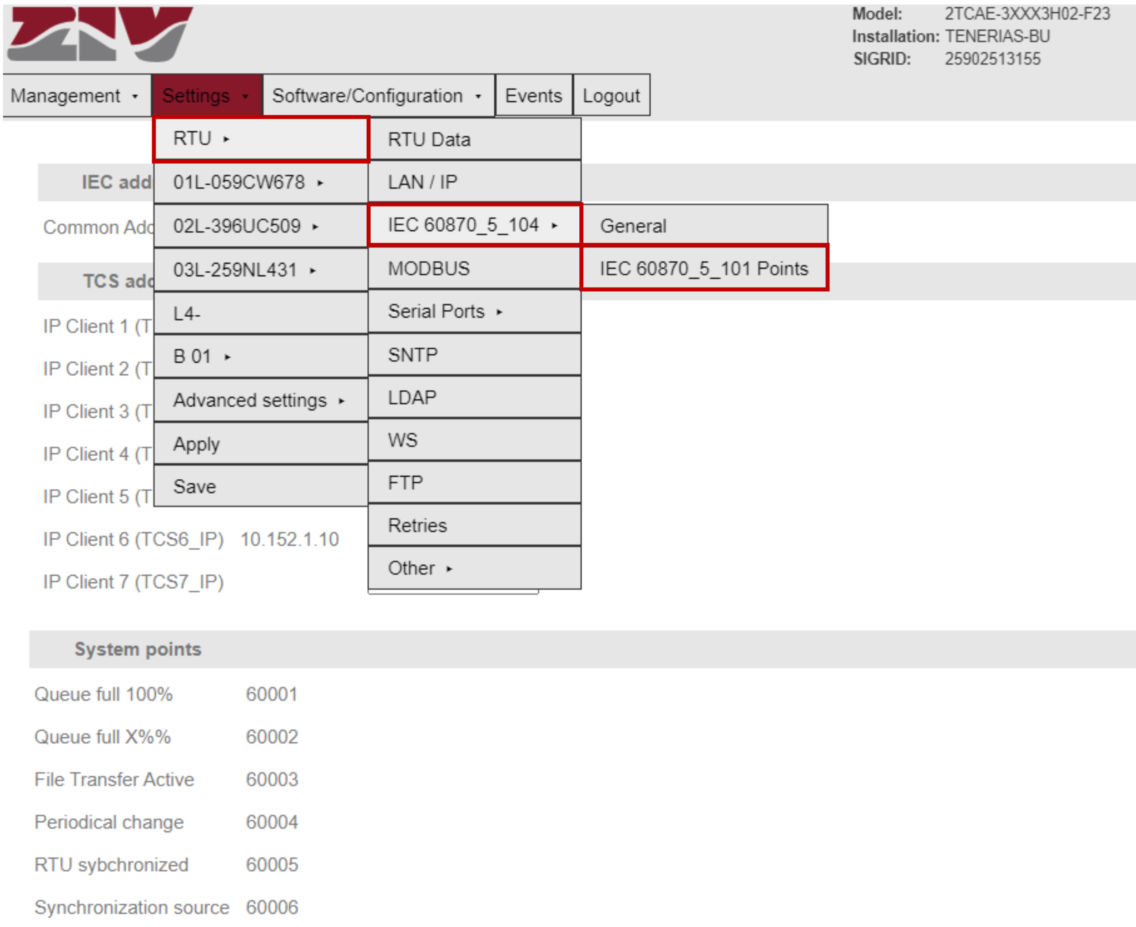


Figure 1.4.19 Example of Configuration of the Addresses of the IEC 60870-5-104 System Points.

IEC 60870_5_101: System Points			
Setting	**Range**	**Step**	**Default**
Queue Full at 100%.	0 - 16777215	1	60001
Queue Full at X%	0 - 16777215	1	60002
Active File Transfer	0 - 16777215		60003
Periodic Change	0 - 16777215	1	60004
Synchronized RTU	0 - 16777215	1	60005
Synchronization Source	0 - 16777215	1	60006

IEC 60870_5_101: User Points

In this section you will configure the Mapping between Signals (digital and analog) and Commands of the **2TCA-E** equipment and the corresponding Points and Commands of the IEC 60870-5-104 protocol. For each **point** of the IEC 60870-5-104 protocol, the following parameters will be configured:

- **Point 101**. IOA address of the Single, Double or Analog Point of the IEC 60870-5-104 protocol. Depending on the type of point, this value must be between the lower and upper IOA ranges corresponding to the type of point, explained below.
- **TCA signal**. Single, Double or Analogue signal of the **2TCA-E** equipment to be sent to the Controller Station by IEC 60870-5-104 protocol.
- **Command 101**. Single or Double Command IOA address from IEC 60870-5-104 protocol. Depending on the command type, this value must be between the lower and upper IOA ranges corresponding to the command type, explained below. A command can be associated with any simple signal. If this setting is not left empty, there is no command associated with point 101.
- **Type** It is used to adjust the type of point 101 and whether it has an associated command or not. The possible values for this setting are: Single Signal / Double Signal / Analog Measurement / Double Command - Single Signal / Double Command - Double Signal.
- **Description**. Text field to identify the single point.
- **Hysteresis (%)**. Reflects the variation, both positive and negative, that an analog signal must undergo with respect to the last value sent by IEC 60870-5-104 to consider that the analog signal has changed. A value of 0 implies the absence of hysteresis and, therefore, in each period of exploration it will be considered that the value of the measurement has changed.
- **Lower Range and Upper Range**

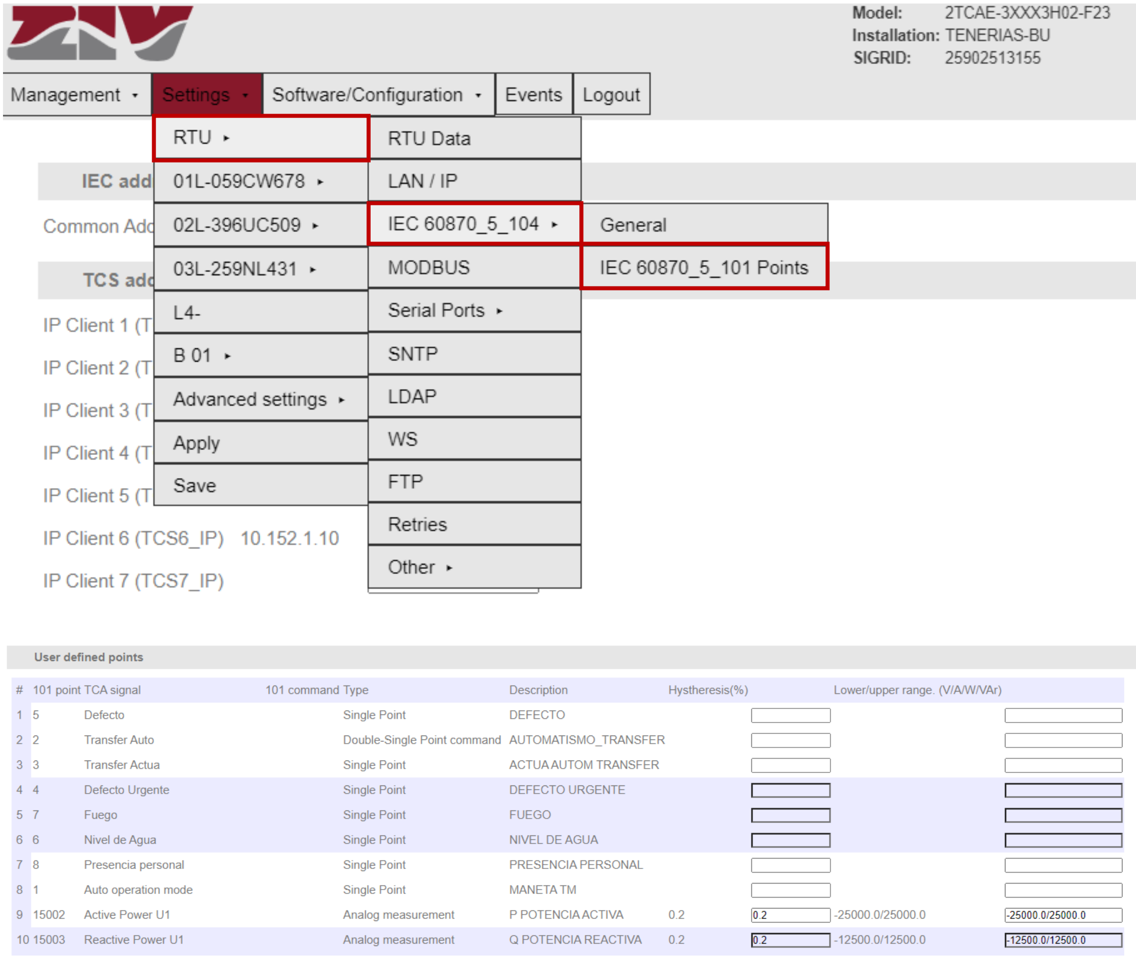


Figure 1.4.20 Example of Configuration of User Point Addresses IEC 60870-5-104 (Points).

IEC 60870_5_101: User Points			
Setting	**Range**	**Step**	**Default**
Point 101	0 - 16777215	1	1
2TCA-E signal			
Command 101	0 – 16777215	1	1
Hysteresis (%)	0 – 100	0.000000001	0.3
Type	Simple signal Double signal Analog Measurement Double command – single signal Double command – double signal		Simple signal
Description			

IEC 60870_5_101: Ranges of IOAs

In this section you will configure the Information Object Addresses (IOAs) that will delimit the IOA ranges for the different types of IEC 60870-5-104 protocol data (Single, Double and Analog Points, as well as Single and Double Commands).

- **Lower Range Single Points**. Lower IOA address of the range corresponding to Single Points.
- **Superior Range Single Points**. Upper IOA direction of the range corresponding to Simple Points.
- **Lower Range Double Points**. Lower IOA direction of the range corresponding to Double Points.
- **Superior Range Double Points**. Upper IOA direction of the range corresponding to Double Points.
- **Lower Range Analog Points**. Lower IOA direction of the range corresponding to Analog Points.
- **Superior Range Analog Points**. Upper IOA direction of the range corresponding to Analog Points.
- **Lower Range Simple Commands**. Lower IOA direction of the range corresponding to Simple Commands.
- **Superior Rank Simple Commands**. Upper IOA direction of the range corresponding to Simple Commands.
- **Lower Range Double Commands**. Lower IOA direction of the range corresponding to Double Commands.
- **Superior Range Double Commands**. Upper IOA direction of the range corresponding to Double Orders.

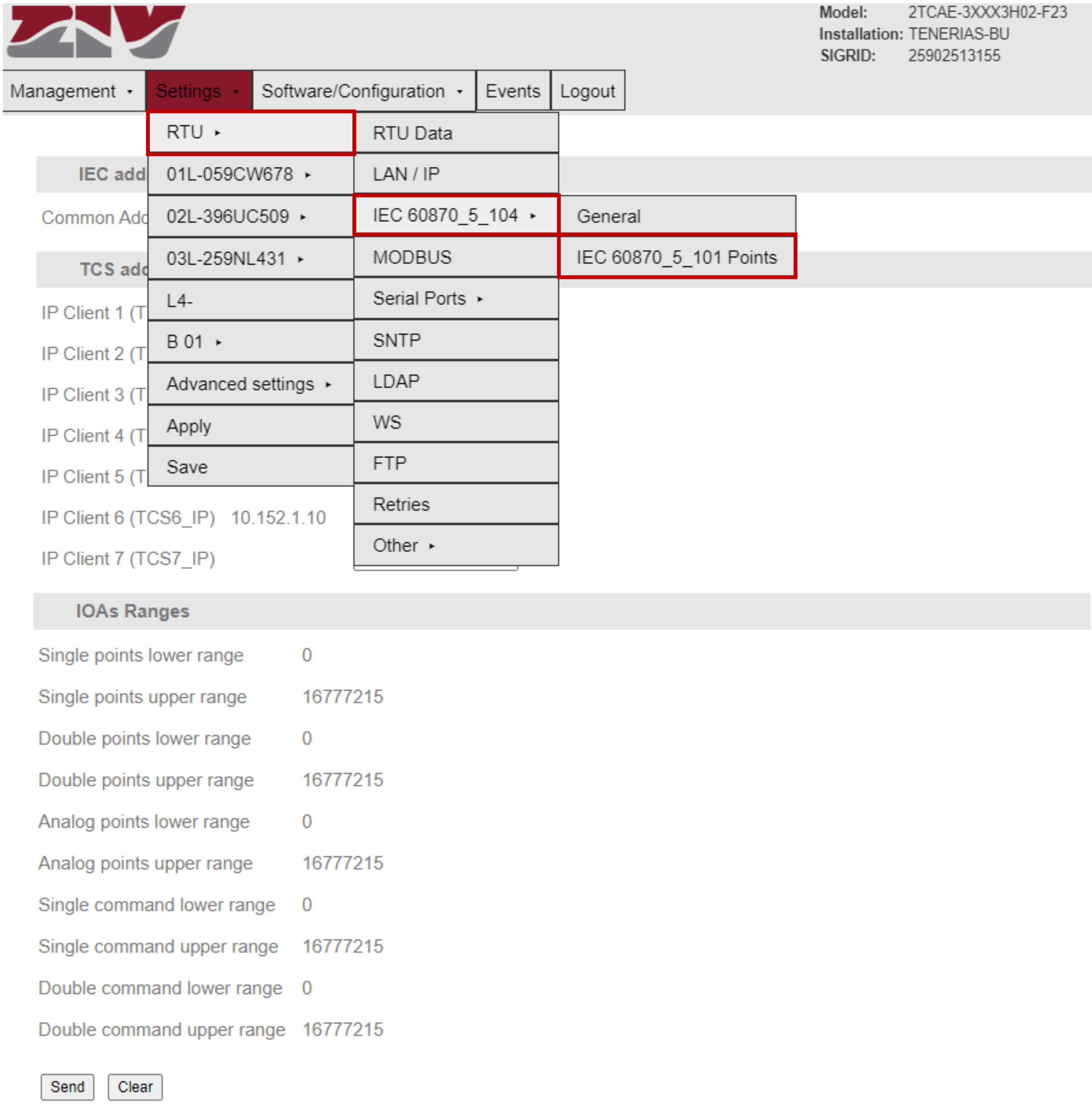


Figure 1.4.21 Example of IOAs Range Configuration.

IEC 60870_5_101: Ranges of IOAs			
Setting	**Range**	**Step**	**Default**
Lower range single points	0 - 16777215	1	0
Superior range single points	0 - 16777215	1	16777215
Lower range double points	0 - 16777215	1	0
Superior range double points	0 - 16777215	1	16777215
Lower range analogue points	0 - 16777215	1	0
Superior range of analogue points	0 - 16777215	1	16777215
Lower range of simple commands	0 - 16777215	1	0
Superior range of simple commands	0 - 16777215	1	16777215
Lower rank double commands	0 - 16777215	1	0
Superior range double commands	0 - 16777215	1	16777215

Once the desired parameters have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

1.4.6.c Modbus Protocol

The Smart RTU model acts as a MODBUS master for up to 3 devices. P1 and P2 serial ports can be configured as RS232 or RS485 and the slave IEDs will be connected to them. The communication settings are independent by port. The generic settings can be modified through the web page while the particular settings are defined using the configuration program ***ZIVe-NET Tool***® and are loaded to the IED using the configuration file generated (see Chapter 4.8).

Settings / RTU / Modbus / Port X			
Setting	**Range**	**Step**	**Default**
Receive Timeout	100 – 60000 ms	1	200ms
Max Retries	1 – 10	1	4
Out Cycle Time	1 – 300 s	1	1s
Measurements Cycle	1000 – 60000 ms	1	1000ms

The available and configurable MODBUS functions in the RTU are the following ones:

ModBus Function	Function Name	Start Directions
01	Read Coil Status	0 x addresses
02	Read Input Status	1 x addresses
03	Read Holding Registers	4 x addresses
04	Read Input Registers	3 x addresses

See Chapter 4.8 to configure the MODBUS map address of the RTU.

1.4.7 Web Services

Web Services will be available depending on the model. Web services is a method of communication between the equipment and the central system in order to exchange information and correctly manage the equipment as long as such information is not required in real time.

The communication protocol for Web Services is SOAP over HTTP and covers SOAP 1.2 and WSDL 1.1 standards.

Web services are synchronous, so the central system when invoking a Web Service will always wait for the response of the equipment and communication will be a single thread, so an error response will be sent when trying to perform two actions at once, the remote will only respond correctly to the first request that arrives.

The web services will only be available through the remote interface of the equipment, ETH1, that is, only the requests that arrive through ip_rtu1 and ip_rtu2 will be taken into account.

1.4.7.a Available Web Services

- **Configuration status (S01, R01).**
  The system asks the device for information about its configuration to determine if there has been any change that requires the complete configuration to be obtained again, or if there is an FW version later than the one containing the RTU.
- **Complete configuration of the remote (S02, R02).**
  The system asks the device for information about its complete configuration. Because the R02 response can be significant in size, this web service will contain two operations:
  - The first one with usual format, input and output with format: XSD:string.
  - The second operation, the remote information will come in binary format: xsd: base64Binary, which the web service must compress beforehand.
- **Configuration partial load of the remote (S03, R03).**
  The system will ask the remote to change some of the parameters of its configuration. This web service will contain two operations:
  - The first one with usual format, input and output with format: XSD:string
  - The second operation, the remote information will come in binary format: xsd: base64Binary, which the web service must compress beforehand.
- **Remote events file (S04, R04).**
  The system asks the equipment for the event file, being able to filter by dates, group and type of event.
- **Firmware load to the remote (S05, R05).**
  The system asks the remote to load a new firmware, which can consist of loading all or part of the firmware.
- **Complete configuration load of the remote (S08, R08).**
  The system prompts the device to load a complete configuration.
- **Request for first configuration (Y01, R01).**
  When the equipment is started and after its first start-up, the equipment will send to the system a **Request for first configuration event**, to warn you that the equipment has just been started and that, for the moment, its configuration has not been revised.
  This service is important because the remote may be operating under unexpected conditions, so the device will wait a while to receive a response from the system and in case it does not arrive, it will try again. This forwarding process will run indefinitely until the system receives a response.
- **Problems in the remote (Y03, Z03)**
  The equipment will have a special characterization of some events that will cause the sending of a spontaneous message to the system.

The remote one waits a time t_out in receiving the answer. If after this time the remote does not receive a reply, the retry policy will be executed, so the service will be resent as many times as indicated by the parameter n, configured in the equipment. If the number of retries is exhausted without obtaining a response, the event will be considered lost, indicating in the following web service the existence of pending events.

- **Firmware loading event completed (Y04, Z04)**
  With this service, the equipment notifies the system that it has been successfully updated with the new firmware sent.
  The remote waits a time t_out to receive the answer, if after this time the remote does not receive any answer the sending of the service will be reattempted. This service will be resent as many times as the parameter n, configured in the equipment, is indicated. If the number of retries is exhausted without obtaining a response, the event will be considered lost.

1.4.7.b Web Services Settings

In this section you will configure the necessary settings to be configured in the equipment for the proper functioning of web services. Within the menu, Parameters / RTU / WS, you will find all settings.

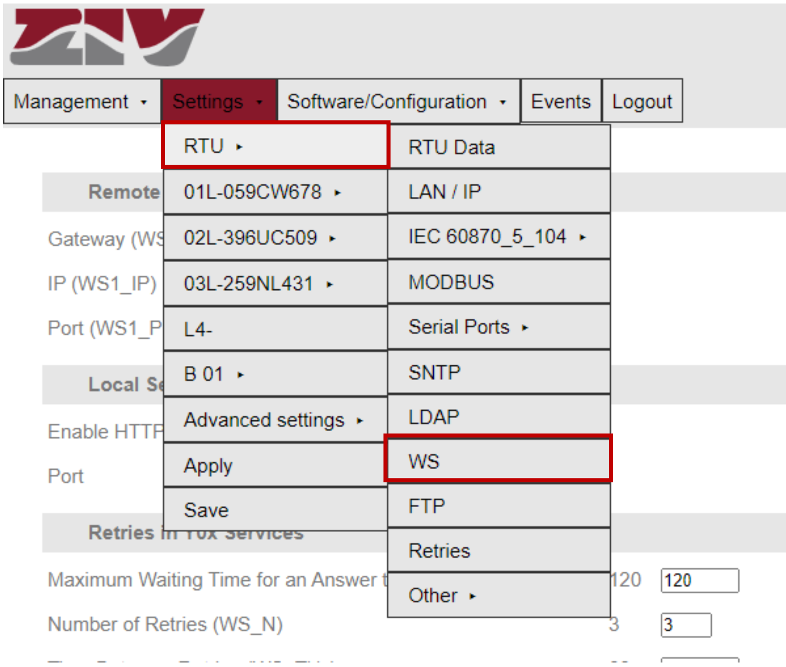


Figure 1.4.22 Menu for Configuration of Web Services.

Web Services			
Setting	**Range**	**Step**	**Default**
IP	ddd.ddd.ddd.ddd (1)		200.0.0.100
Gateway	ddd.ddd.ddd.ddd (1)		empty
Port	1 - 65535		8080
Waiting time to Y0x response	1 - 3600		120
Number of retries	0 - 3600		3
Time between retries	0 - 3600		60

- **Remote Server**
  - Gateway (WS1_GTW): Gateway to be used for connection to the server.
  - IP (WS1_IP): IP address of the server, in this case the central system that will receive all Y0X services.
  - Port (WS1_PORT): Communication port where the server will listen to Y0x services.

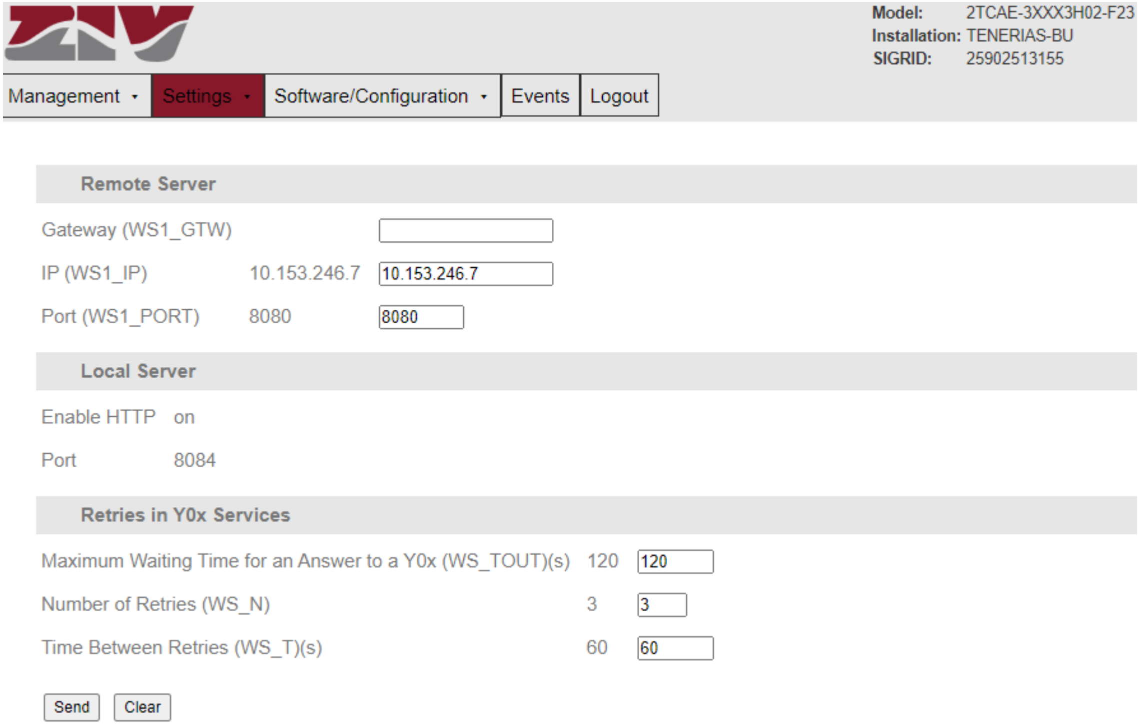


Figure 1.4.23 Settings for Remote Server Configuration.

- **Local Server**
  - HTTP Enable: Enabling Web Services.
  - Port: Communication port through which the equipment will listen to all S0x services.

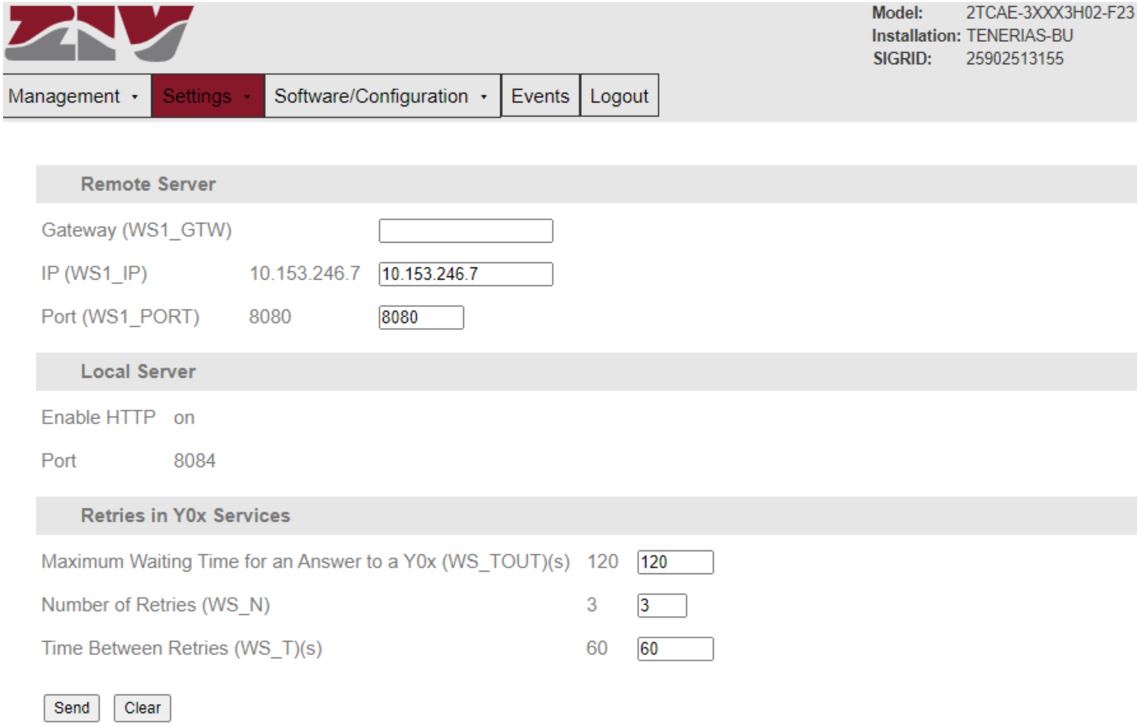


Figure 1.4.24 Settings for Local Server Configuration.

- **Retries Control in Y0X Services**
  - WS_TOUT: Maximum waiting time to receive a response to a Y0x.
  - WS_N: Number of retries.
  - WS_T: Time between retries.

Y0X Services Retries			
Setting	**Range**	**Step**	**Default**
Maximum waiting time to receive a response to a Y0x	1 - 3600 s	1	120 s
Number of retries	0 - 9	1	3
Time between retries	1 - 3600 s	1	60 s

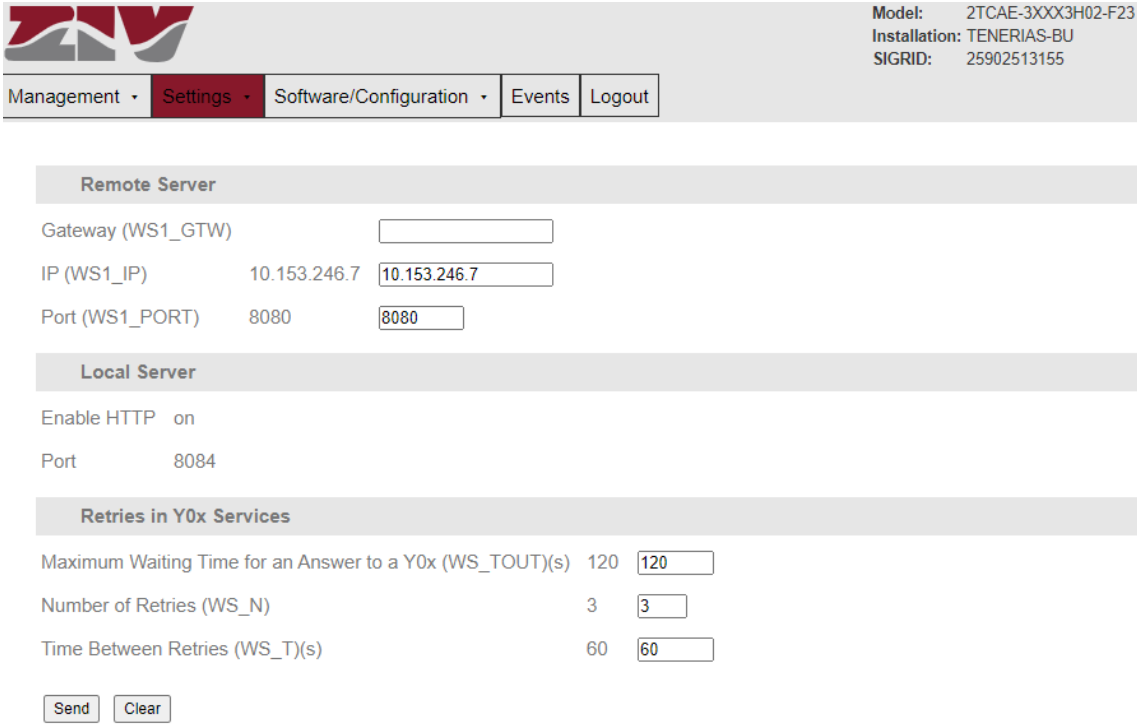


Figure 1.4.25 Settings for Retry Policy Configuration.

Once the desired parameters have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

1.4.8 Access and Authentication

The **2TCA-E** equipment has three Access Modes: **Console Access**, **Web Access** and **Shell Access**.

The **2TCA-E** equipment has three User Authentication Modes, a Local Mode and a Remote Mode (LDAP). Depending on the client profile, the settings of some of the remote methods may be hidden on the web server.

Local authentication consists of checking users and passwords with users stored internally on the **2TCA-E** equipment, while Remote authentication is performed against an external server, which is the one that stores information about users, which checks users and passwords, and the one that informs whether it is an Authorized User, as well as the Permissions held by that user.

1.4.8.a Access

The **2TCA-E** equipment has three access modes:

- **Local HMI Access**: Serial connection through the serial COM port.
- **Web Access**: Network connection using a Web browser.
- **Shell Access**: Network connection using a Telnet or ssh client.

To each of these Access Modes you can assign the desired Authentication Mode. The parameters to configure the Authentication Mode for each Access Mode are the following, adjustable within the **Access** option of the **Parameters** tab:

- **Authentication Method**. Indicates the Authentication Mode used for the corresponding Access Mode. The possible values are: local (Local Authentication), or **ldap** (**LDAP** Remote Authentication).
- **Alternative Local Access**: For Access Modes for which a Remote Authentication Mode has been configured, it indicates whether, when there is no accessibility to the remote servers, Local Authentication (☑) or not (☐) should be used as an alternative method. This parameter is fixed and always enabled for **Local HMI Access** mode.

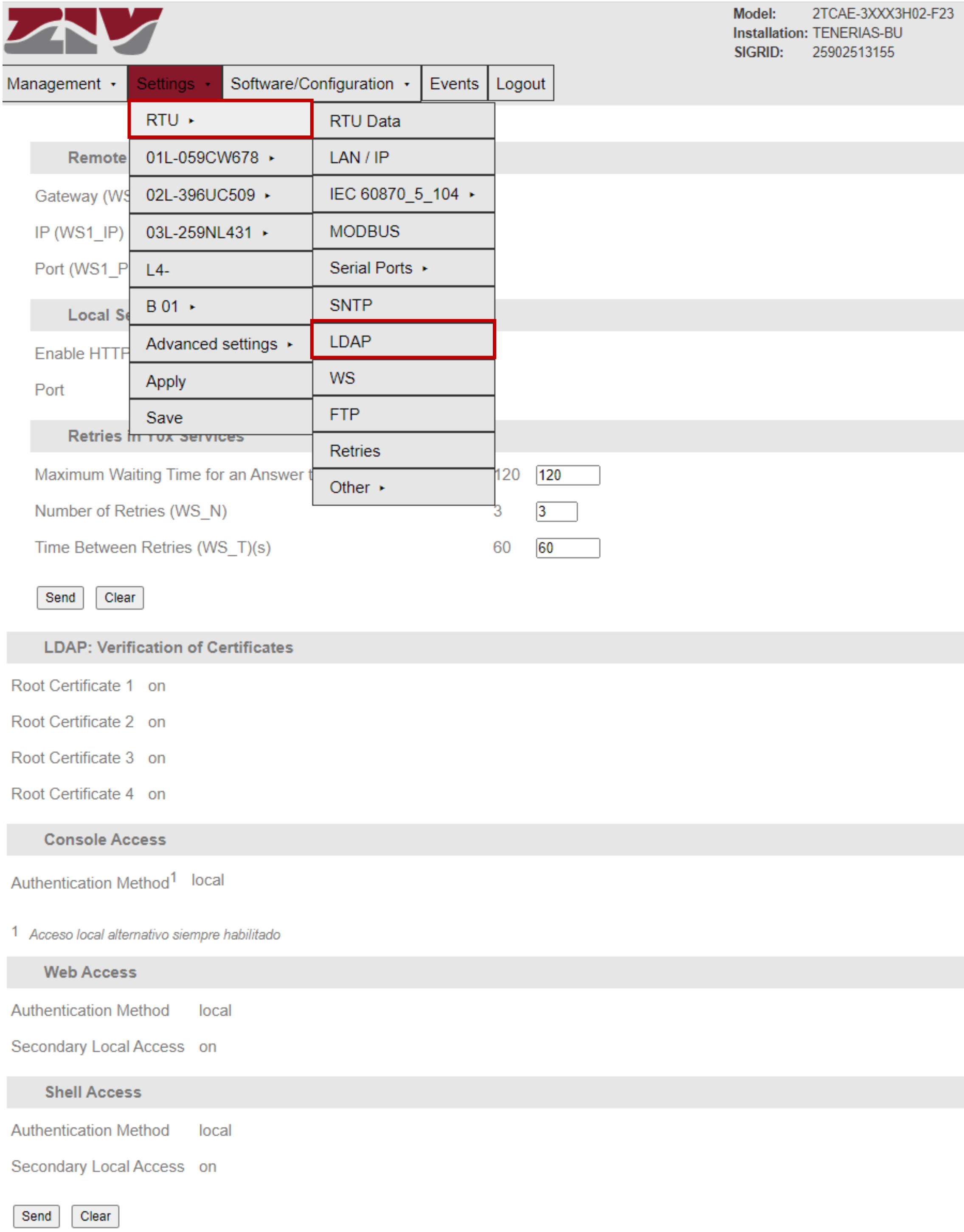


Figure 1.4.26 Example of Authentication Mode configuration for each Access Mode.

Access Modes			
Setting	**Range**	**Step**	**Default**
Console Access			
Authentication Method	local / ldap		local
Web Access			
Authentication Method	local / ldap		local
Secondary Local Access	YES / NO		YES
Shell Access			
Authentication Method	local / ldap		local
Secondary Local Access	YES / NO		YES

At the same time, the **2TCA-E** equipment has two **User Profiles**: **Display only** and **Modification**. Each user will be associated with one of these permissions.

In the case of **Local Authentication** it will be fixed in the **2TCA-E** unit (User: **Display only**; Administrator: **Modification**, see section 1.4.8.d Local Authentication).

In the case of **Remote Authentication** it will be configured in the server.

Note that the 2TCA-E unit distinguishes between upper and lower case letters when entering the user name and password.

Once a user has been authenticated by one of the three Access Modes, a User Session begins. The **2TCA-E** equipment will end this session if in a certain time it does not detect any activity due to this access. The configuration parameter is **Session Expiration** and it is configured in minutes.

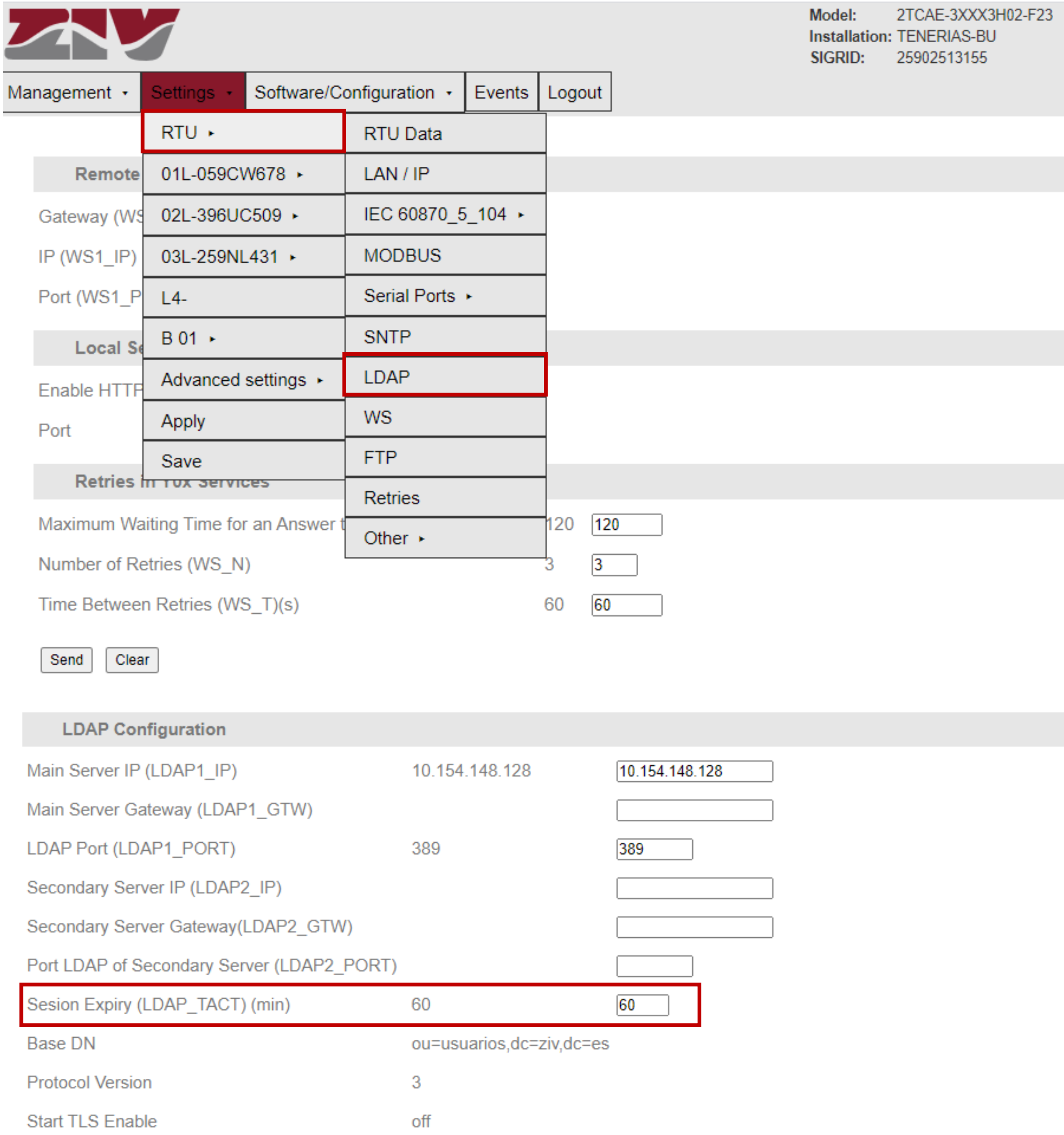


Figure 1.4.27 Example of Session Timeout Configuration.

Session			
Setting	**Range**	**Step**	**Default**
Session Expiration (min)	1 - 60 min	1	10 min

From the **Web** access you can end the session whenever the user wants, by clicking on the ***LogOut*** option.

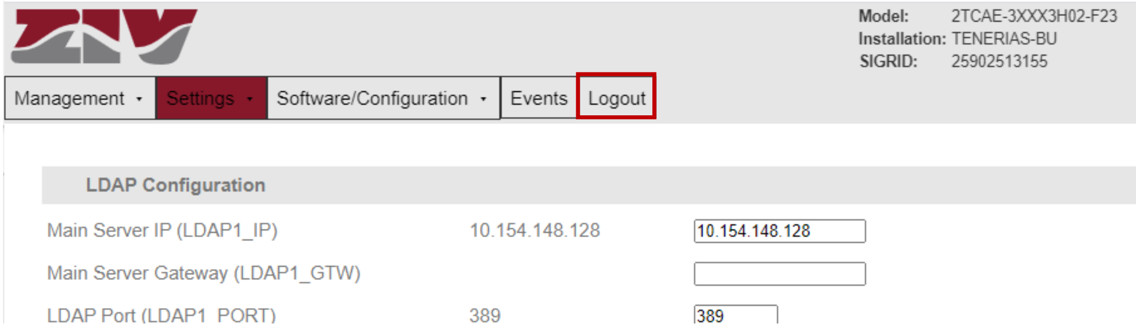


Figure 1.4.28 User Session End Option.

Once the desired parameters have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

1.4.8.b WEB Server

The **2TCA-E** equipment has an internal WEB server through which it is possible to perform both tasks of configuration as well as tasks of consultation of statistics and registration of events. The server is divided into the following tabs:

Maintenance
It includes the representation of the single line diagram of the installation and reflects the state of the different elements or alarms. It also allows to know statistical data of measurements, filiation information as download files or oscillographic records stored in the device, as well as fault reports.
Parameters.
It allows the configuration of the equipment in detail and organized on the basis of the different functionalities.
SW and Configuration.
It allows the update of the installed software, as well as the change of the configuration in a global way by means of XML file.
Historical.
It allows visualizing the events stored in the device's non-volatile memory and downloading them by means of a file. Includes basic filters to search for specific events.

It is possible to access this server either through the remote interface or through the local interface using the addresses of each of the interfaces, and through http and https services.

It is possible to configure the access port of both protocols and the enabling of each of them separately in the remote ports through the **Administration** tab. The default port for the http protocol is 80 and for the secure https protocol is 443.

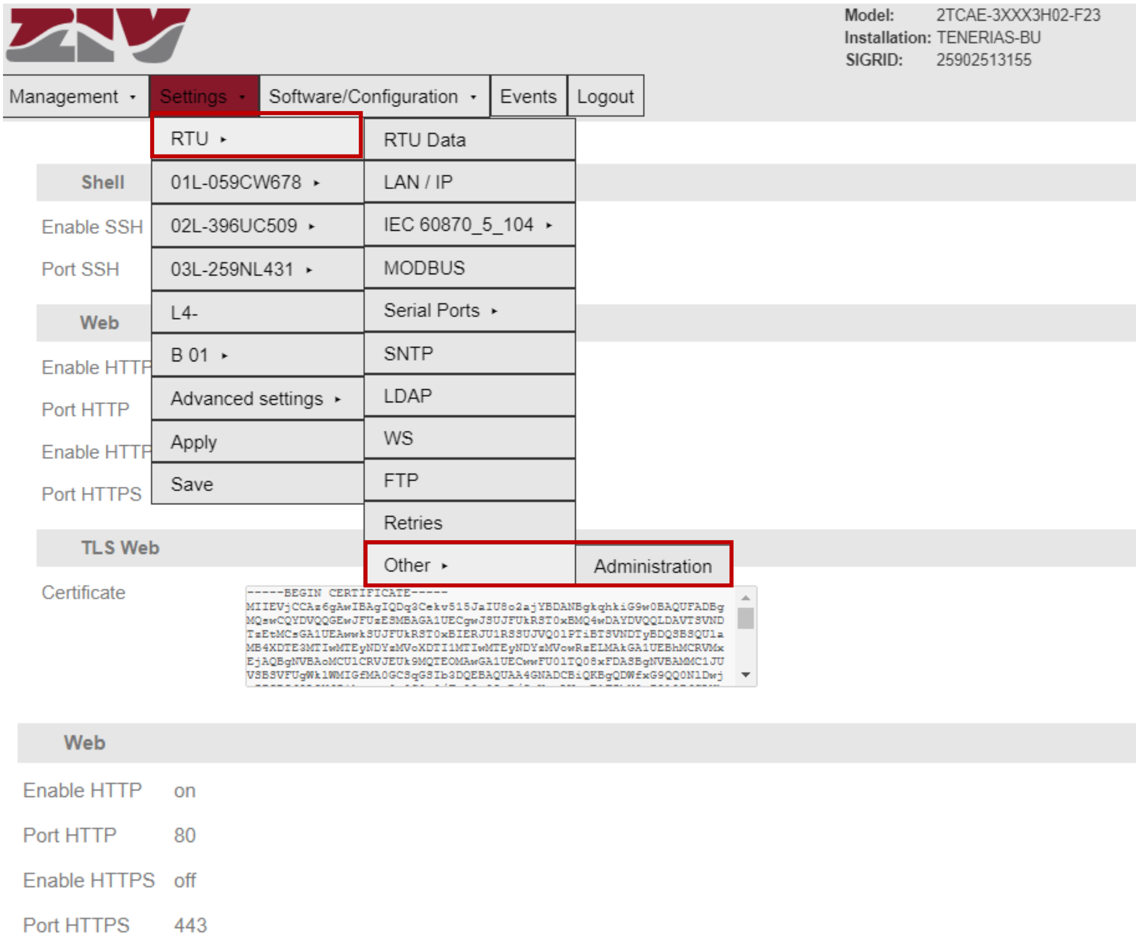


Figure 1.4.29 Example of Configuration for Web Access.

Administration			
Setting	**Range**	**Step**	**Default**
Web			
HTTP Enable	YES / NO		YES
HTTP Port	1 - 65535		80
HTTPS Enable	YES / NO		NO
HTTPS Port	1 - 65535		443

For secure access to the WEB server, the equipment uses the TLS transport layer. Within the security configuration, it is possible to manage both the certificate of the equipment as well as the private key and the password of the same. The TLS transport layer is individually certified by protocols, since the TLS Web is oriented to https, and the TLS SSH for its part is for the connection via SSH.

The equipment can operate with the usual types of encryption such as RSA, AES-128, AES-256 or Diffie-Hellman.

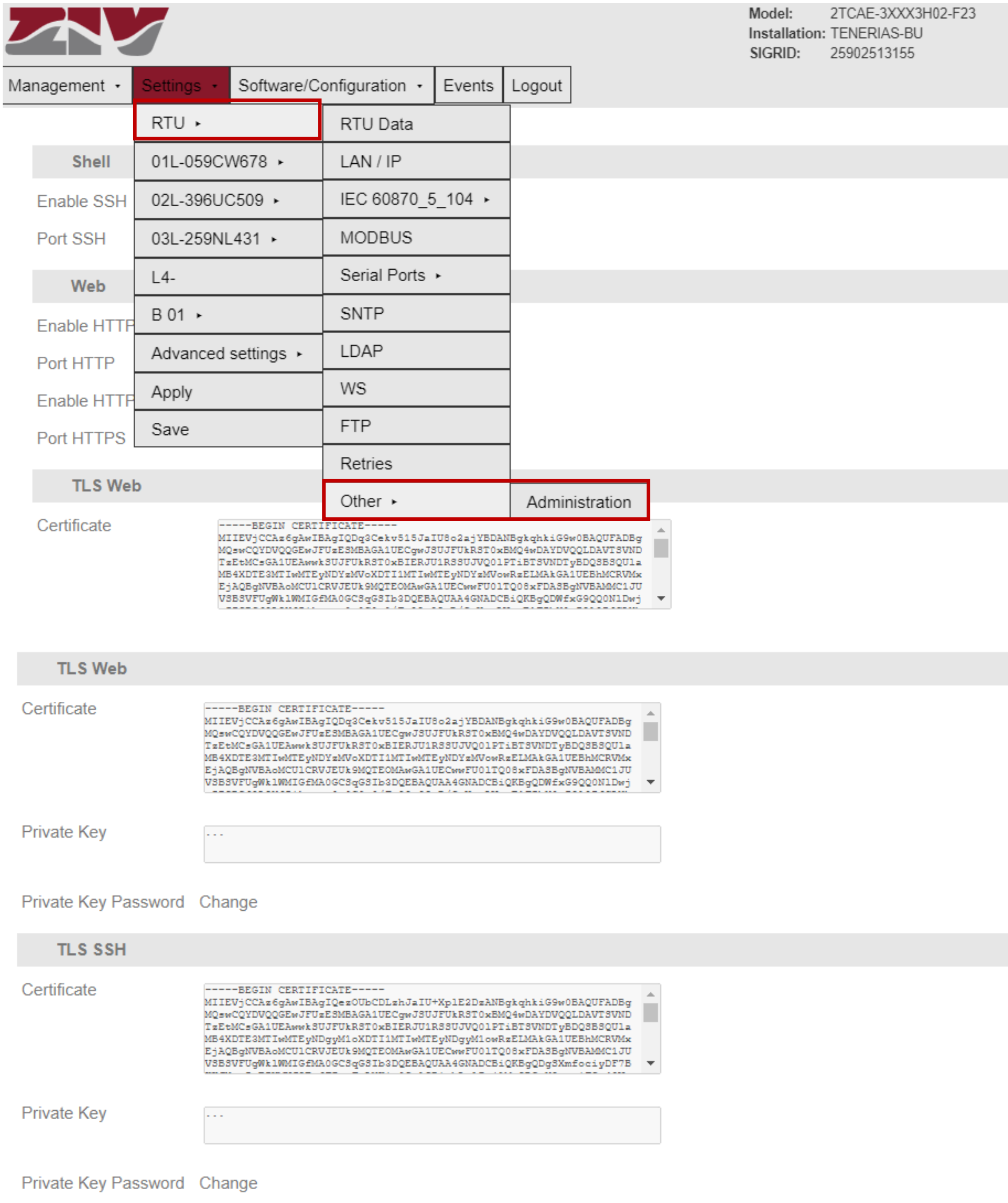


Figure 1.4.30 Example of Configuration for Certificates and Private Keys of the TLS Layer.

The certificates or private key are embedded in the firmware of the equipment in the advanced settings part, so if you want to change them you must perform a software update of the equipment.

These certificates cannot be downloaded in any way, neither together with the rest of the advanced settings, nor through the command line.

Likewise, the equipment can manage up to 4 root certificates from certifying entities, for the validation of certificates received from external servers for authentication protocols such as LDAP.

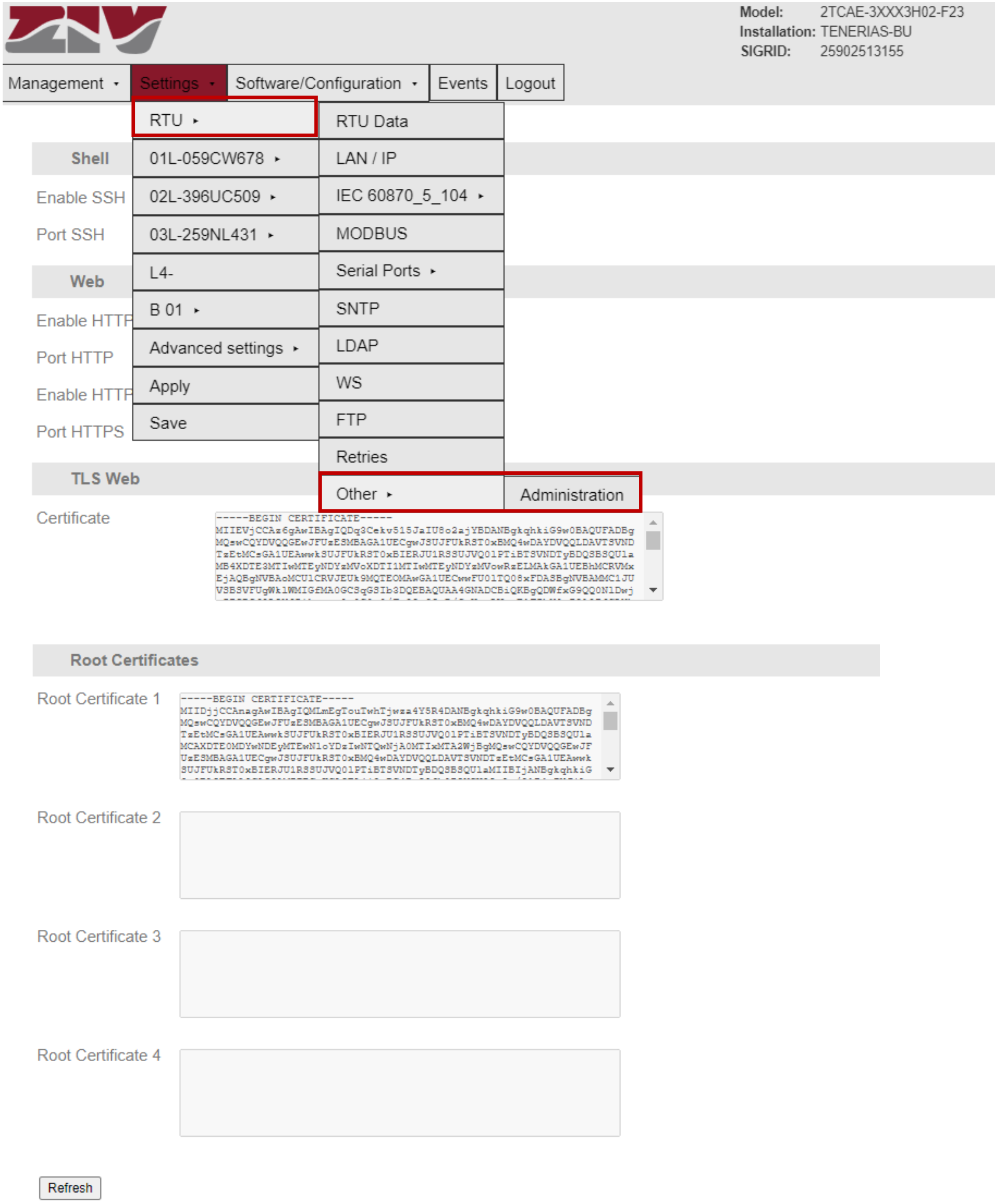


Figure 1.4.31 Root Certificates of Certifying Entities.

1.4.8.c Shell

The **2TCA-E** equipment has an internal Shell or command line that can be accessed via an ssh connection. This type of connection is disabled by default because at the security level it presents a better image, and this happens both in the local port of the computer and in the remote port. But it is possible to change this condition.

Finally, it is possible to determine the port of the ssh service, its default value being port 22.

In the case of using the ssh secure service, the equipment uses for this type of connection the same TLS protocol with the same certificate and private key as the WEB server.

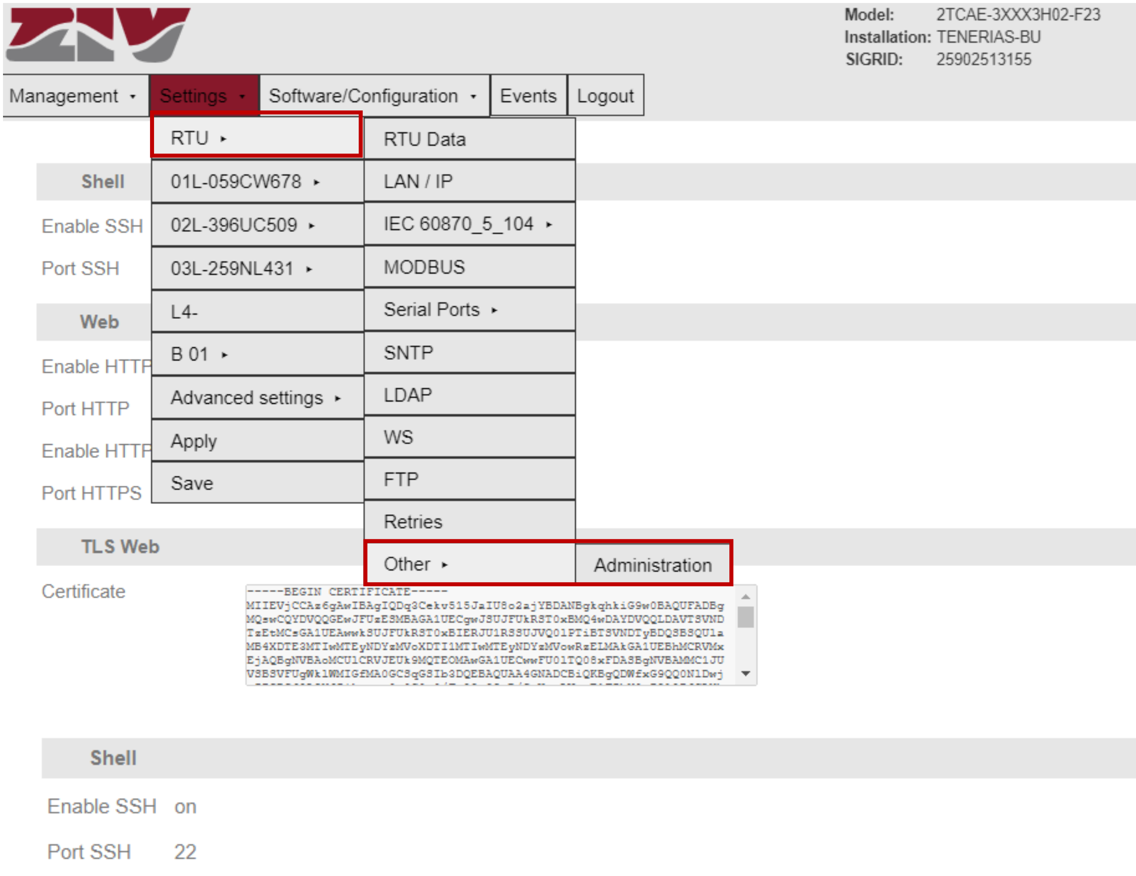


Figure 1.4.32 Example of Configuration of Telnet and SSH Services.

Administration			
Setting	**Range**	**Step**	**Default**
Shell			
Remote Port Telnet Enable	YES / NO		NO
Remote Port SSH Enable	YES / NO		YES
SSH Port	1 - 65535		22

1.4.8.d Local Authentication

Local Authentication consists of checking the user and password entered by a user with the users stored internally in the **2TCA-E** unit. The **2TCA-E** unit has two users stored internally:

Access Control			
Setting	**Range**	**Default**	**IED Model**
Viewer Identifier	5 - 20 Characteres	consulta	2TCA-E
Viewer Password	8 - 20 Characteres	consulta	2TCA-E
Administrator Identifier	5 - 20 Characteres	admin	2TCA-E
Admininstrator Password	8 - 20 Characteres	modifica	2TCA-E
Viewer Identifier	5 - 20 Characteres	Viewer	2TCA-E (SmartRTU)
Viewer Password	8 - 20 Characteres	Passwd@01	2TCA-E (SmartRTU)
Administrator Identifier	5 - 20 Characteres	Administrator	2TCA-E (SmartRTU)
Admininstrator Password	8 - 20 Characteres	Passwd@02	2TCA-E (SmartRTU)

Users and their passwords are only editable and are open to change through WEB services or with the Web Page settings in **2TCA-E** (SmartRTU) model.

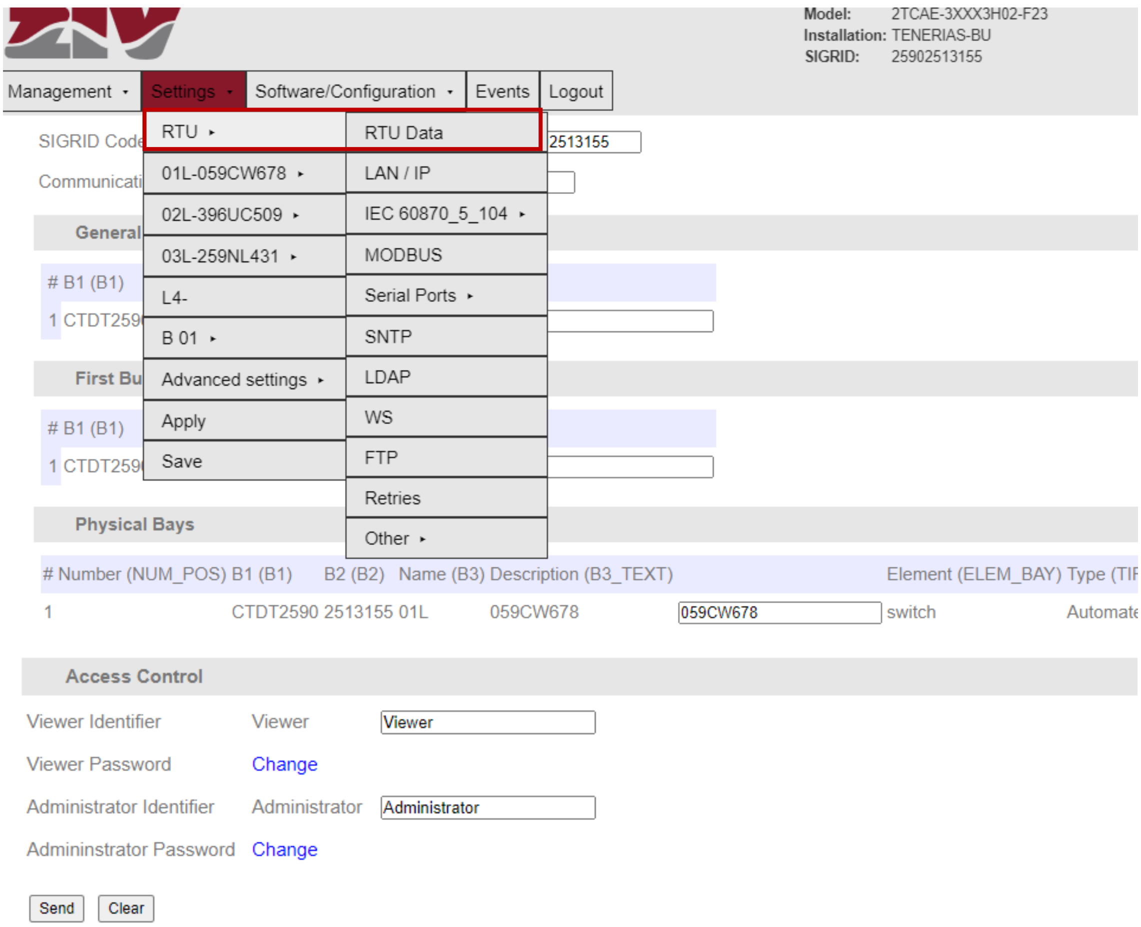


Figure 1.4.33 Example of Configuration of Local users

When you press ***Change***, the following window will appear allowing you to change the password.

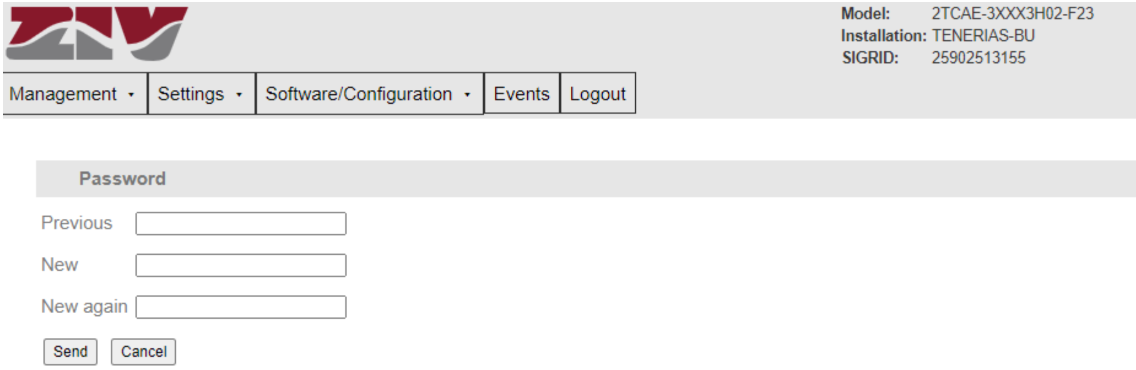


Figure 1.4.34 Example of Change the Password.

> *Remember to write down all changes related to User Name and Password. If you forget them, it will not be possible to access the 2TCAE (SmartRTU) equipment using Local Authentication.*

When the **Local** Authentication mode is used, each time a user enters a User and a Password, they are compared with the two existing users to determine if that user is allowed to access the **2TCA-E** equipment and with what permission.

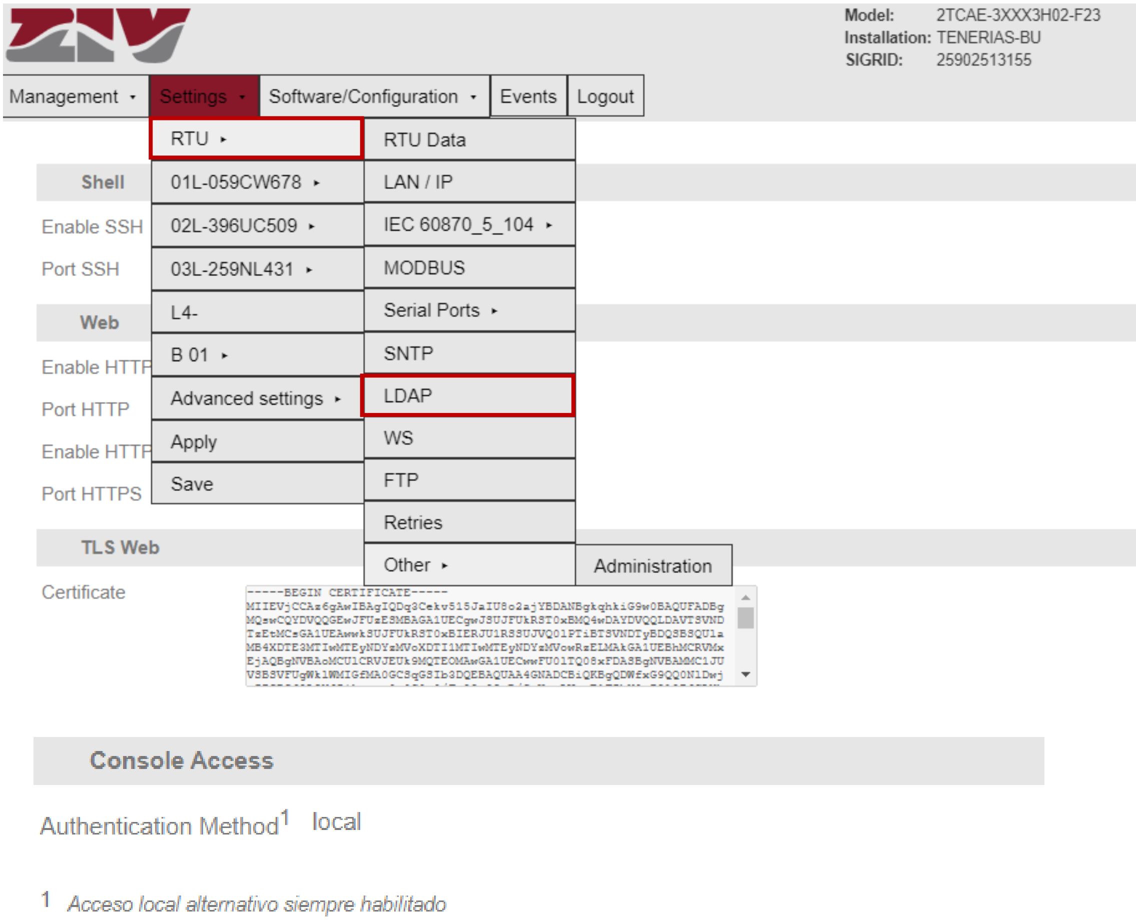


Figure 1.4.35 Alternative Local Authentication always Enabled for HMI Access.

This **Local** Authentication Mode is always enabled by default for local HMI Access as an Alternate Authentication Mode. This means that, if a Remote Authentication Mode is configured for HMI Access and there is no accessibility to the remote servers, this **Local** Authentication Mode will be used as an Alternative Mode.

For the other two Access Modes (**Web** and **Shell**) it is configurable to use the Local Authentication Mode as Alternative Mode. The alternative mode will be considered only when the connection with the authentication server is not possible and after having made the attempts configured in the system.

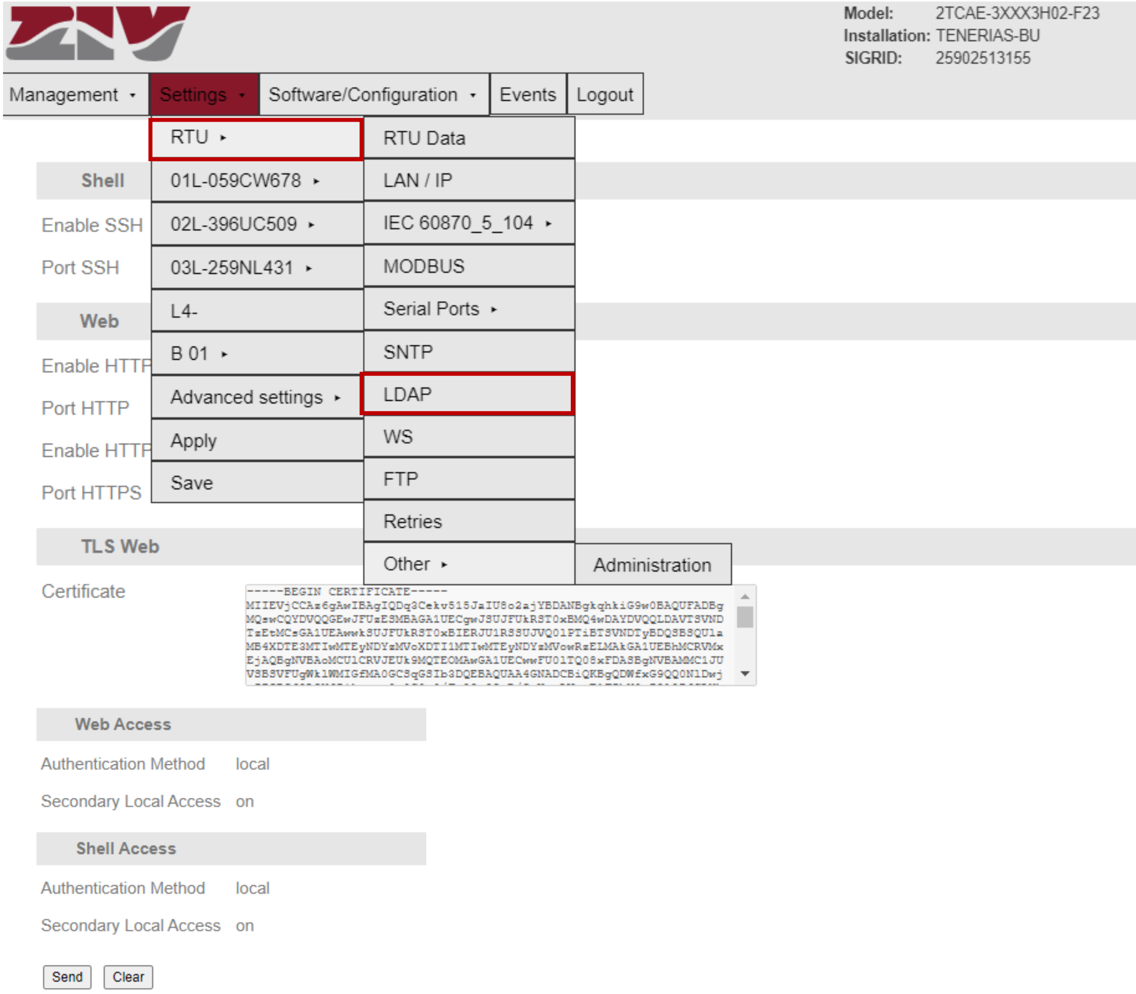


Figure 1.4.36 **Example of Alternative Local Authentication Configuration for Web and Shell Accesses.**

1.4.8.e Remote Authentication

Remote Authentication consists of checking the User and Password entered by a user with the users stored on an External Server. The **2TCA-E** IED incorporates a **Remote** Authentication method based on a standard protocol: **LDAP**.

- **LDAP Remote Authentication**

LDAP (Lightweight Directory Access Protocol) is a Remote Authentication protocol that provides Directory Services, organizing the information in very similar way to a file system or domain name service (DNS) on the Internet does. The following **LDAP**-related parameters can be configured, adjustable within the LDAP option of the **Parameters** menu:

- **Main Server IP**: IP address of the main **LDAP** server.
- **Alternative Server IP**: IP address of the secondary or alternative **LDAP** server.
- **Base DN**: Organizational Unit (OU) in which users are stored.
- **Protocol Version**: **LDAP** protocol version that will be used by the **2TCA-E**.

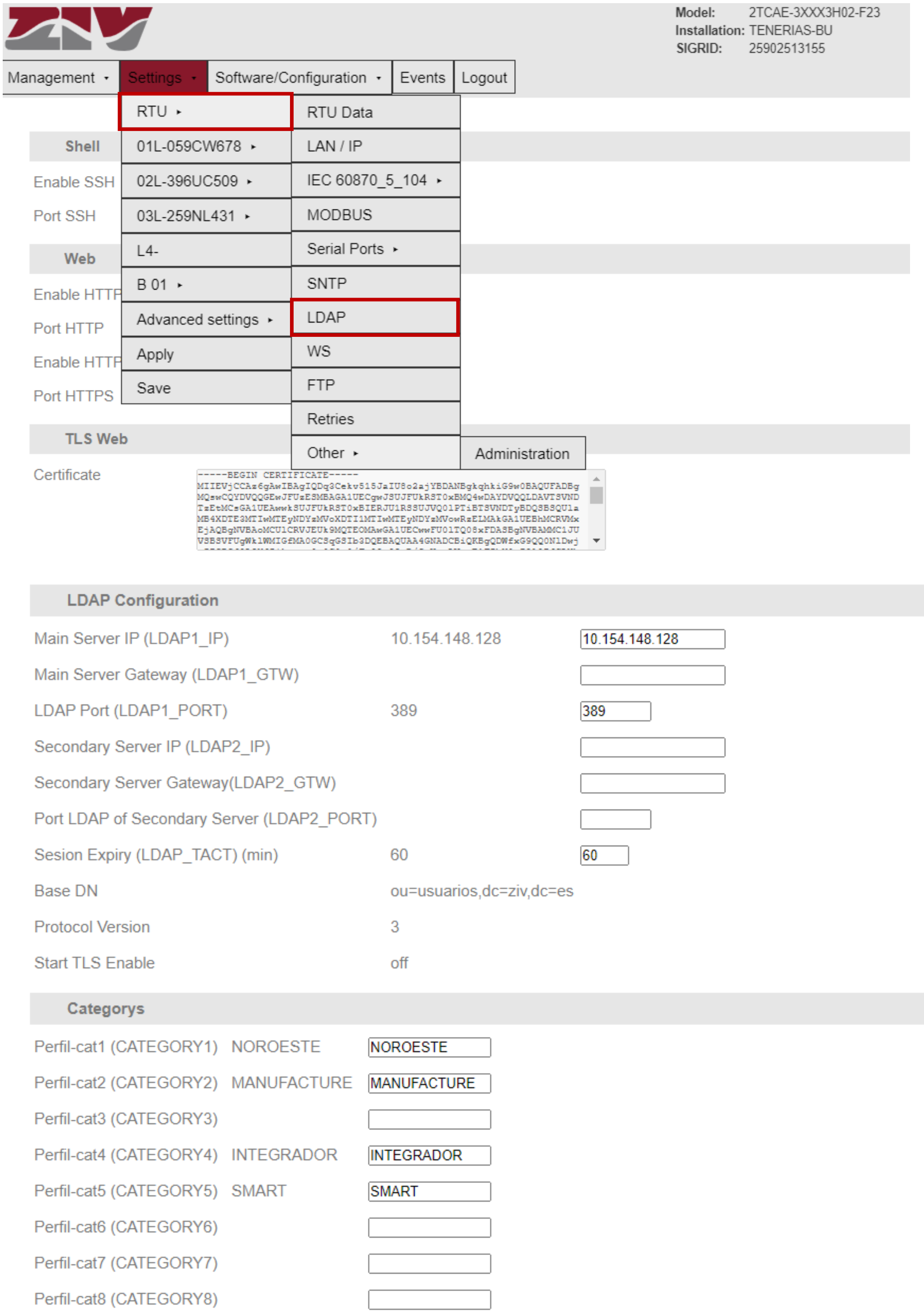


Figure 1.4.37 Example of LDAP Remote Authentication Protocol Configuration.

In addition, the Output Routes can be configured for each of the possible **LDAP** servers under the **LDAP** option of the **Parameters** menu:

- **Main Server Gateway**: Gateway to be used for the connection with the Main **LDAP** server. You can choose between the two possible Gateways that can be configured for the **2TCA-E** equipment (see **LAN (eth0) Gateways** of the same configuration screen).
- **Secondary Server Gateway**: Gateway to be used for the connection with the Secondary **LDAP** server. You can choose between the two possible Gateways that can be configured for the **2TCA-E** equipment (see **LAN (eth0) Gateways** of the same configuration screen).

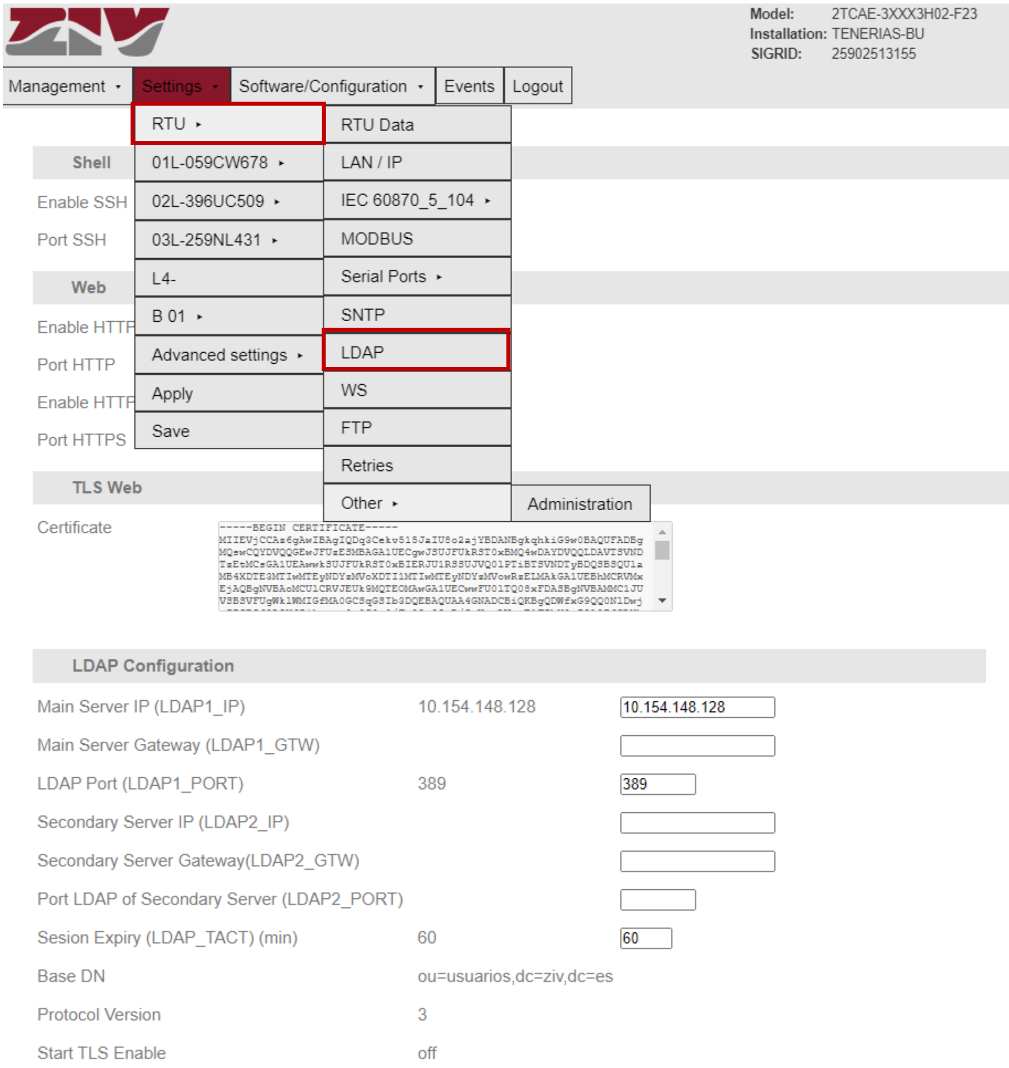


Figure 1.4.38 Example of Routes Configuration for LDAP.

It is also possible to use this protocol in its secure version, **LDAPS**. In this case it is necessary to enable the use of the TLS layer for the LDAP client in the **LDAP** tab and the service port.

LDAP			
Setting	**Range**	**Step**	**Default**
Main Server IP	ddd.ddd.ddd.ddd		empty
Alternative Server IP	ddd.ddd.ddd.ddd		empty
Base DN		0 - 60 characters	ou=users dc=ziv dc=es
Protocol Version	2 / 3	1	3

LDAP Routes			
Setting	**Range**	**Step**	**Default**
Main Server Gateway	Gateway1 / Gateway2		empty
Alternative Server Gateway	Gateway1 / Gateway2		empty

It is possible to determine independent identifiers for each of the servers with the following fields:

- **Distinguish Name** (CN): Name / alias of the server.
- **Organization** (O): Name of the organization to which the server belongs.
- **Organization Unit** (OU): Name of the department or unit of the organization to which the server belongs.

These fields are checked on the public certificate provided by the server to verify its authenticity.

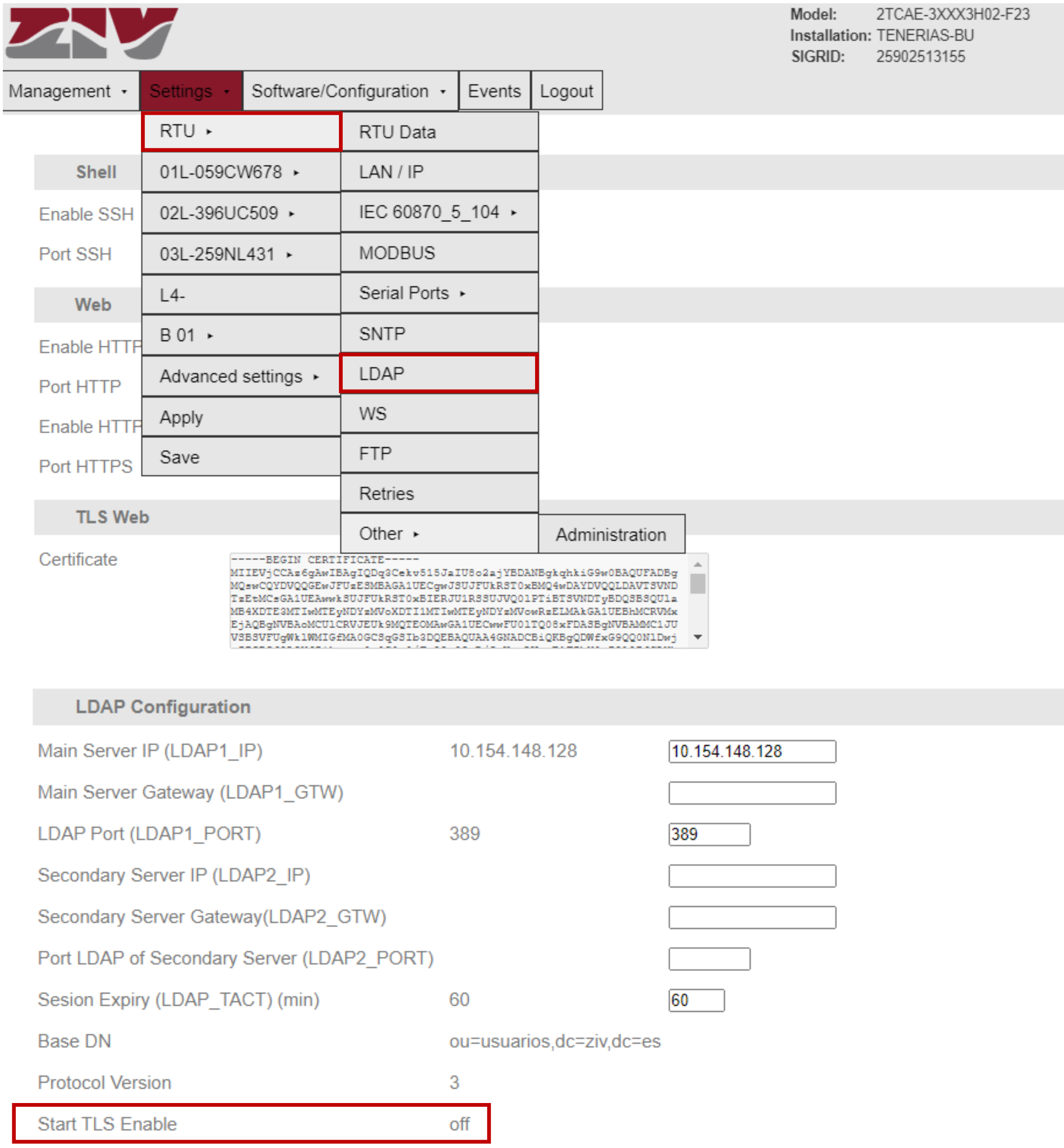


Figure 1.4.39 Example of LDAPS Authentication Service Enabling.

Administration			
Setting	**Range**	**Step**	**Default**
LDAP			
Start TLS Enable	YES / NO		YES
LDAP Port	1 - 65535		389
LDAP: Certificate Verification			
Root Certificate n Enable	YES / NO		NO

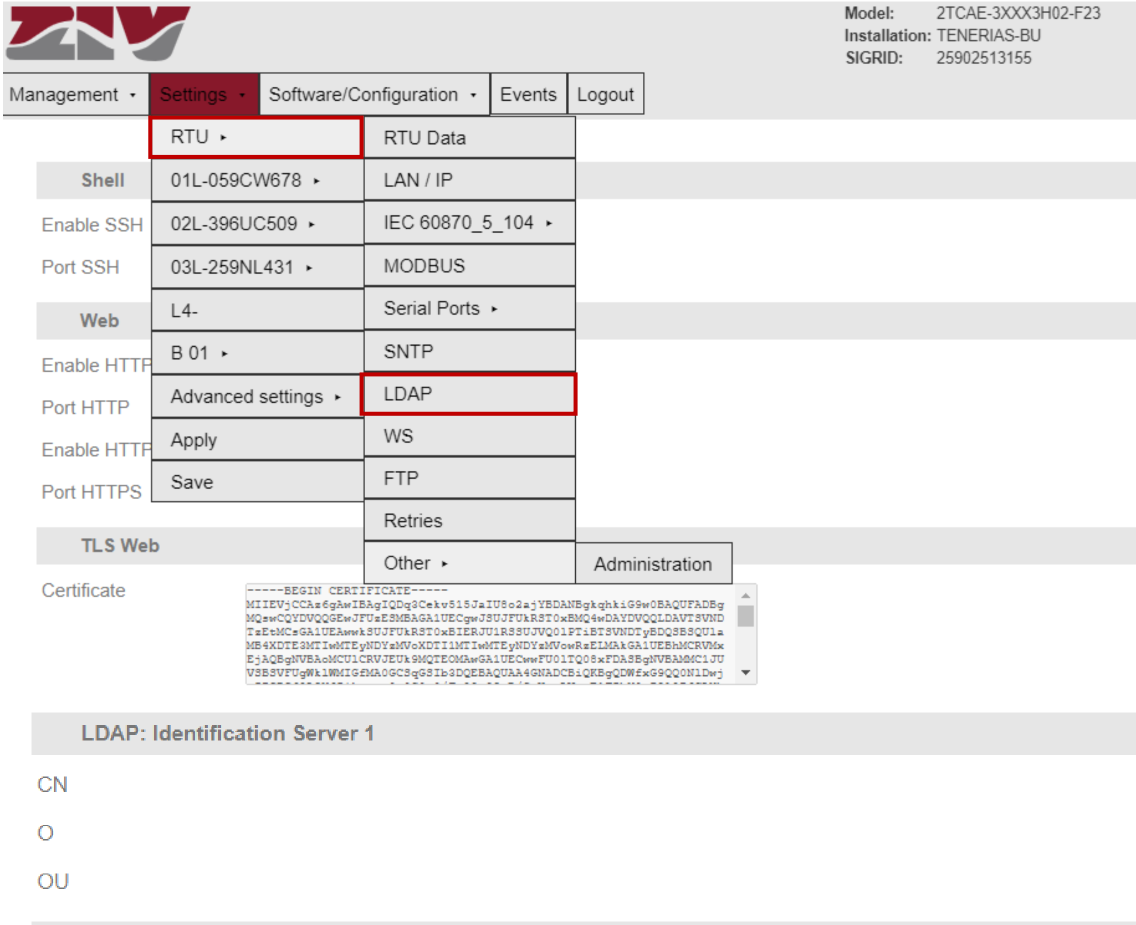


Figure 1.4.40 Example of LDAP Server Identifiers Configuration.

With regard to access to LDAP servers securely via the TLS layer, the equipment can store up to four independent root certificates from certification bodies, as mentioned in the section on the web server. It is possible to select which of these root certificates are considered during the authentication process by configuration.

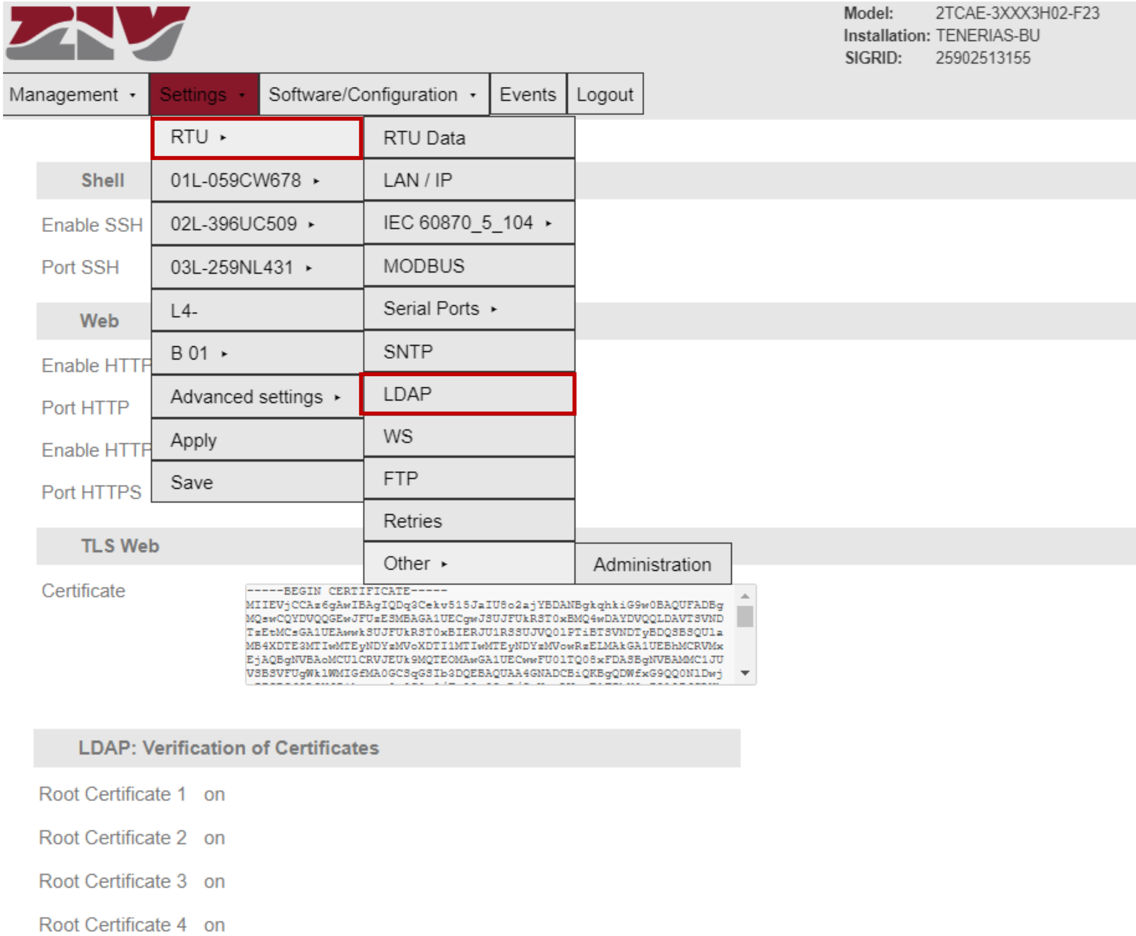


Figure 1.4.41 Example of Configuration of Root Certificates Considered in LDAPS.

1.4.9 SNTP Synchronization

The **2TCA-E** unit works as a Client of the SNTP (Simple Network Time Protocol) protocol, so that the unit can automatically synchronize its clock with a reliable time source. A maximum of two SNTP (Main and Alternative Source) servers can be configured.

The time format received by SNTP protocol from the various synchronization sources is UTC. The dating of all **2TCA-E** equipment level events in terms of storage in internal databases is also done in UTC format. It is therefore at the level of presentation (local operation HMIs, individual screens of UCPs, sending to the remote control) where the correction to local time is carried out and the offset that could introduce the summer or winter time is added.

A single diffusion synchronization system is established based on priorities. In other words, the SNTP servers that are configured are the only sources that are probed to obtain synchronization information and are carried out exclusively by means of the Unicast service.

The time levels **T1**, **T2**, **T3** and **T4** are used to determine the time of the **2TCA-E** equipment:

- **T1**: Time at which the customer has sent the original request.
- **T2**: Time at which the server received the original request.
- **T3**: Time at which the server has sent a response to the client.
- **T4**: Time at which the client received the response from the server.

Information received through the Primary Synchronization Source is considered a priority and is subject to information received in the **Leap Indicator**. Thus, when receiving a synchronization message with this field at **3** (**not synchronized clock**), the **2TCA-E** equipment tries to obtain a correct synchronization through the Alternative Source.

The **2TCA-E** considers its internal clock synchronized with valid time with the reception of the first message with correct time stamp (**Leap Indicator different from value 3**) regardless of the Synchronization Source that sends it. At this moment, a timer that can be parameterized by the user and controls the validity of the internal clock of the **2TCA-E** equipment is reset.

If the **2TCA-E** unit does not obtain a correct time pattern from any of the defined sources and the time parameterized in the timer (**Synchronization Failure Time**) has elapsed, the internal clock is updated to **Not Synchronized Clock**.

If the internal clock does not have a reliable time, the internal clock becomes valid at the moment that it receives a synchronization message from one of the sources defined with a **Leap Indicator** field other than value 3.

1.4.9.a Settings

The **2TCA-E** unit has the following parameters related to the SNTP client, which can be adjusted under the SNTP option of the Parameters menu:

- **IP Main Server**. IP address of the main SNTP server (Main Source). The value of 0.0.0.0 will mean non-existent main SNTP server.
- **IP Secondary Server**. IP address of the secondary SNTP server (Alternative Source). The value of 0.0.0.0 will mean non-existent alternative SNTP server.
- **Polling Interval**. Time interval in minutes at which the defined SNTP servers are polled for synchronization information. This time interval is independent of the duration of the synchronization cycles (synchronization cycle being understood as the set of requests and retries made to both the Main Source and the Alternative Source), which means that each synchronization cycle can have a variable duration. When the timer is met, there may be two cases:
  - There is no synchronization cycle running. In this case, a new one is started.
  - There is a synchronization cycle running. In this case, this synchronization request is undone. The next synchronization cycle is attempted minutes later and the synchronization cycle in progress is ended normally.
- **Response Waiting Time**. Waiting Time for Response to a Unicast request for synchronization to a SNTP server. If no response has been received in that time, a cycle of reattempts of Unicast requests to that server begins.
- **Number of Retries**. Number of Retries of Unicast requests to a SNTP server in case of not receiving a response to the Unicast message.
  Once the **Number of Retries** is finished, in the case of the Main Source, a new synchronization attempt with the Alternative Source is restarted.
  In the case of reattempts with the Alternative Source, the synchronization attempt for this interval ends and is attempted again in the following period.
  A value of 0 means that there is no retry, the first error is switched from Source or the Polling Interval is finished.
- **Synchronization Failure Time**. Elapsed time in minutes in which no correct synchronization response (Leap Indicator different from value 3) has been received by any of the sources configured to consider the internal clock of the **2TCA-E** equipment as not synchronized.

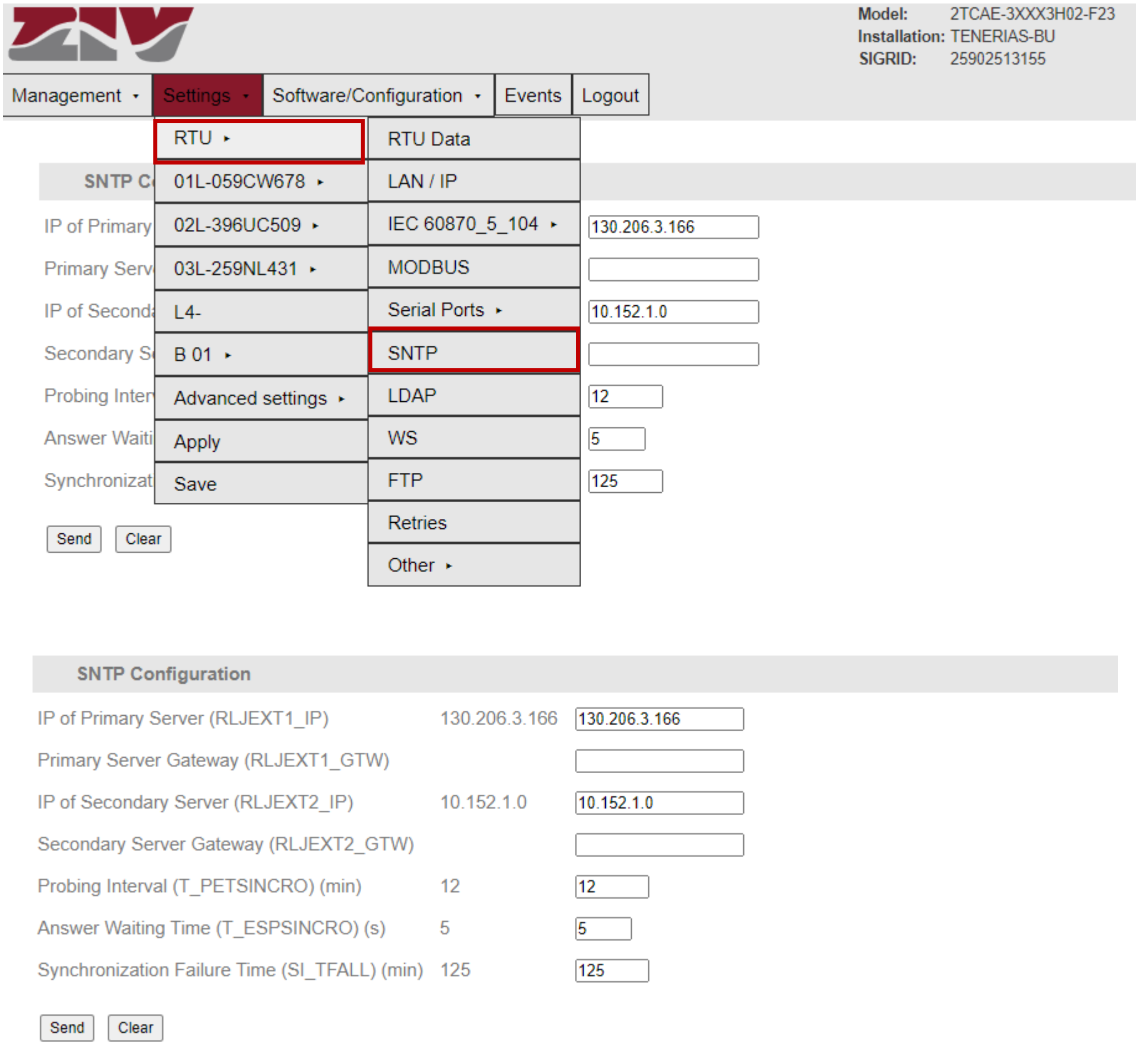


Figure 1.4.42 SNTP Client Configuration Example.

SNTP			
Setting	**Range**	**Step**	**Default**
IP Main Server	ddd.ddd.ddd.ddd (1)		empty
Alternative IP Server	ddd.ddd.ddd.ddd (1)		empty
Polling Interval	1 - 1440 min	1	60 min
Response Waiting Time	1 - 60 s	1	5 s
Number of Retries	0 - 9	1	3
Synchronization Failure Time	1 - 1440 min	1	125 min

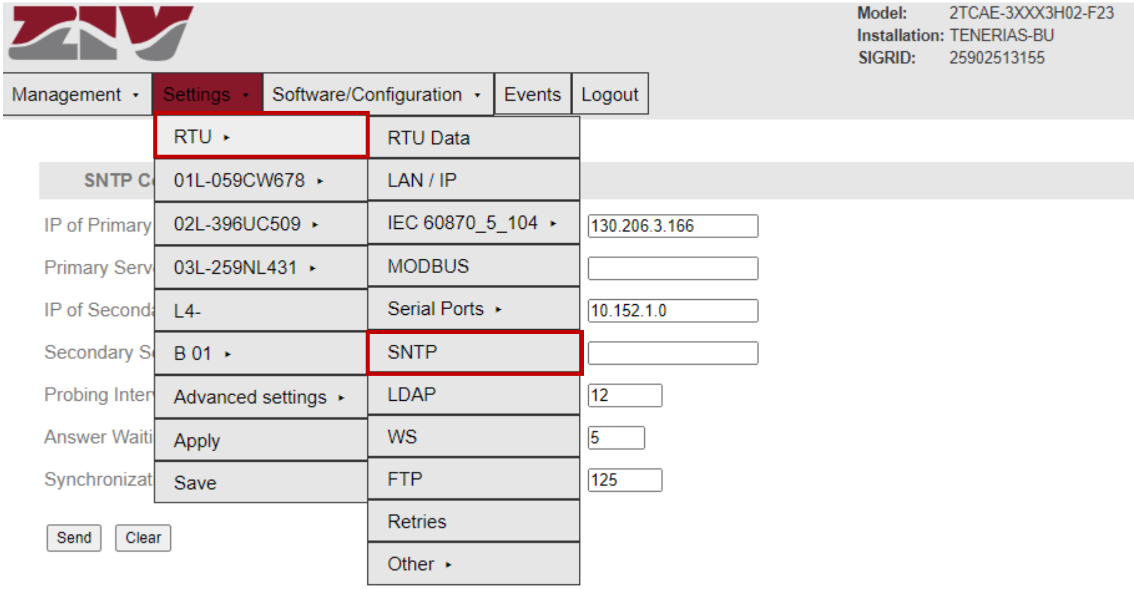
SNTP Routes			
Setting	**Range**	**Step**	**Default**
Main Server Gateway	Gateway1 / Gateway2		empty
Alternative Server Gateway	Gateway1 / Gateway2		empty

SNTP Event Mask			
Setting	**Range**	**Step**	**Default**
Clock Synchronization	YES / NO		NO

(1) The value 255.255.255.255 is not accepted as it is a multicast address.

In addition, the output paths for each possible SNTP server can be configured under the SNTP option in the **Parameters** menu:

- **Gateway Main Server**. Gateway to be used for the connection to the main SNTP server. You can choose between the two possible Gateways that can be configured for the **2TCA-E** equipment.
- **Alternative Server Gateway**. Gateway to use for the connection with the alternative SNTP server. You can choose between the two possible Gateways that can be configured for the **2TCA-E** unit.



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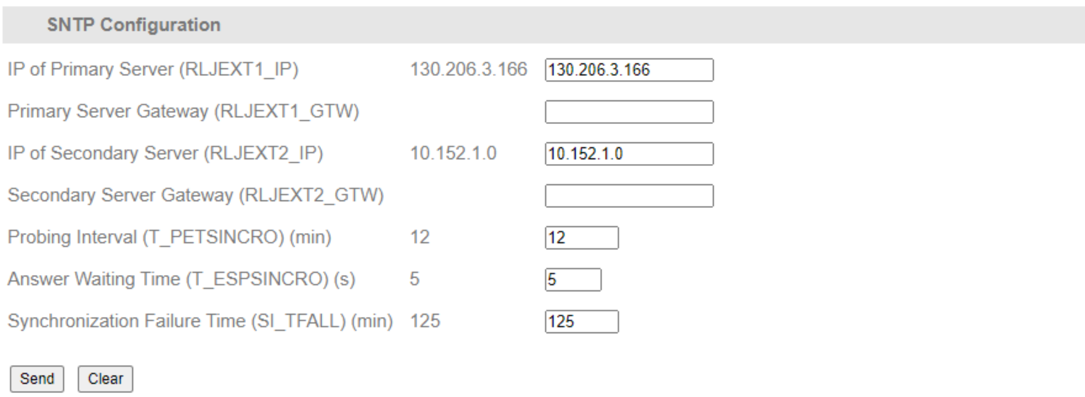

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Figure 1.4.43 Example of Route Configuration for SNTP.

- **SNTP Synchronization**

SNTP			
Setting	**Range**	**Step**	**Default**
IP Main Server	ddd.ddd.ddd.ddd (1)		empty
IP Alternative Server	ddd.ddd.ddd.ddd (1)		empty
Polling Interval	1 - 1440 min	1	60 min
Waiting Time to Response	1 - 60 s	1	5 s
Number of Retries	0 - 9	1	3
Synchronization Failure Time	1 - 1440 min	1	125 min

SNTP Routes			
Setting	**Range**	**Step**	**Default**
Main Server Gateway	Gateway1 / Gateway2		empty
Alternative Server Gateway	Gateway1 / Gateway2		empty

SNTP Event Mask			
Setting	**Range**	**Step**	**Default**
Clock Synchronization	YES / NO		NO

(1) The value 255.255.255.255 is not accepted as it is a multicast address.

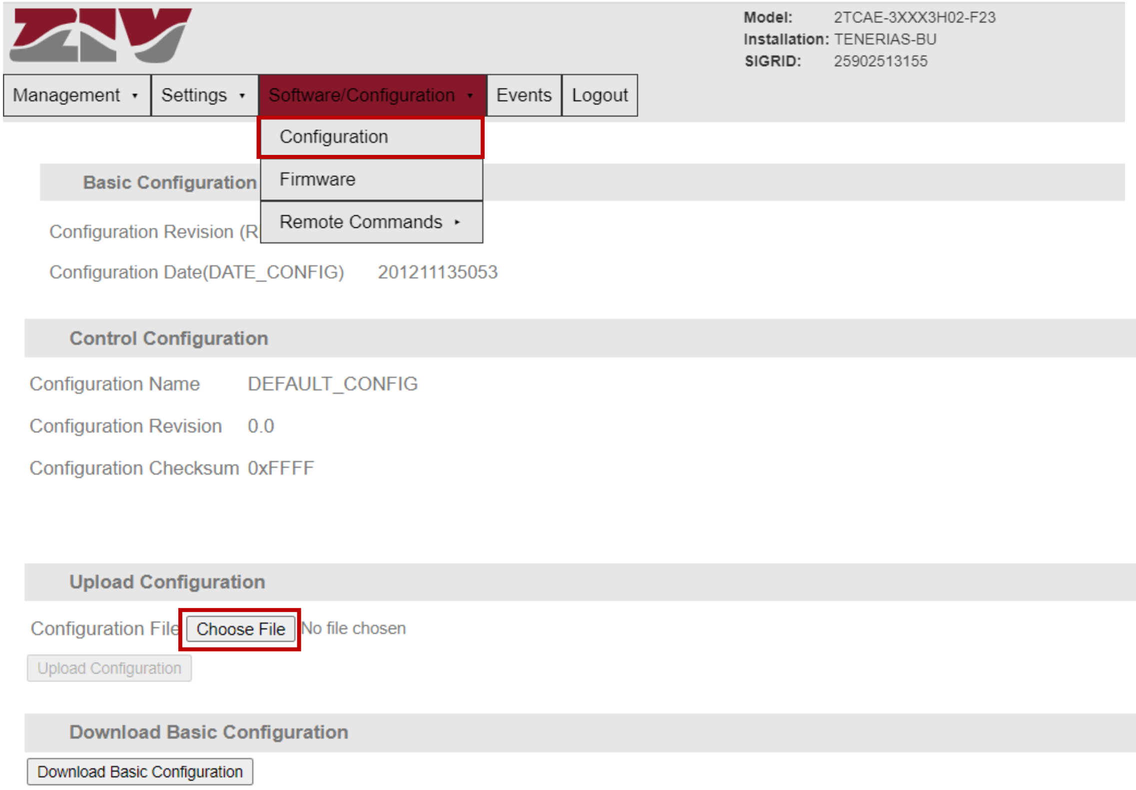
1.4.10 IED Configuration

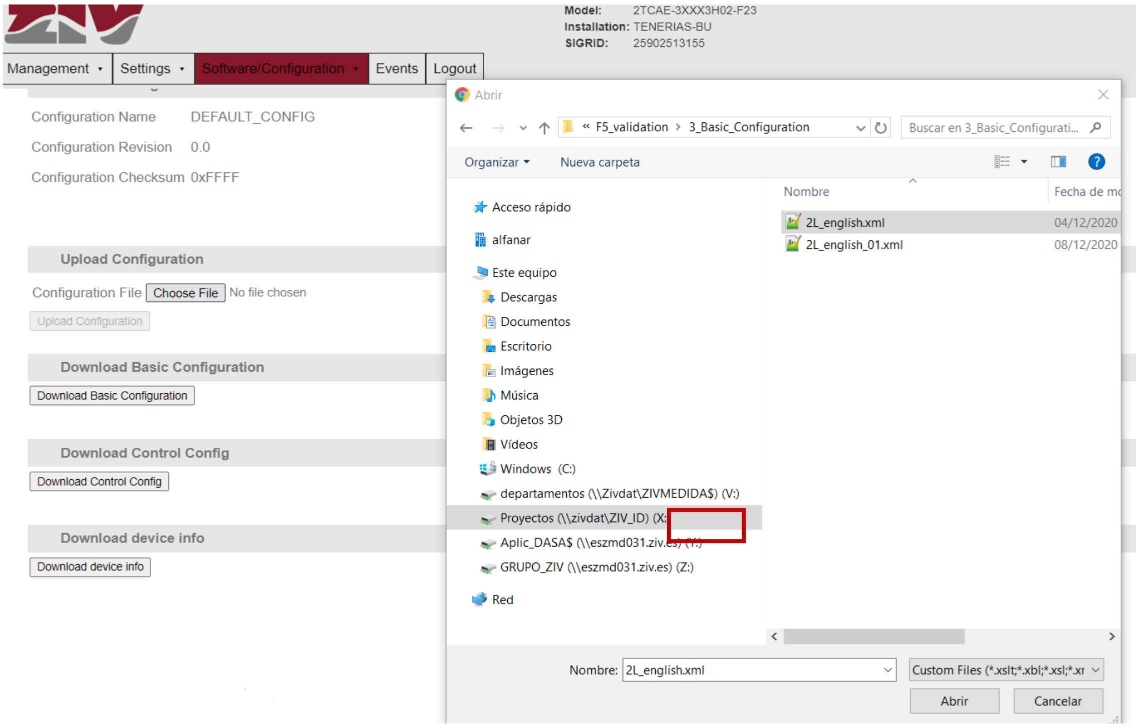
The **2TCA-E** equipment implements the configuration file transfer functionality through its **Web** access. It is possible to **Load** a configuration stored in a PC to the **2TCA-E** unit, as well as to **Download** both the configuration and the device information from the **2TCA-E** unit to the PC. The communication and information of the device are stored in XML files.

1.4.10.a Load a Configuration

To load a configuration from the PC to the **2TCA-E** unit, follow these steps:

- Connect from the PC via **Web** access with a user who has modification permission.
- Select the **Software / Configuration** option. In the **Configuration** section, click on the **Browse / Select** file button depending on the Web browser used.





A file selection window appears in which you have to select the XML file containing the configuration you want to upload to the **2TCA-E** unit and press the ***Open*** button.

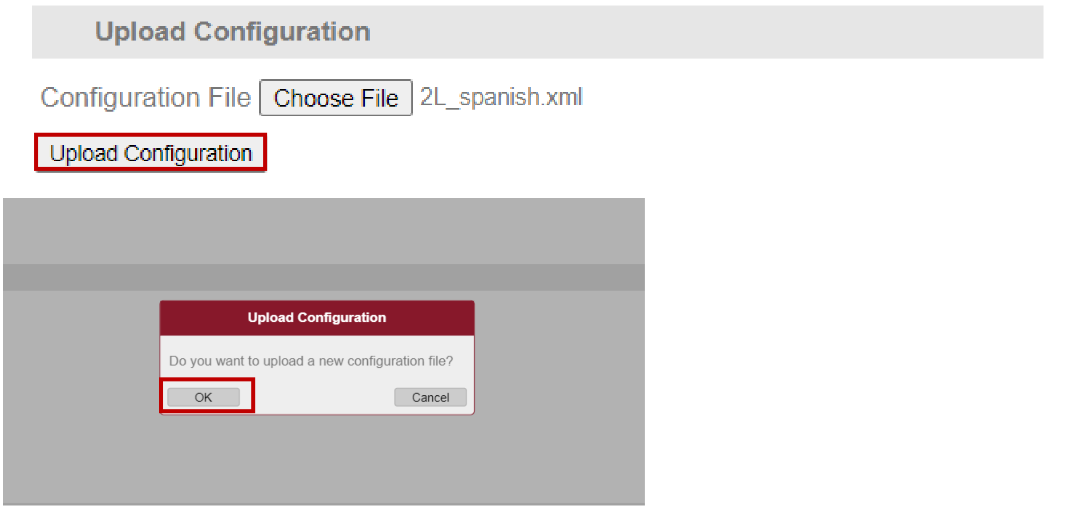


Figure 1.4.44 Load Configuration.

Once the configuration has been selected, click on the Up*load* ***Configuration*** & OK buttons and wait for the process to finish.

If errors occur in loading the configuration, a message appears indicating the list of errors that have occurred. The most common reasons are two: the file does not have a valid structure according to the file or exchange scheme or the value of a setting is outside the accepted range.

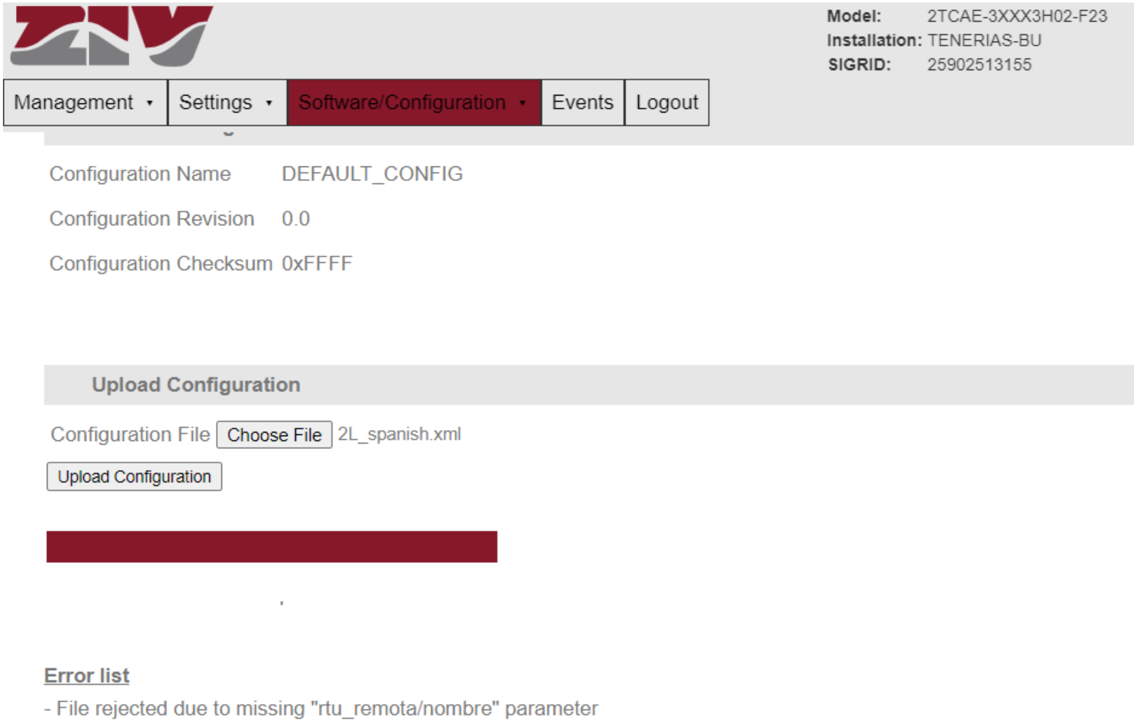


Figure 1.4.45 Failed Configuration Load.

If the configuration has been successfully loaded into the **2TCA-E** unit, a message appears indicating that the loading has been successful. The configuration is stored in the non-volatile memory of the device and the services restarted with the new configuration.

The revision of the configuration file contained within the file is loaded into the general identifier of the equipment configuration. The date is calculated internally when the file is stored in the non-volatile memory of the device.

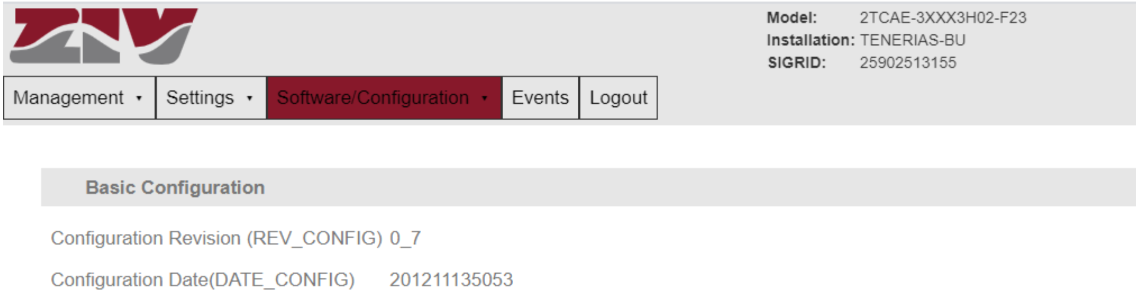


Figure 1.4.46 Identification of the Configuration File Version.

If you make a change of one or more changes in the settings by navigating through the **Parameters** tab, and pressing the ***Save*** option, these changes will be reflected in the configuration version by adding a suffix "0_i" and increasing the value of i sequentially after each memory storage of a new configuration.

1.4.10.b Download Basic Configuration

In order to download a configuration of the **2TCA-E** unit to a PC, the following steps must be carried out:

- Connect from the PC via **Web** access.
- Select the **Software / Configuration** option. In the **Configuration** section, click on the **Download Basic Configuration** button. The file with the configuration will be downloaded in the download directory that is configured in the Web browser and with the name "AllConfigRTU.xml".

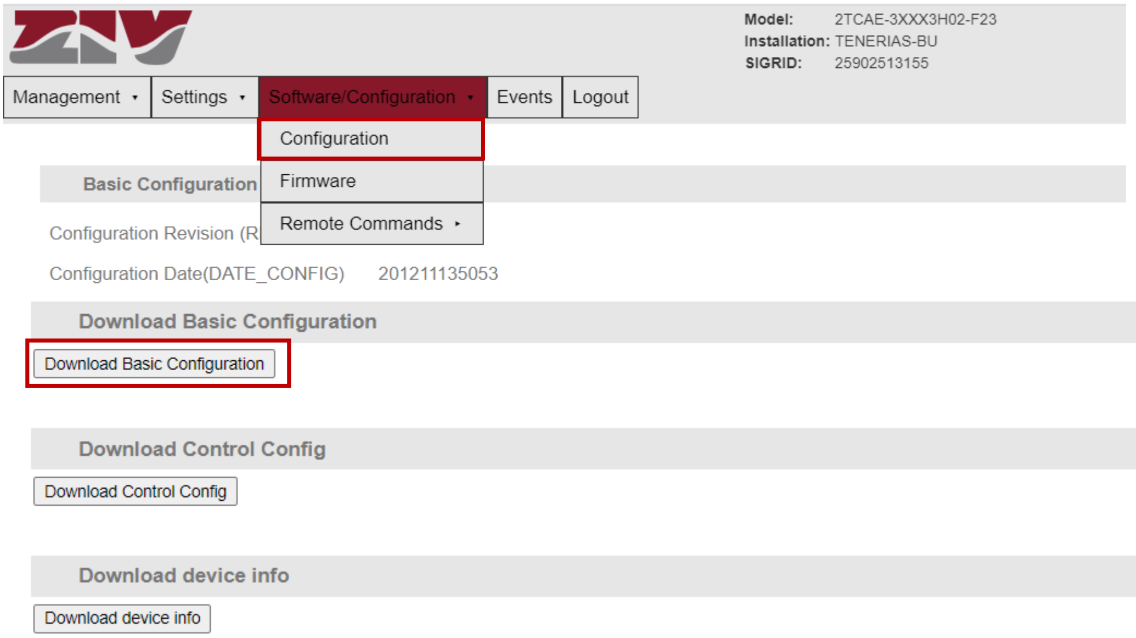


Figure 1.4.47 Download Configuration.

1.4.10.c Download Control Configuration

In order to download a control configuration of the **2TCA-E** unit to a PC, the following steps must be carried out:

- Connect from the PC via **Web** access.
- Select the **Software / Configuration** option. In the **Configuration** section, click on the **Download Control Config** button. The file with the configuration will be downloaded in the download directory that is configured in the Web browser and with the name "AllConfigRTU.xml".

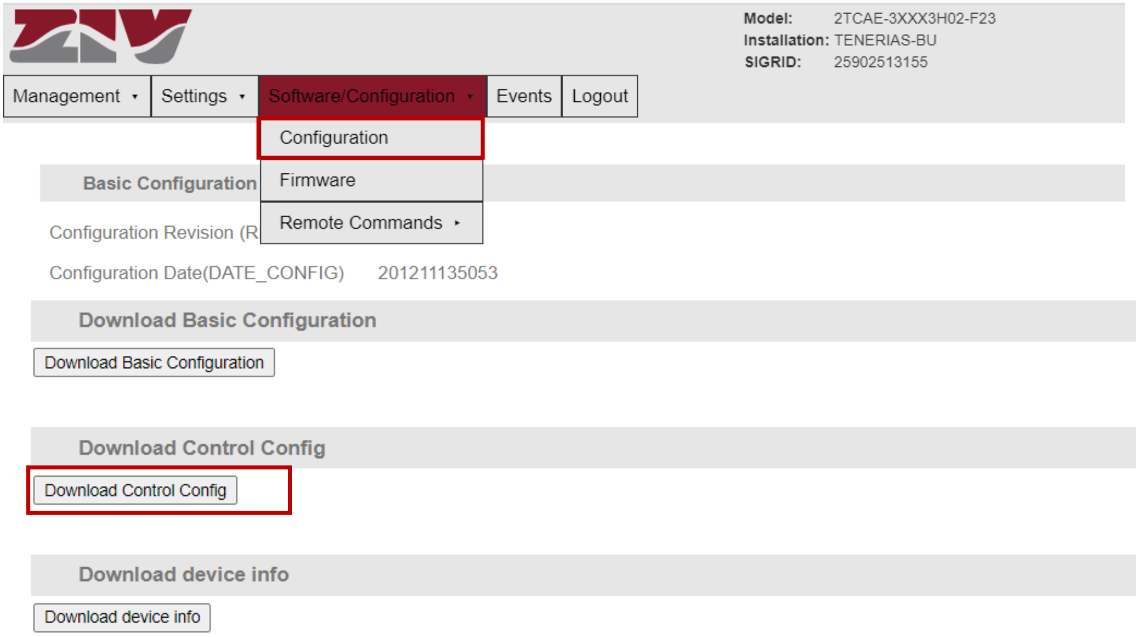


Figure 1.4.48 Download Control Configuration.

1.4.10.d Download Device Information

To download the device information from the **2TCA-E** to a PC, follow these steps:

- Connect from the PC via **Web** access.
- Select the **Software / Configuration** option. In the **Configuration** section, click on the **Download Device Information** button. The file with the device information will be downloaded to the download directory that is configured in the Web browser and named "VersionRTU.xml".

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

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

Installation should be accomplished in accordance with the dimension diagrams.

- **Connections**

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

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.

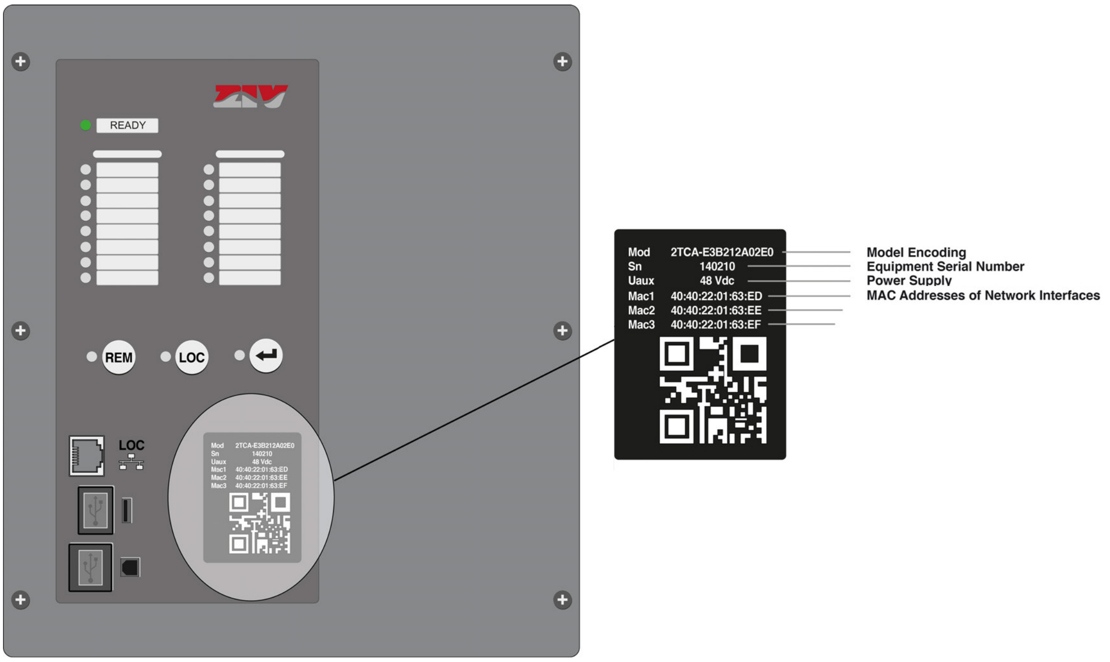


Figure 1.5.1 Name Plate (2TCA-E).

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 1000 VAC are applied during one second between this group and all the rest.

WARNING!

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 Metering Tests

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:

I	I	PHASE of I	PHASE of I	V APPLIED	V MEASURED
X	X ±0.5%	Y	Y ±0.25º	X	X ±1%

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

1.5.6 Configuration by Web

The aim of this section is to give guidelines on the parameters that should be adjusted by the user for the implementation of a **2TCA-E** equipment regarding the communications.

To configure a **2TCA-E** unit through its Web interface, it will be done from a PC that is in the same subnet as the **2TCA-E** unit through the LOC connector. The local IP address assigned to the **2TCA-E** unit by default is **100.0.0.1** with netmask **255.255.255.0**, so the IP address of the PC must be one of the range **100.0.0.2 / 100.0.0.254** with netmask **255.255.255.0**. For this purpose, any standard Web browser can be used, entering the IP address assigned to the **2TCA-E** unit in the address bar. As a first step to access, the User and Password will be requested.

Please note that the 2TCA-E unit is case sensitive when entering the User and Password. Any time you want to modify any setting, you firstly have to send the setting to the IED, then apply the changes and finally save them. The IED will start using the new setting after applying the changes. If the applied settings have not been saved they will be lost if the IED is switched off.

Since the default authentication mode for Web access is **Local** (**Access** option, **Web Access** section), the user must enter the local data of user and password and press ***Send***.

Figure 1.5.2 User and Password Request.

Once logged in, it is possible to select whether access is to be made in **Administrator** mode or in **Visualization**. The mode is defined by checking in the corresponding box that appears in the new screen.

Figure 1.5.3 Selection of the Operating Mode.

If there is a previous session active in **Administration** mode, when sending the access data, a dialog screen will appear indicating the desired option for resolving the access conflict:

- Cancel the active session and log in as administrator.
- Enter in visualization mode.
- Exit and try again later.

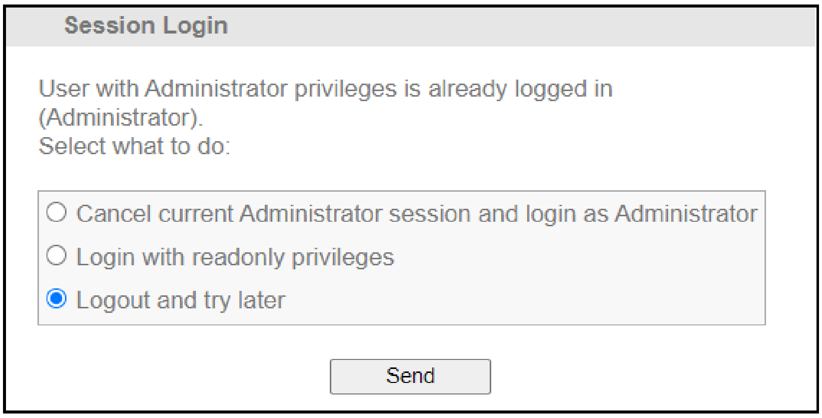


Figure 1.5.4 Access Conflict Resolution in Administration Mode.

The IP addresses and local network masks of the **2TCA-E** equipment are adjusted with those supplied by the customer in the **LAN** option of the **Parameters** menu. The IP address and local subnet mask are set in section **LOC**, while the IP addresses and remote subnet masks for the two possible IEC 60870-5-104 protocol network interfaces are set in section **ETH1**. Once the desired parameters of the option have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

If you are going to access the **2TCA-E** unit from outside your local network, you will need to configure the gateways in the same tab. In this menu, we will configure the IP addresses of the two possible gateways, as well as the default gateway.

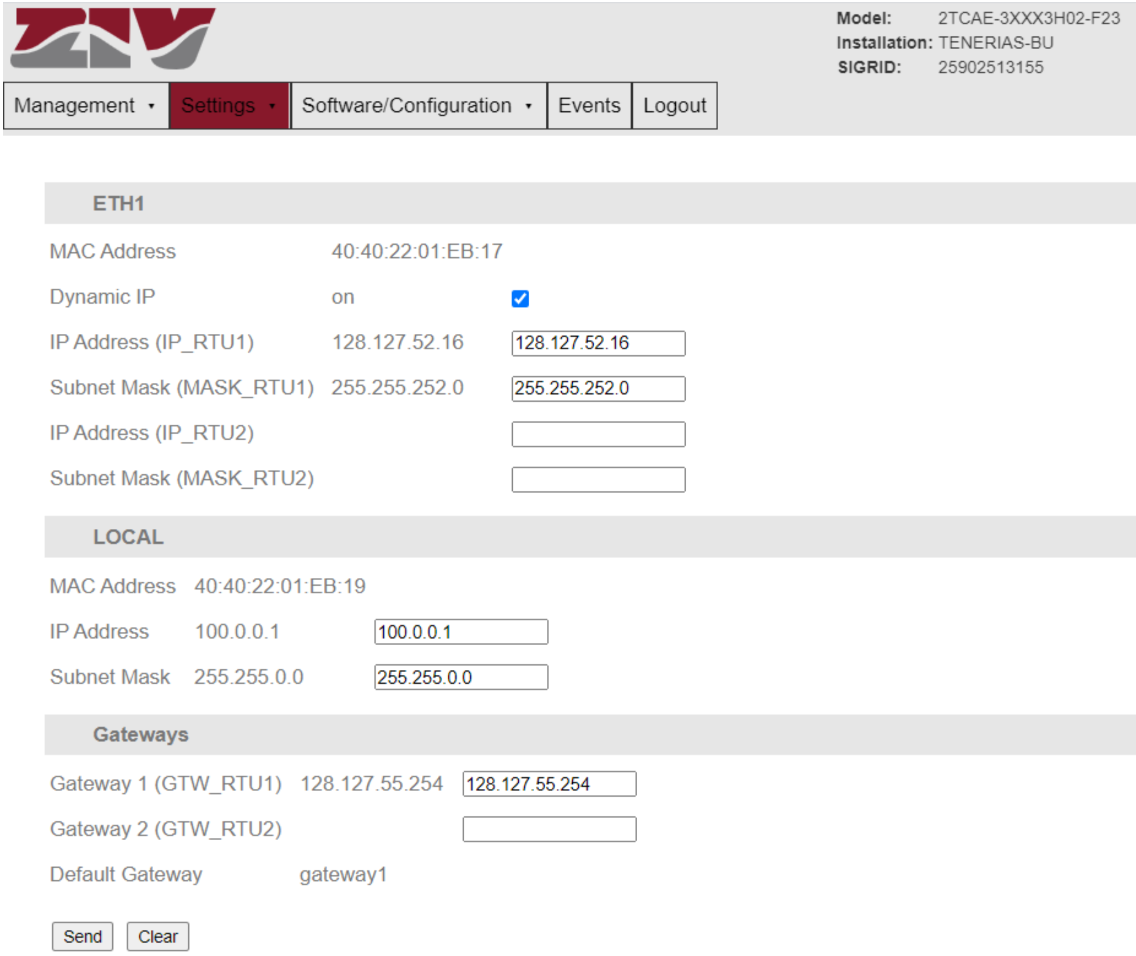


Figure 1.5.5 IP and Gateways Addreses Configuration Example.

The **2TCA-E** equipment has a series of predetermined external connections, such as the 8 possible clients of the **IEC 60870-5-104** protocol, the two possible **SNTP** servers and the remote authentication server with **LDAP** protocol. It is possible to assign one of the two Gateways configured for the **2TCA-E** unit to each of these possible default external connections. The gateway configuration is integrated for each functionality.

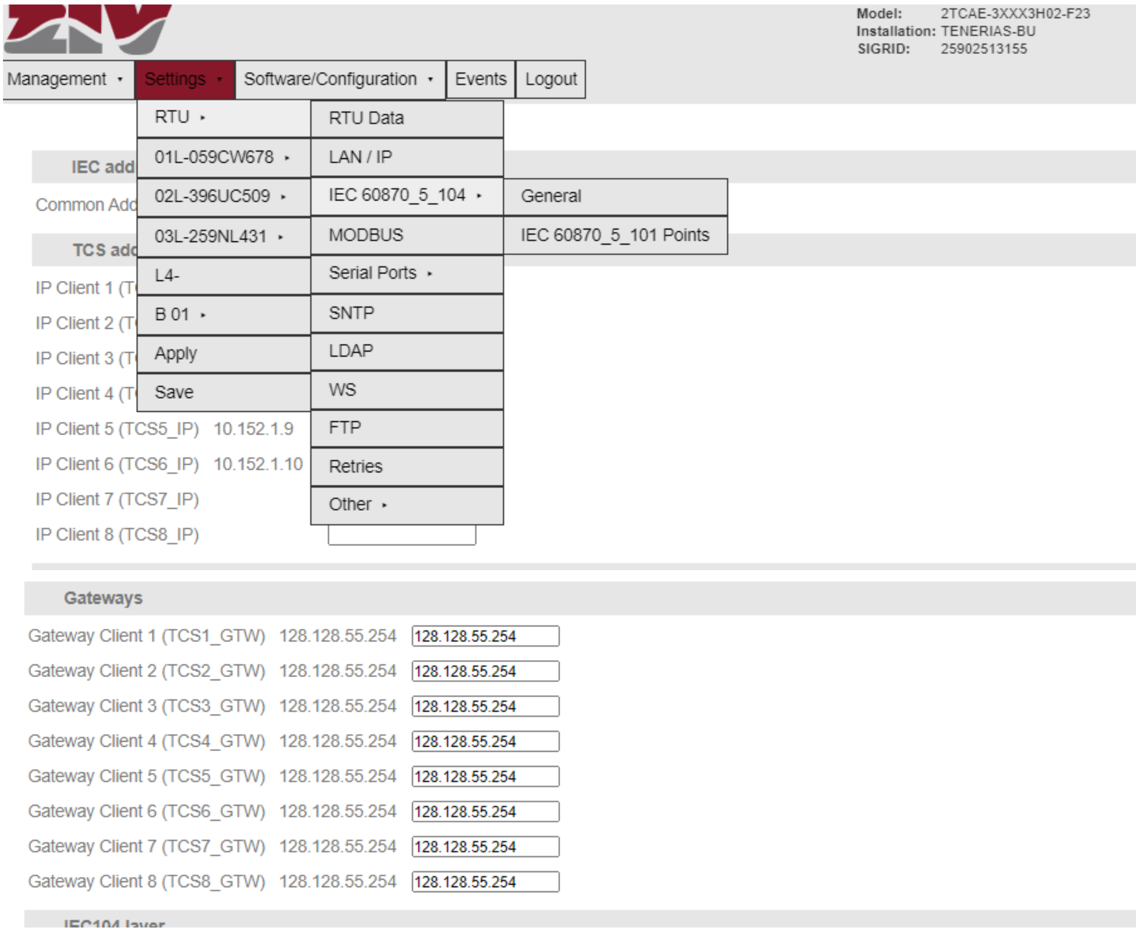


Figure 1.5.6 Example of Gateways of Predetermined External Connections.

In the **SNTP** option of the **Parameters** menu, the parameters for SNTP synchronization can be adjusted. The IP addresses of the two possible SNTP servers, as well as the different timings and number of retries will be adjusted to suit the customer's requirements. Once the desired parameters of the **SNTP** option have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

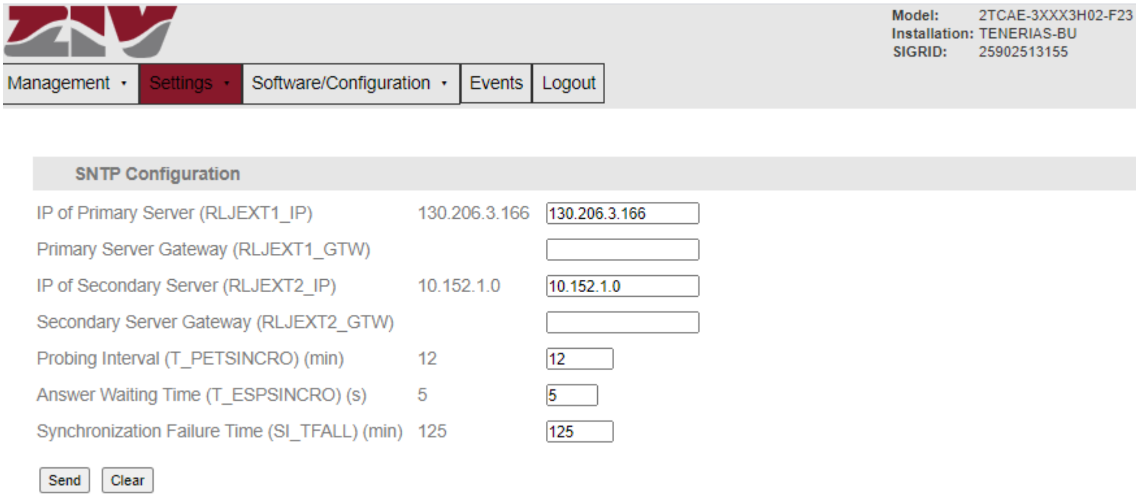


Figure 1.5.7 SNTP Synchronization Example.

In the **LDAP** option of the **Parameters** menu you can adjust the parameters related to the Access Modes to the **2TCA-E** equipment (**Local HMI Access**, **Web Access** or **Telnet Access**), as well as the Authentication Modes associated to each Access Mode and the parameters to adjust the Remote Authentication Mode (**LDAP**).

The Local Authentication Mode employs the users stored internally on the **2TCA-E** equipment, while the Remote Authentication Modes employ external servers to store users, using the **2TCA-E** equipment and the **LDAP** protocol to remotely authenticate against these servers.

- In relation to Access Modes, the timer can be set to terminate access in case of inactivity (**Session** section), as well as the authentication mode (**Local**, **LDAP**) used for each access mode (**Local HMI Access**, **Web Access** and **Shell Access** sections).

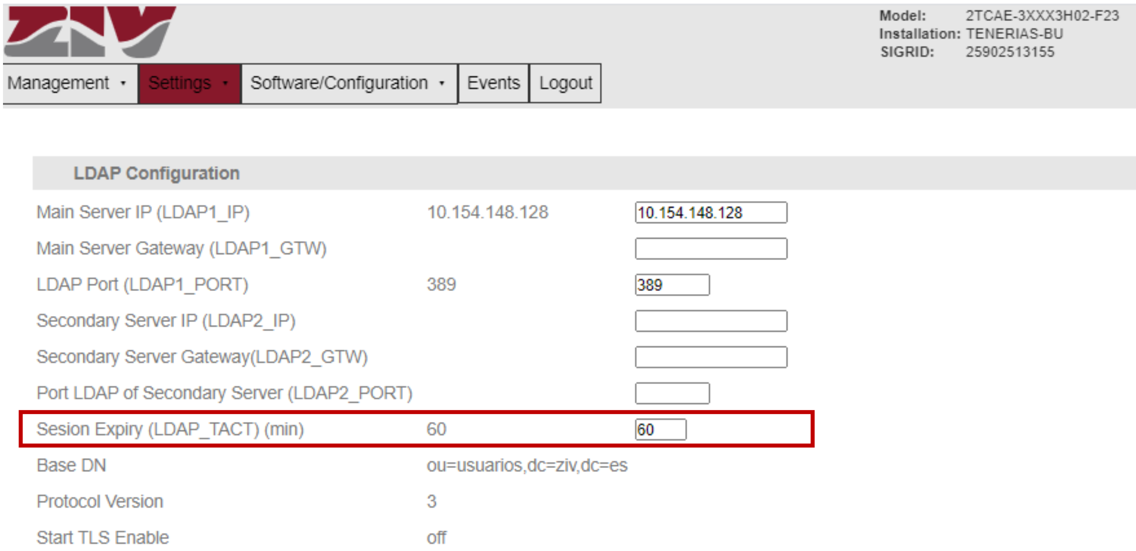


Figure 1.5.8 Sesion Expiry Configuration Example.

- If a remote authentication mode (**LDAP**) is selected, the local authentication mode can be configured as an alternative mode in case of remote authentication failure.

- With regard to Remote Authentication Modes, the IP addresses of the remote authentication servers (main and alternative) can be adjusted, as well as other particular parameters for the remote authentication mode in the LDAP section.

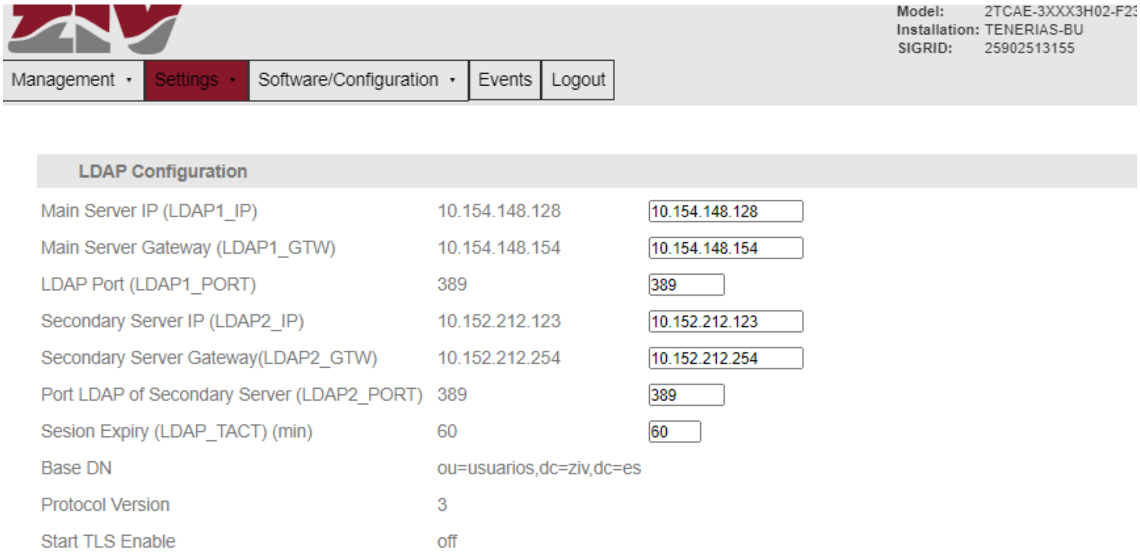


Figure 1.5.9 LDAP Setting Configuration Example.

Once the desired parameters of the **Access** option have been set, press ***Send*** to send these settings to the **2TCA-E**.

The **2TCA-E** IED has the possibility of communicating with one or more Remote Control offices (or controlling stations) using the IEC 60870-5-104 communications protocol. In the **IEC 60870_5_104** option of the **Parameters** menu, the parameters related to this communications protocol can be adjusted. Most of the parameters will keep their default value, unless the customer indicates that he wants different values. The parameters that must be configured are indicated below:

- **IP addresses of each of the up to 8 possible clients**. They are configured in the **Connections** section and correspond to the **Client IP** parameter. If for a specific client:
  - No connections allowed, the IP client **0.0.0.0** will be configured.
  - Connections from any IP are allowed, the client IP **255.255.255.255** will be configured.

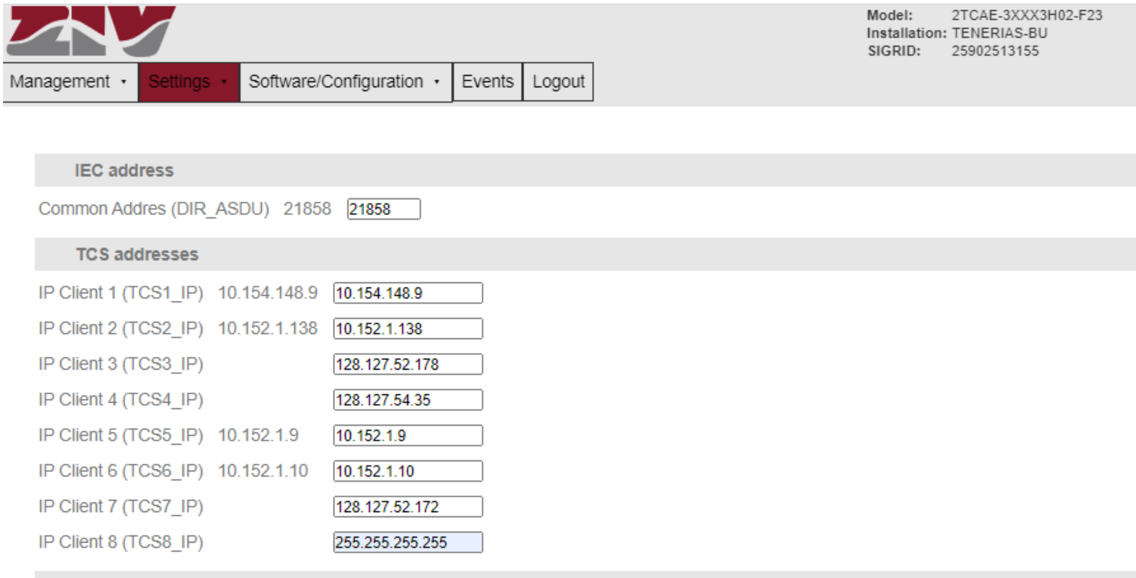


Figure 1.5.10 Example of IEC 60870-5-104 Protocol Client Configuration.

In this section it is possible configure their gateways.

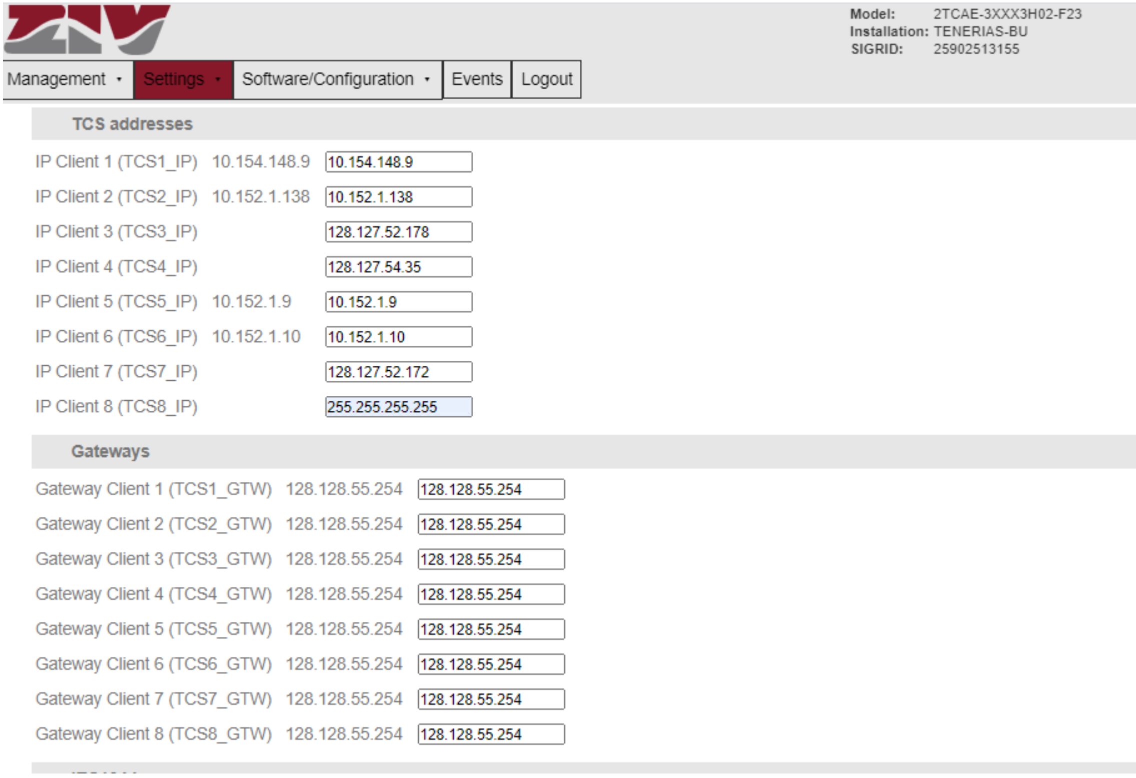


Figure 1.5.11 Example of IEC 60870-5-104 Gateways Configurations.

- **Remote address of the 2TCA-E** (**Common Address of ASDU**). It is configured in the **IEC Address** section and corresponds to the **Application Layer Address** parameter.

- **User signals and commands**. They are configured in section **IEC 60870_5_101**: **User Points**. The **Enable** parameter will be enabled for all the points to be sent to the Remote Control dispatch. It will be configured for each one of them:
  - Information object address (IOA) of the IEC 60870-5-104 protocol (**Point 101** parameter).
  - Digital or analog signal of the **2TCA-E** equipment associated with that point (**TCA Signal** parameter).
  - In the case of analogs, the hysteresis value or band value (**Hysteresis** parameter), which is the percentage that must vary the value of the measurement to be sent to the dispatch.

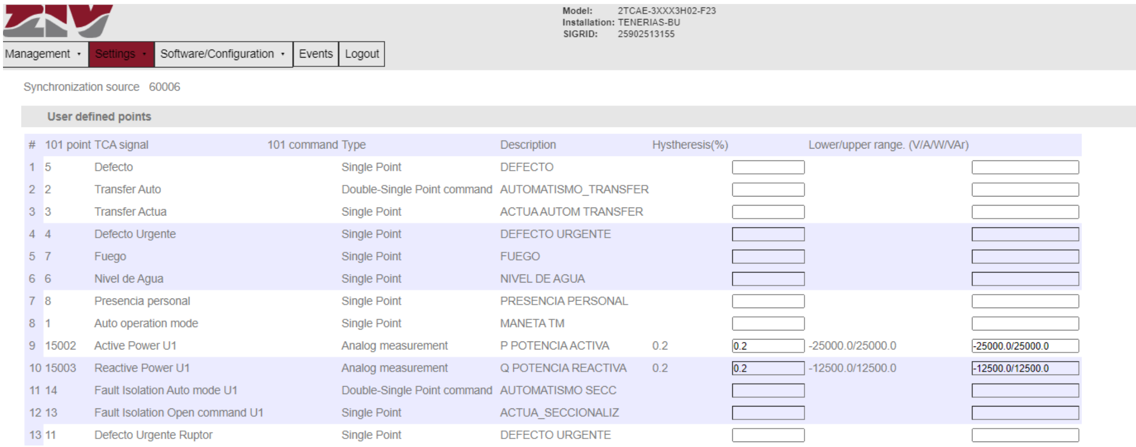


Figure 1.5.12 Example of Configuration of the User Signals of the IEC 60870-5-104 Protocol.

Once the desired parameters of the IEC 60870_5_104 option have been set, press ***Send*** to send these settings to the **2TCA-E** unit.

Once all the desired parameters have been set, press Apply changes and finally save them. The IED will start using the new setting after applying the changes. If the applied settings have not been saved they will be lost if the IED is switched off.

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 (module and angle).

In order to proceed with the test, primary injections will be done to check the polarity and transformation ratios. These tests can only be carried out if there are no restrictions related to the energization of the bay and all the other devices of the bay where the RTU 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 IED shows in the measurement screen (**Management/ Statistics/Measures**) 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 web page of the device or in the communication program should comply with the values which are specified in the Measurement Accuracy paragraph in Chapter 1.3, Technical Data.

1.6.3 Current Connections (2TCA-E)

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 web 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 should comply with the values which are specified in the Measurement Accuracy paragraph in Chapter 1.3, Technical Data.

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

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

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

1.6.4 Current Connections (2TCA-E SmartRTU)

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 IED shows in the measurement screen (**Management/ Statistics/Measures**) 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 web page of the device or in the communication program should comply with the values which are specified in the Measurement Accuracy paragraph in Chapter 1.3, Technical Data.

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

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

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

1.7 Standards and Type Tests

The equipment satisfies the standards indicated below. When not specified, the standard is UNE 21-136 (IEC-60255).

1.7.1 Insulation

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

1.7.2 Electromagnetic Compatibility

100khz and 1 MHz Burst Test	*61000-4-18 / IEC-60255-26*
Common mode	**2,5 kV**
	1 kV in communication ports
Differential mode (except communication ports)	**1 kV**
Damped Oscillatory Magnetic Field Immunity Test	*IEC 61000-4-10*
100KHz and 40 Transients/s	**±100 A/m**
1MHz and 400 Transient/s	**±100 A/m**
Fast Transient Disturbance Test	*IEC 61000-4-4 Class IV (IEC-60255-22-4)*
Analog inputs, DIs, DOs, PS	**4 kV (5kz)**
In communication ports	**2 kV (5kz)**
Radiated Electromagnetic Field Disturbance	
AM 80% 1KHz, range 80MHz-3GHz	**10 V/m**
Conducted Electromagnetic Field Disturbance	*IEC 61000-4-6 Class III*
Frequency band from 0.15 to 80Mhz and	**10 Vrms**
Specific frequencies: 27Mhz and 68MHz	

Electrostatic Discharge	*IEC 61000-4-2 Class IV (IEC 60255-26)*
Contact Mode	**±8 kV ±10 %**
In Air Mode	**±15 kV ±10 %**

Surge Immunity Test	*IEC-61000-4-5 (IEC 60255-26)*
	(1,2/50µs - 8/20µs)
Differential mode	
Power Supply	**±2 kV**
Analog inputs, DIs and DOs	**±1 kV**
Common mode	
Power Supply	**±4 kV**
Analog inputs, DIs and DOs	**±2 kV**
Communication Ports	**±2 kV**

Radiated Electromagnetic Field Disturbance at Industrial Frequency (50/60 Hz)	*IEC61000-4-8 Class V (IEC 60255-26)*
Continuous levels	**100 A/m**
2 second applications	**1000 A/m**

Radio Frequency Emissivity	
Radiated	*EN55022, EN55032 (IEC 60255-26)* **Class B**
Conducted	*EN55011, EN55032* **Class A**

1.7.3 Environmental Test

Temperature	*IEC 60068-2*
Cold work limit conditions	*IEC 60068-2-1*
	-25º C, **16 hours**
Dry heat limit conditions	*IEC 60068-2-2*
	+70º C, **16 hours**
Humid heat	*IEC 60068-2-78*
	+40º C, 93% relative humidity**, 96h**,
Quick temperature changes	*IEC 60068-2-14 / IEC 61131-2*
	IED disconnected
	-25º C for **3h** and
	+70º C for **3h** (**5 cycles**)
Operating range	From **-25º C** to **+70º C**
Storage range	From **-40º C** to **+85º C**
Humidity	95% (non-condensing)

1.7.4 Power Supply

DC Alimentation Ripple Immunity	*IEC 61000-4-17*
Ripple	**15%**
Dips, Interruptions and Gradual On / Off Immunity	*IEC 61000-4-29*
Inverse Polarity of the Power Supply	*IEC 61131-2*

1.7.5 Mechanical Test

Vibration (sinusoidal)	*IEC-60068-2-64*
	10-200Hz ; $1(m/s^2)^2/Hz$
	200-2000Hz ; $0.3(m/s^2)^2/Hz$
External Protection Levels	*IEC-60529 / IEC 60068-2-75*
	IPX2B

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

1.8 Schemes and Drawings

Dimension and Drill Hole Schemes

2TCA-E; 1/2 rack of 19”	>>	4BF0105/0009
2TCA-E Smart RTU (1/2 rack de 19”)	>>	4BF0105/0011

External Connection Schemes

CPU + EDs	>>	3RX0209/0001
FA + SDs	>>	3RX0209/0002
EDs + V + I	>>	3RX0209/0003
EDs + I	>>	3RX0209/0004
CPU + Eds (Smart RTU)	>>	3RX0209/0005
FA + SDs (Smart RTU)	>>	3RX0209/0006
EDs + V + I (Smart RTU)	>>	3RX0209/0007
EDs + I (Smart RTU)	>>	3RX0209/0008

Escala 1:1
Scale 1:1

REV:	0	500005295	1		2		3		4
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11	12		13		14		15		16

TITULO: TCM DIMENSIONES GENERALES
TITLE: TCM GENERAL DIMMENSIONS

PROYECTO / *PROJECT*: TCA-E

Rev: 0

NUM: 4BF01050009

	Fecha/ *Date*	Nombre/ *Name*
Dibujado/ *Drawn*	28-01-2019	C.G.M
Aprovado/ *Approved*	28-01-2019	P.A.B

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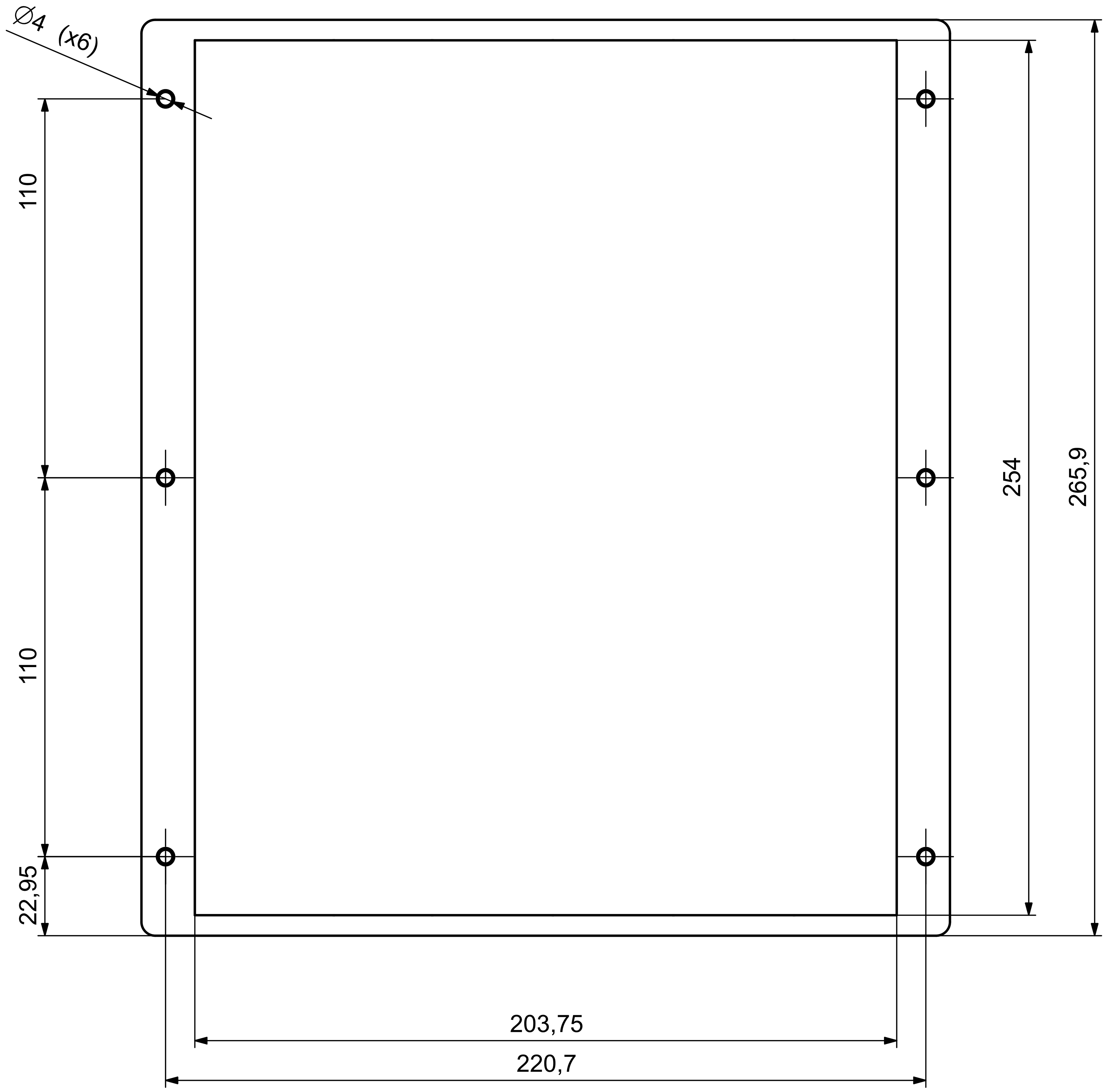

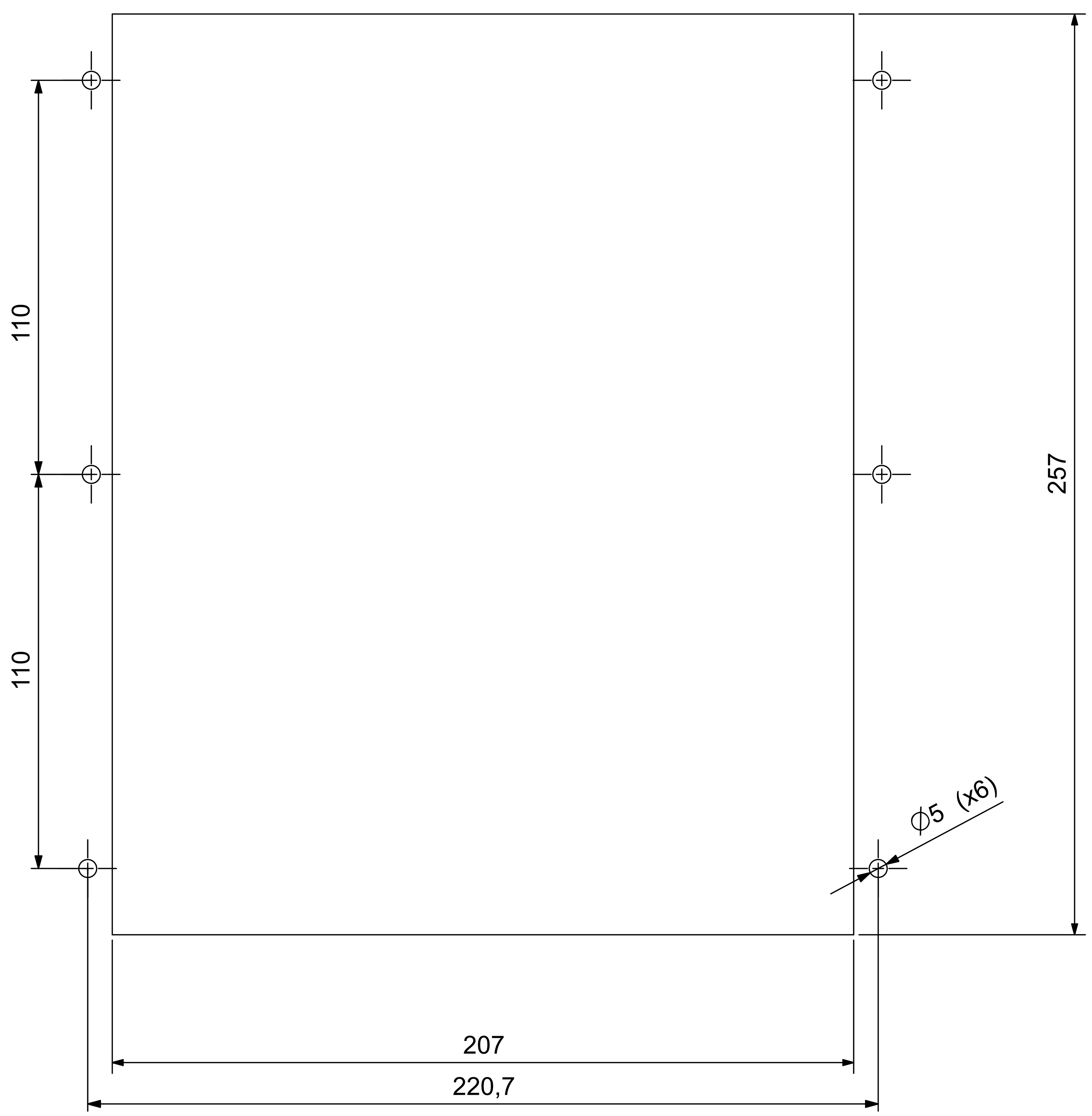

Taladros de 5mm ∅
5mm ∅ Drilling

Escala 1:1
Scale 1:1

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TITULO: TCM TALADRADO
TITLE: TCM TALADRADO

PROYECTO / *PROJECT*: TCA-E

Rev: 0

NUM: 4BF01050009

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Aprovado/ *Approved*	28-01-2019	P.A.B	*Continued on sheet:*

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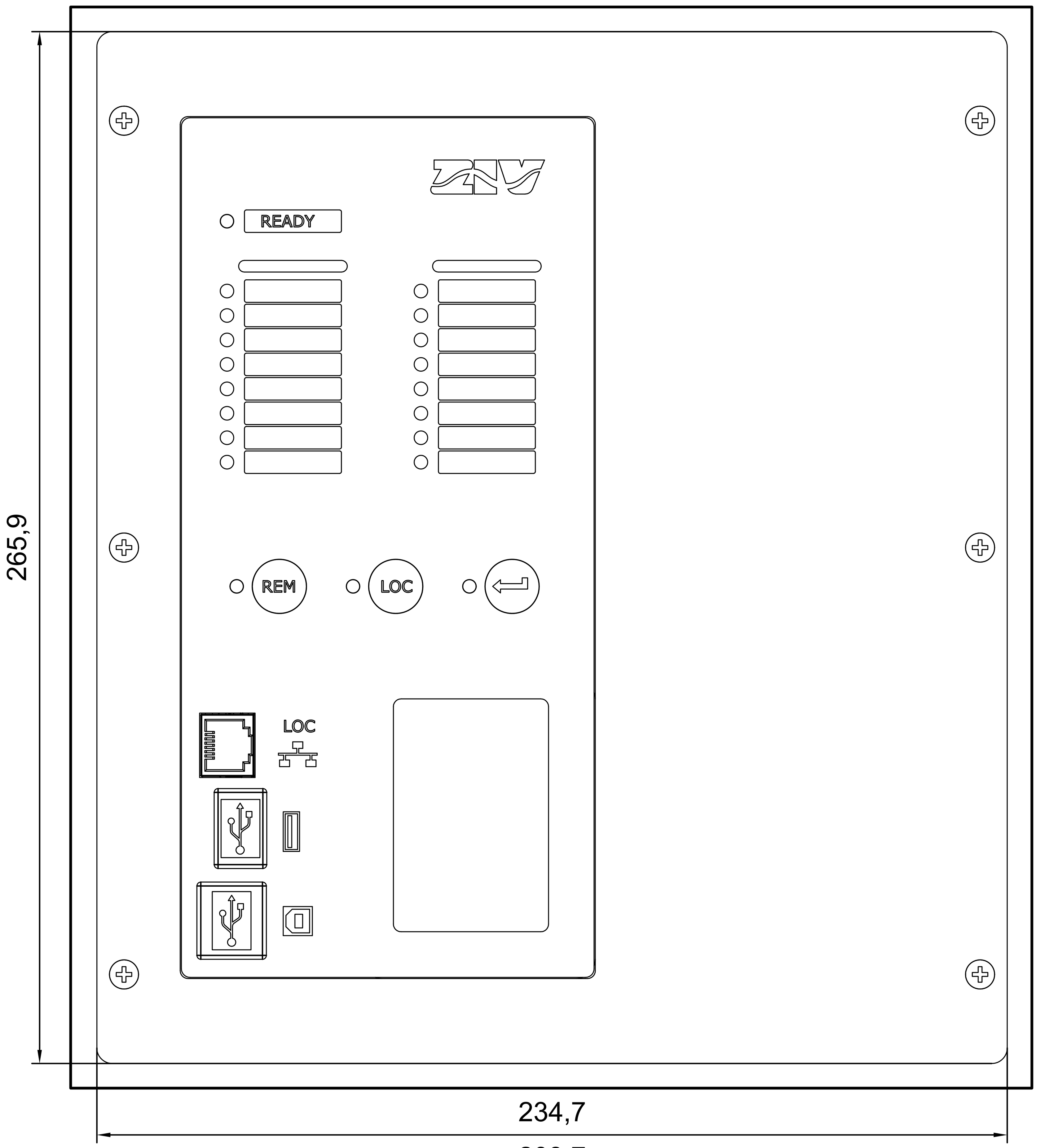

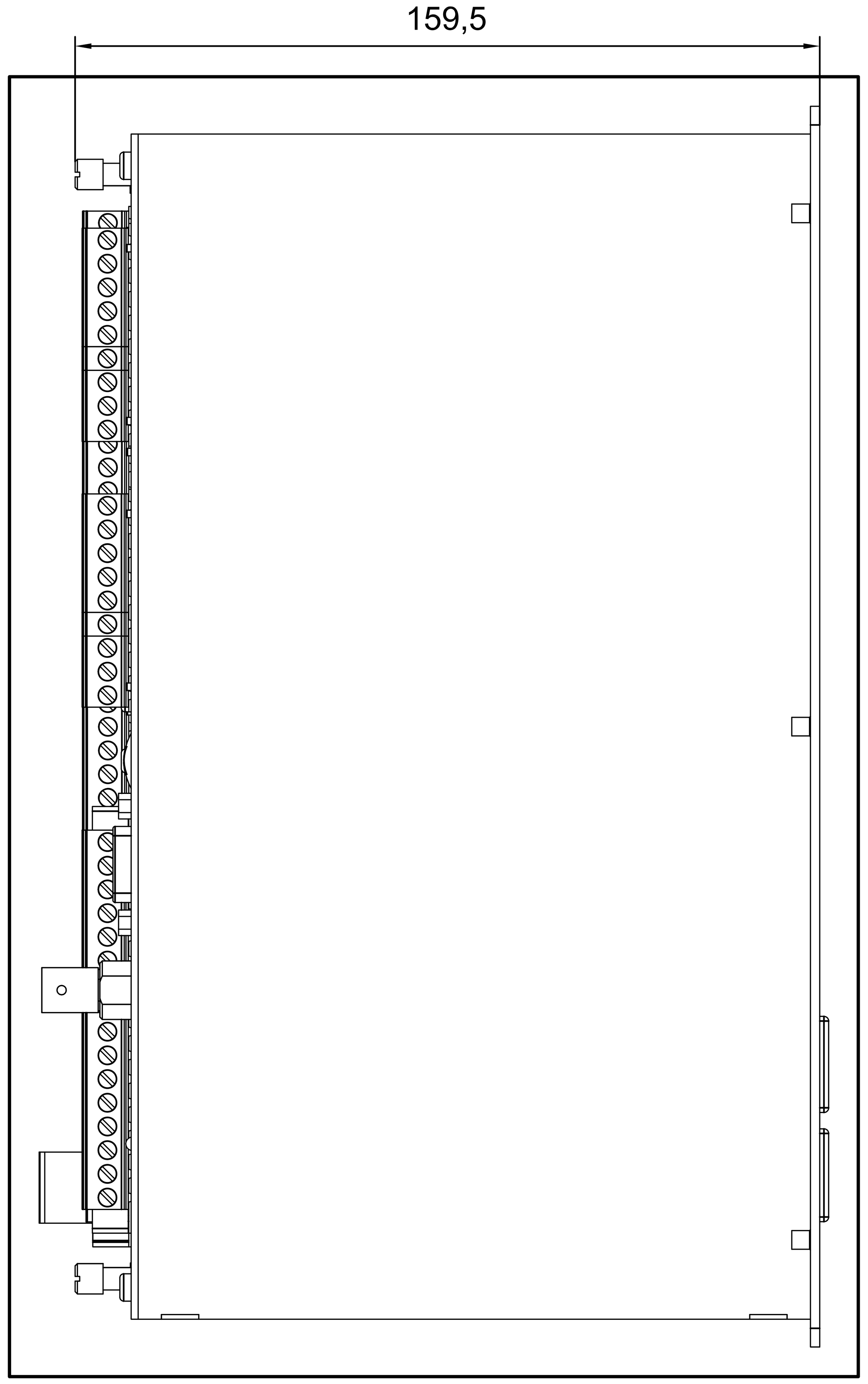

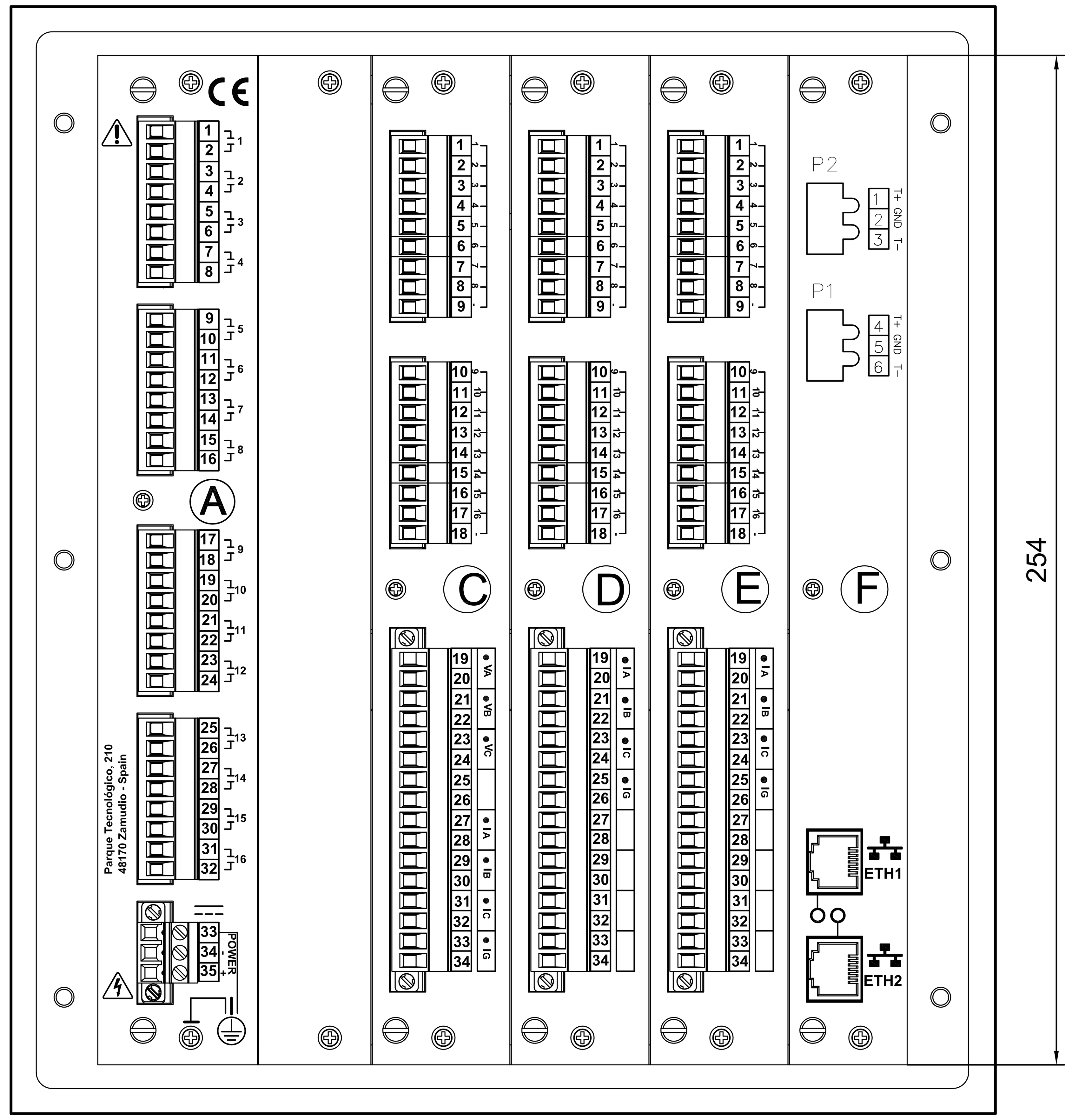

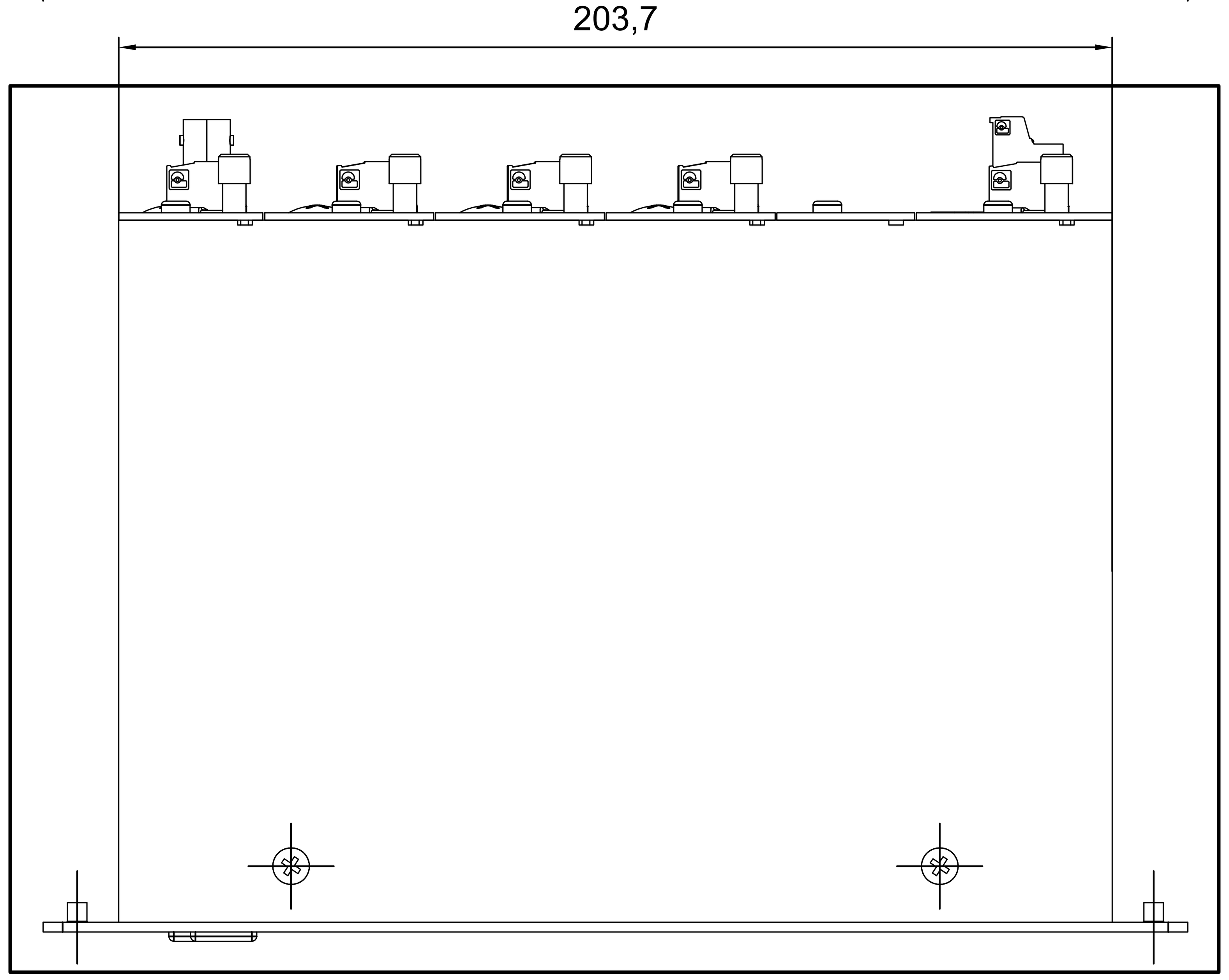

Escala 1:1
Scale 1:1

TITULO: TCM DIMENSIONES GENERALES
TITLE: TCM GENERAL DIMMENSIONS

PROYECTO / PROJECT: TCA-E

Rev: 0
Rev.1 25/01/21
Rev.2 06/07/21

NUM: 4BF01050011

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Dibujado/ Drawn	06/07/2021	C.G.M.	Continúa en hoja: / Continued on sheet: 2
Aprovado/ Approved	14/12/2020	L.G.G.	

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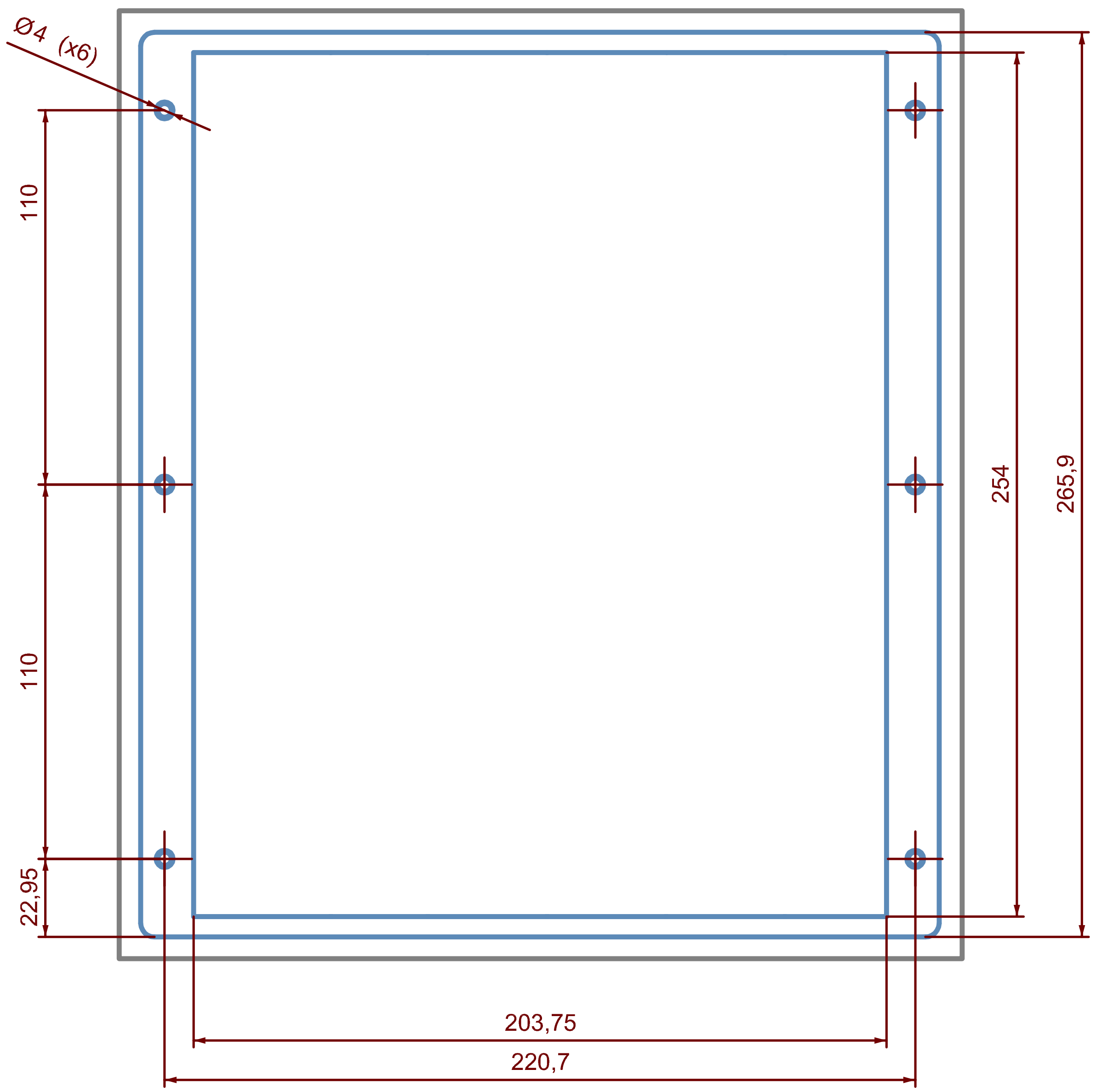

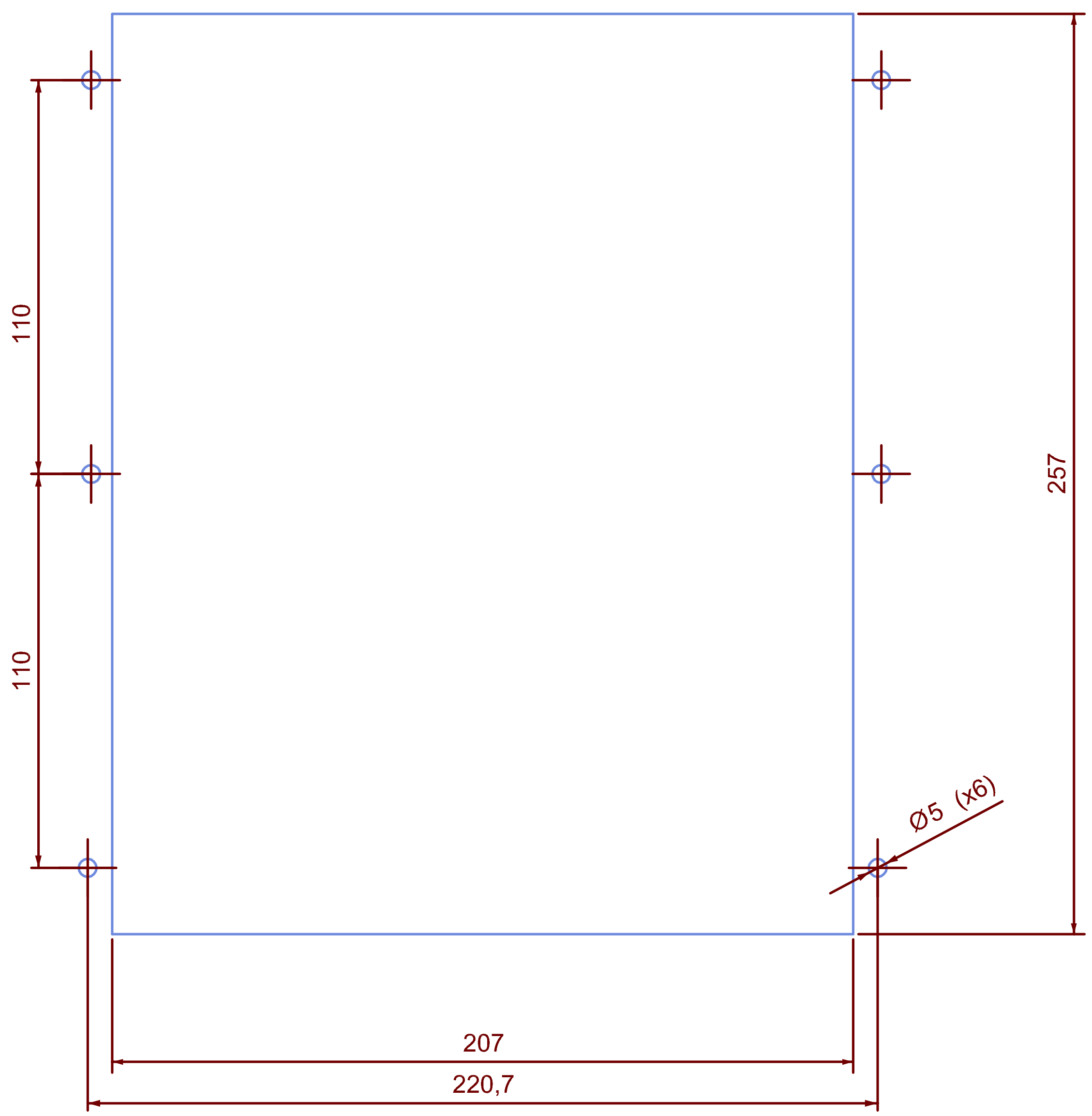

Taladros de 5mm Ø
5mm Ø Drilling

Escala 1:1
Scale 1:1

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TITULO: / TITLE: SMART RTU TALADRADO / SMART RTU DRILLING

PROYECTO / PROJECT: TCAE (SMART RTU)

Rev: 0

NUM:4BF01050011

	Fecha/ Date	Nombre/ Name
Dibujado/ Drawn	14/12/2020	B.V.Y.
Aprovado/ Approved	14/12/2020	L.G.G.

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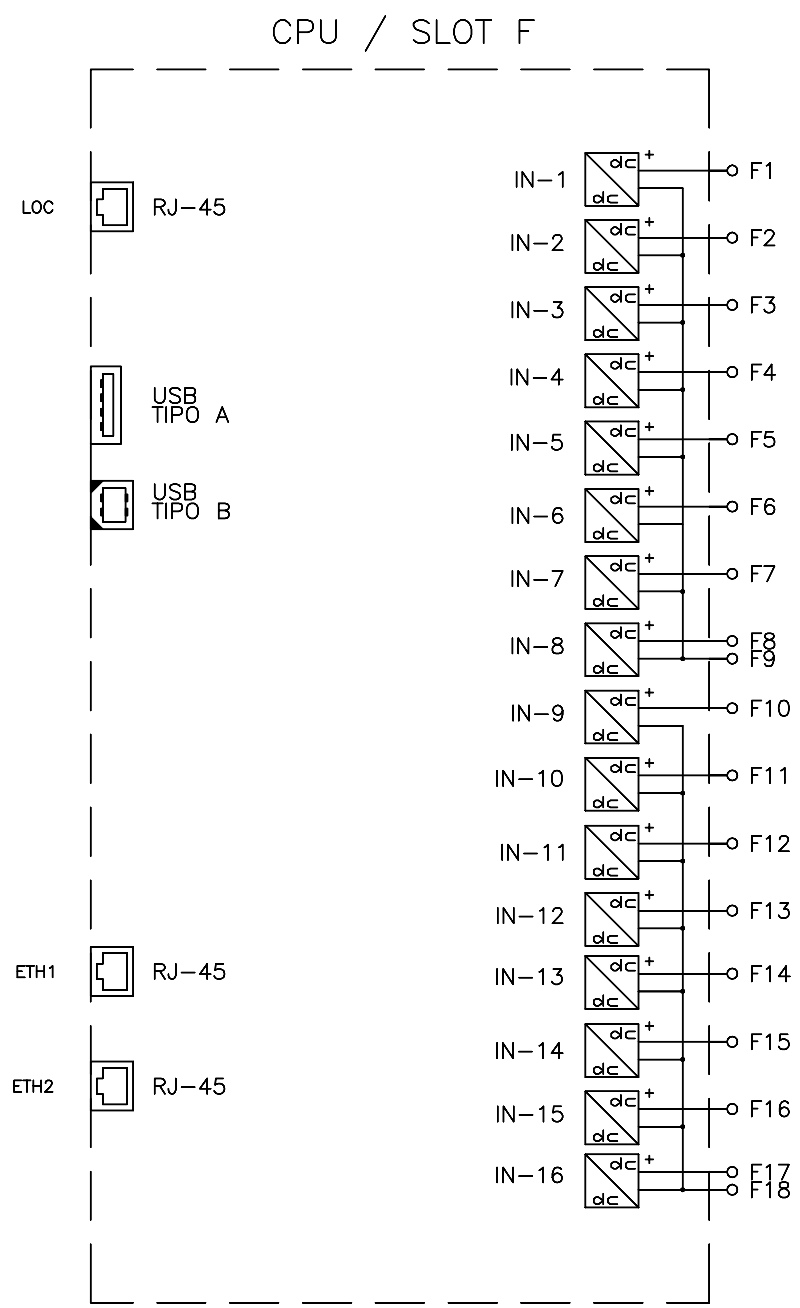
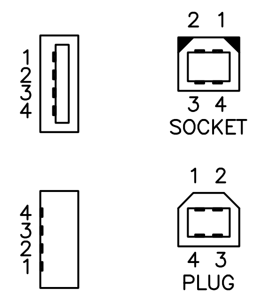


SERIAL PORT
PUERTO SERIE
USB TYPE A, B



SOCKET No	FUNCTION
1	Vcc
2	D–
3	D+
4	GROUND

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

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TITULO: CONEXIONES EXTERNAS CPU
TITLE: CPU EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E

Rev.0

NUM.: 3RX0209/0001

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Aprobado / *Approved*	11/03/17	P.A.

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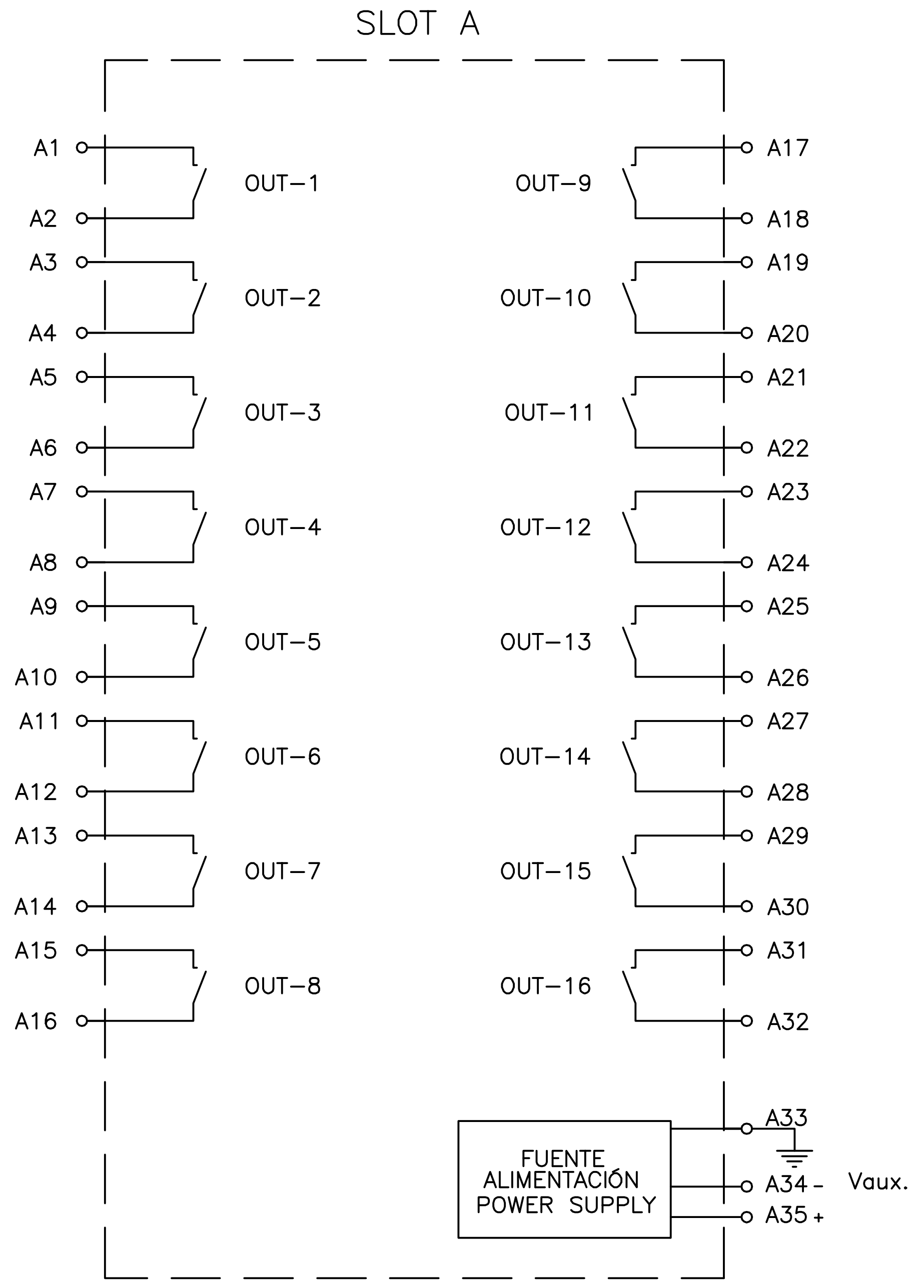

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SLOT	A	B	C	D	E	F
	X					
MODEL	#	#	#	#	#	2

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TITULO: CONEXIONES EXTERNAS
TITLE: EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA−E

Rev.0

NUM.: 3RX0209/0002

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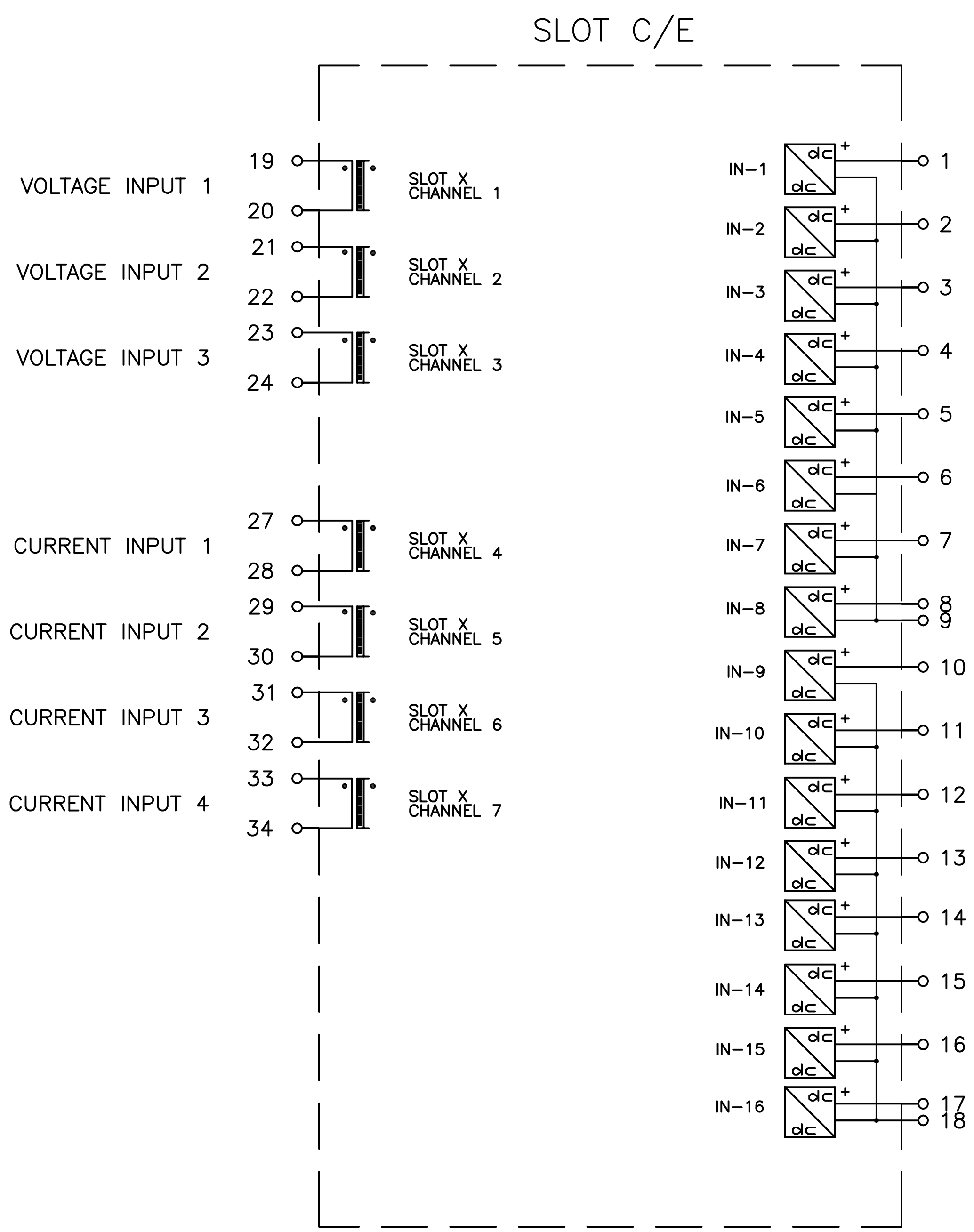

RACK	1/2					
SLOT	A	B	C	D	E	F
			X		X	
MODEL	#	#	#	#	#	2

REV.	0	CD	1		2		3		4	
5		6		7		8		9		10
11		12		13		14		15		16

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS CPU
TITLE: CPU EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E

Rev.0

NUM.: 3RX0209/0003

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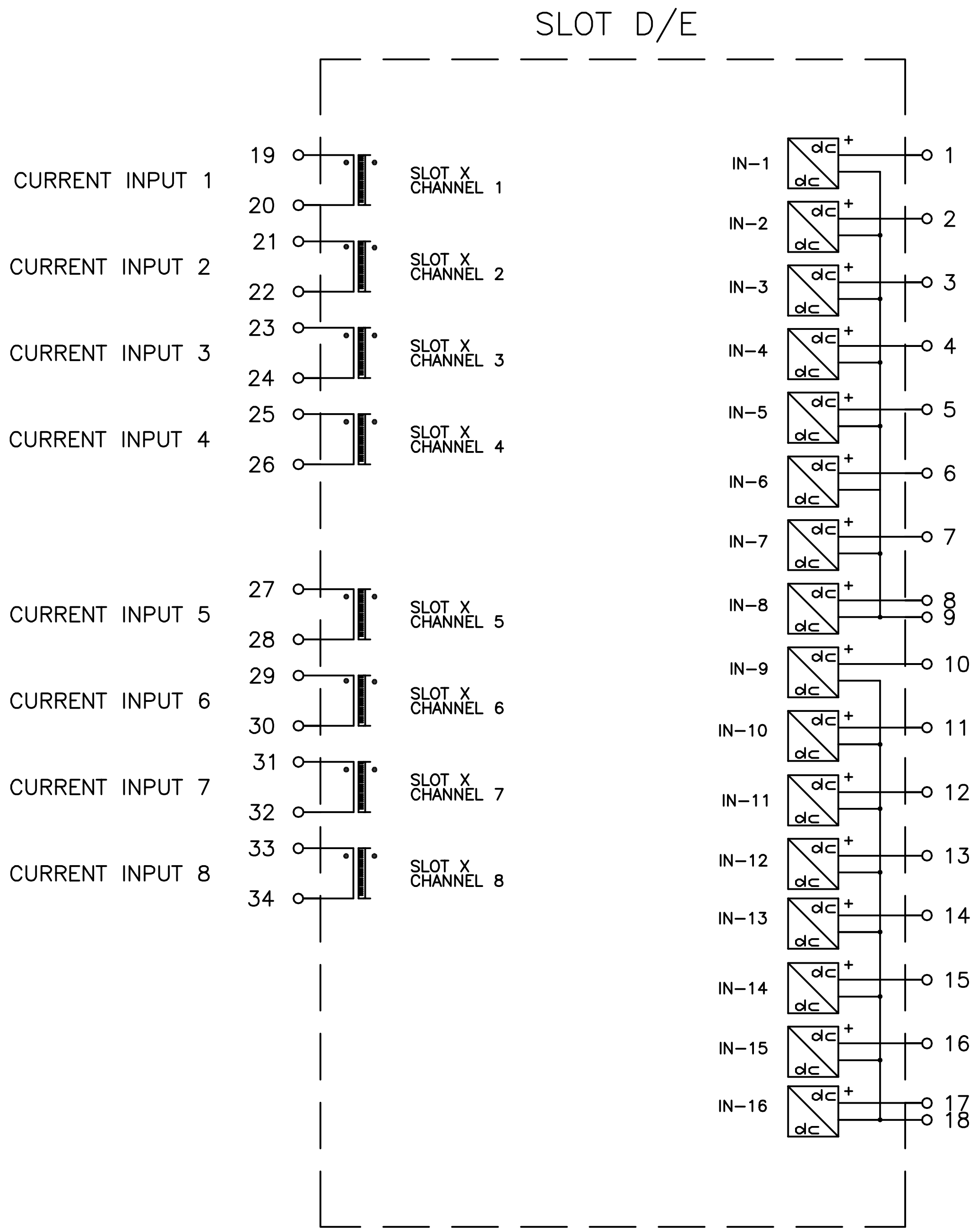

RACK	1/2					
SLOT	A	B	C	D	E	F
				X	X	
MODEL	#	#	#	#	#	2

	REV.	0	CD	1		2		3		4		
5		6		7		8		9		10		
11		12		13		14		15		16		

Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS CPU
TITLE: CPU EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E

Rev.0

NUM.: 3RX0209/0004

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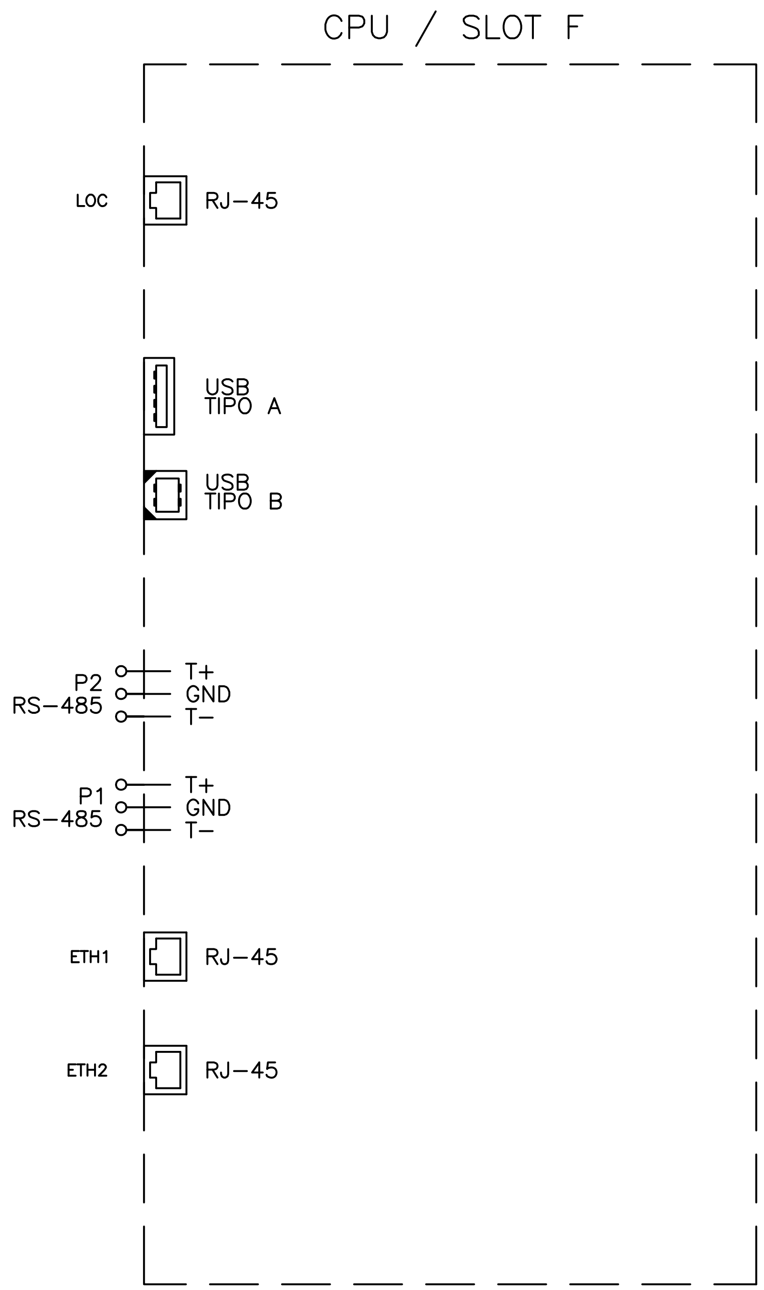
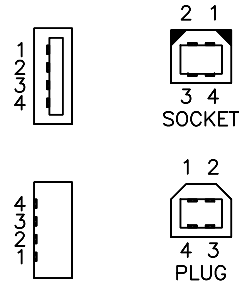
Aprobado / *Approved*	11/03/17	P.A.	Continua en Hoja: / *Continued on sheet:* –

CPU / SLOT F



SERIAL PORT
PUERTO SERIE
USB TYPE A, B



SOCKET No	FUNCTION
1	Vcc
2	D-
3	D+
4	GROUND

RACK	1/2					
SLOT	A	B	C	D	E	F
						CPU
MODEL	#	#	#	#	#	3

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Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS CPU
TITLE: CPU EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E/SMART RTU

Rev.0
Rev.1 06/07/21

NUM.: 3RX0209/0005

	Fecha / *Date*	Nombre / *Name*
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Aprobado / *Approved*	11/12/20	P.A.

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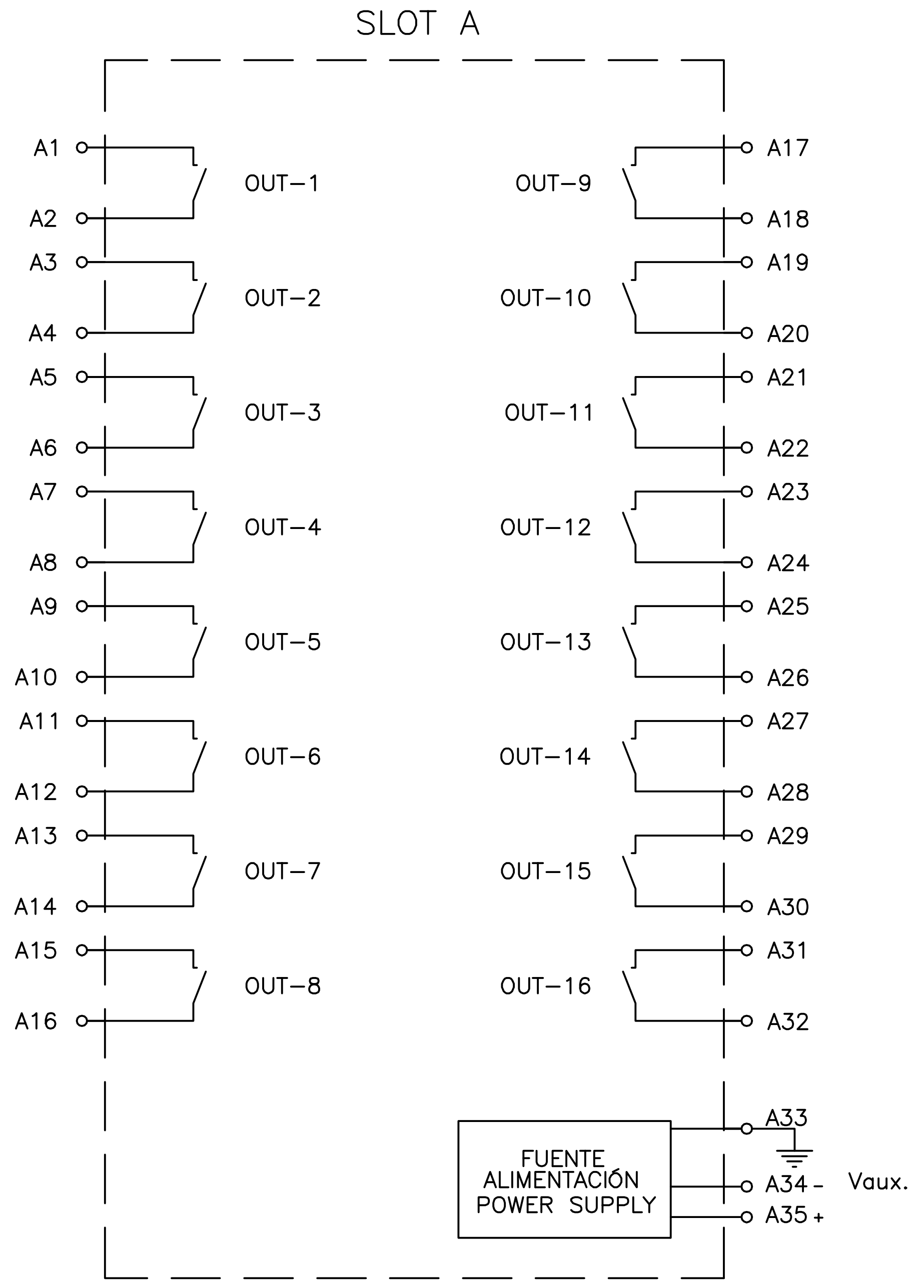

RACK	1/2					
SLOT	A	B	C	D	E	F
	X					
MODEL	#	#	#	#	#	3

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TITULO: CONEXIONES EXTERNAS
TITLE: EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E/SMART RTU

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NUM.: 3RX0209/0006

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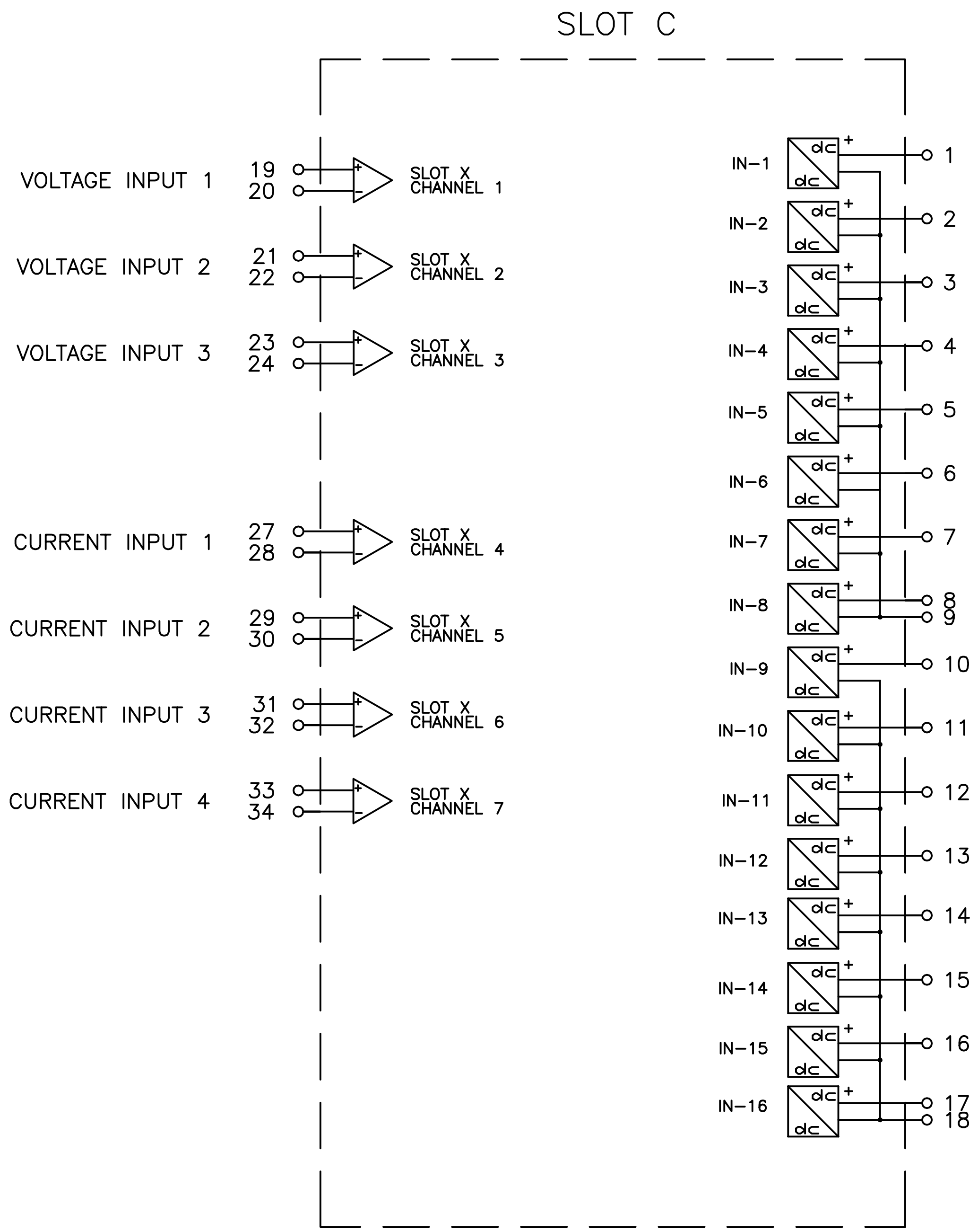

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SLOT	A	B	C	D	E	F
			X			
MODEL	#	#	#	#	#	3

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Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS CPU
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PROYECTO / *PROJECT:* TCM/2TCA-E/SMART RTU

Rev.0

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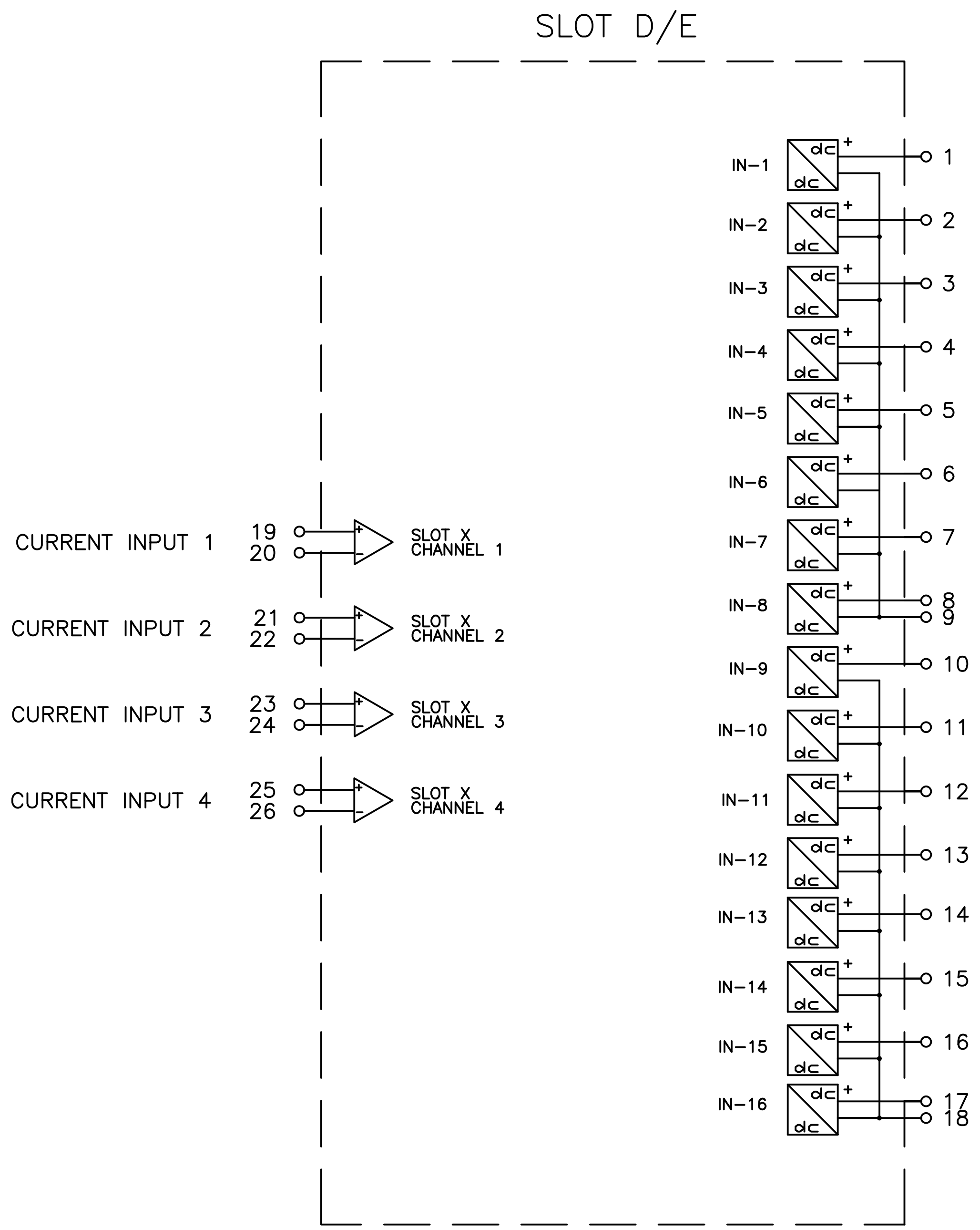

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SLOT	A	B	C	D	E	F
				X	X	
MODEL	#	#	#	#	#	3

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Z I V Aplicaciones y Tecnologia

TITULO: CONEXIONES EXTERNAS CPU
TITLE: CPU EXTERNAL CONNECTIONS

PROYECTO / *PROJECT:* TCM/2TCA-E/SMART RTU

Rev.0
Rev.1 06/07/21

NUM.: 3RX0209/0008

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Aprobado / *Approved*	11/12/20	P.A.

Hoja / *Sheet:* 1

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Chapter 2.

Current Protection Units

2.1 Overcurrent Elements

Overcurrent Protection Elements		
1 x P	Instantaneous Phase Overcurrent	50Fx
1 x P	Instantaneous Neutral Overcurrent	50Nx
1 x P	Time-delayed Phase Overcurrent	51Fx
1 x P	Time-delayed Neutral Overcurrent	51Nx
1 x P	Time-delayed Sensitive Ground Overcurrent	51GSx
1 x P	Ungrounded Directional Overcurrent	67Na

2.1.1 Common Principles

2.1.1.a Operation and Reset

Overcurrent 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.

In case of instantaneous elements, every protection element is provided with a settable output timer, which allows for optional timing of the instantaneous elements whereas in the time elements, the pickup activation enables the time function, which will perform the integration of the measured values. This integration is carried out by applying increments, as a function of the input current, to a counter whose timeout determines the time element operation.

The pickup is reset when the measured value goes down to 1 time the setting value. Drop of the measured RMS value below the pickup setting value results in a quick integrator reset. For output activation, pickup must be active during the entire integration time; any integrator reset brings the integrator back to initial conditions, so that new activations start timing from zero.

2.1.1.b Trip Blocking and Time Delay Disable

Trip Blocking inputs can be programmed into time and instantaneous overcurrent elements, which disable element trip if input is activated before trip is generated. If input is activated after tripping, trip is reset. Even if the element is blocked, it remains operative such that if the relay is under trip conditions when the blocking input is deactivated, the relay will issue a trip command instantaneously. Trip blocking inputs must be programmed before this blocking logic can be used.

Another programmable input exists that can turn a given time overcurrent element into instantaneous. Said input is called **Timer Disable** and is available for all time-delayed elements.

2.1.1.c Element Enable and Disable

Relays are provided with an enable and disable input such that, the element being enabled by protection setting, it can be disabled through the logic under given circumstances. In this way, when the enable input is deactivated, the element is not operative and the element begins to operate from zero when the enable input is activated.

2.1.1.d Harmonics Blocking

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

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

In order to prevent overcurrent elements from operating upon said magnetizing currents, overcurrent elements include the **Second Harmonic Blocking** function.

Parameters / Lx / DPF &AF / Restrictions per second harmonic in overcurrent units				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Phase Overcurrent Units (FSAIF)(%)	PHAR.Str1	0 - 200 %	5 %	20 %
Neutral Overcurrent Units (FSAIN)(%)	PHAR.Str2	0 - 200 %	5 %	20 %

Unmodifiable setting: Hysteresis set to 1%.

2.1.1.e Torque Control (Pickup Blocking Enable)

Torque Control setting, or ***Pickup Blocking Enable***, is associated to Directional Element, enabling or disabling the directional control.

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.

2.1.1.f Time-Delayed Curves

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

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

However, the effective range for **IEC** curves is 0.05 to 1. Effective range for **IEEE** 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).

If the ***Fixed Time*** setting is so small that the curve is not crossed, the relay will operate as if the characteristic curve were normal and not a **Time Limit** curve.

Curve types with **Time Limit** are regular time delayed functions with a time threshold, so that no trip takes place before the specified time. This results in that beyond a specified time the tripping curve turns into a horizontal straight line. This operate time limit coincides with the time setting used in the ***Fixed Time*** option. Three different operating ways can result as a function of the curve selected and the ***Fixed Time*** setting.

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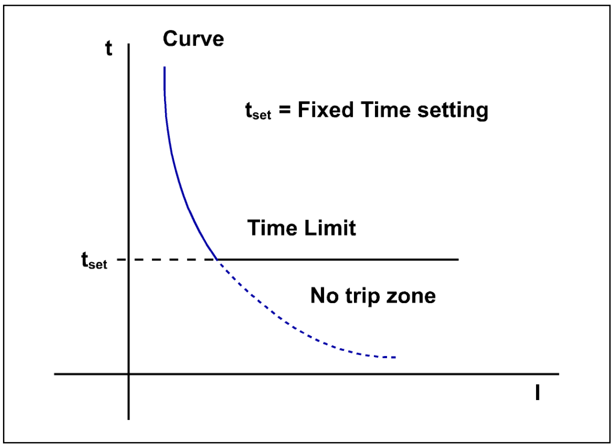


Figure 2.1.1 Time Limit Curve for a Time Overcurrent Element.

It may be that the ***Fixed Time*** setting value is excessive with reference to the curve times for the different indicators, such that the relay may never trip. If this should be the case, if curve time (for the dial setting and a current 1.5 times greater than the setting) is less than the ***Fixed Time*** setting, a time delay corresponding to 1.5 times the current is used as a limit line for element operation.

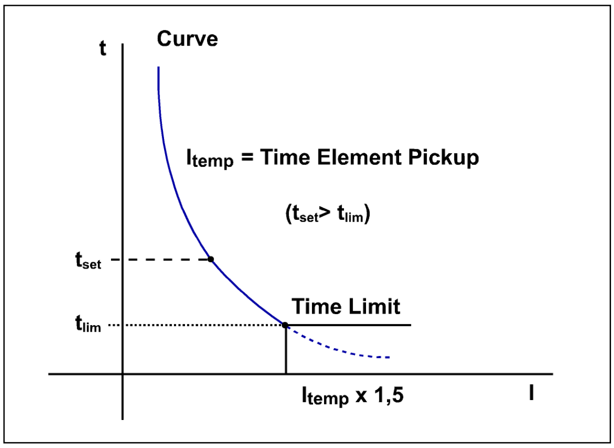


Figure 2.1.2 Diagram of a Curve with Time Limit in case of Fixed Time greater than Curve Time (in Pick-up x 1.5).

Note: It is important to note that, although the curves are defined for an input value of up to 20 times the tap, which is the adjusted pick-up value in each of the time-delayed units, it is not always possible to guarantee this range.

Bear in mind that current channel saturation limits are 3000 A for phases, neutral and sensitive neutral and 60 A for isolated ground. Based on these limits, the "times the tap" for which curves are effective is a function of the setting:

If $\frac{Saturation\ Limit}{Element\ Setting} > 20$ **, curve operation is guaranteed for elements with said setting over the entire tap range (up to 20 times the setting).**

If $\frac{Saturation\ Limit}{Element\ setting} < 20$ **, 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 Neutral element set to 2A, curves will be effective up to** $\frac{3000}{600} = 5$ **times the setting.**

If the current at said Neutral exceeds 3000A, the relay measures said 3000A and trip time corresponds to 5 times the tap. When a current above 20 times the setting is injected, trip time will be the same as for said 20 times.

- **Current / Time Curve: Inverse Functions**

Figures 2.1.3, 2.1.4, 2.1.6, 2.1.6 and 2.1.7 present the inverse curves according to the IEC standards.

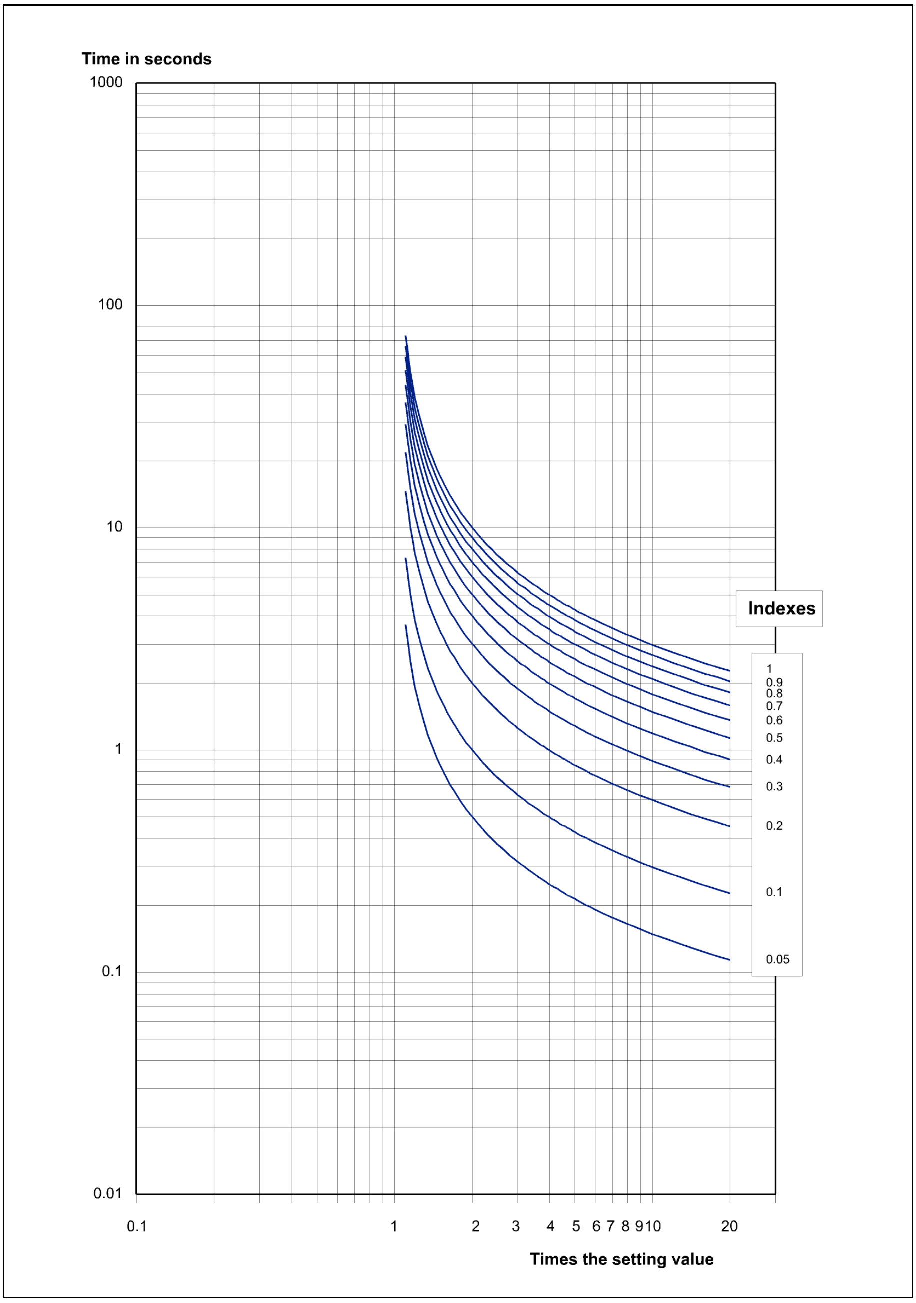


Figure 2.1.3 INVERSE Time Curve (IEC).

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

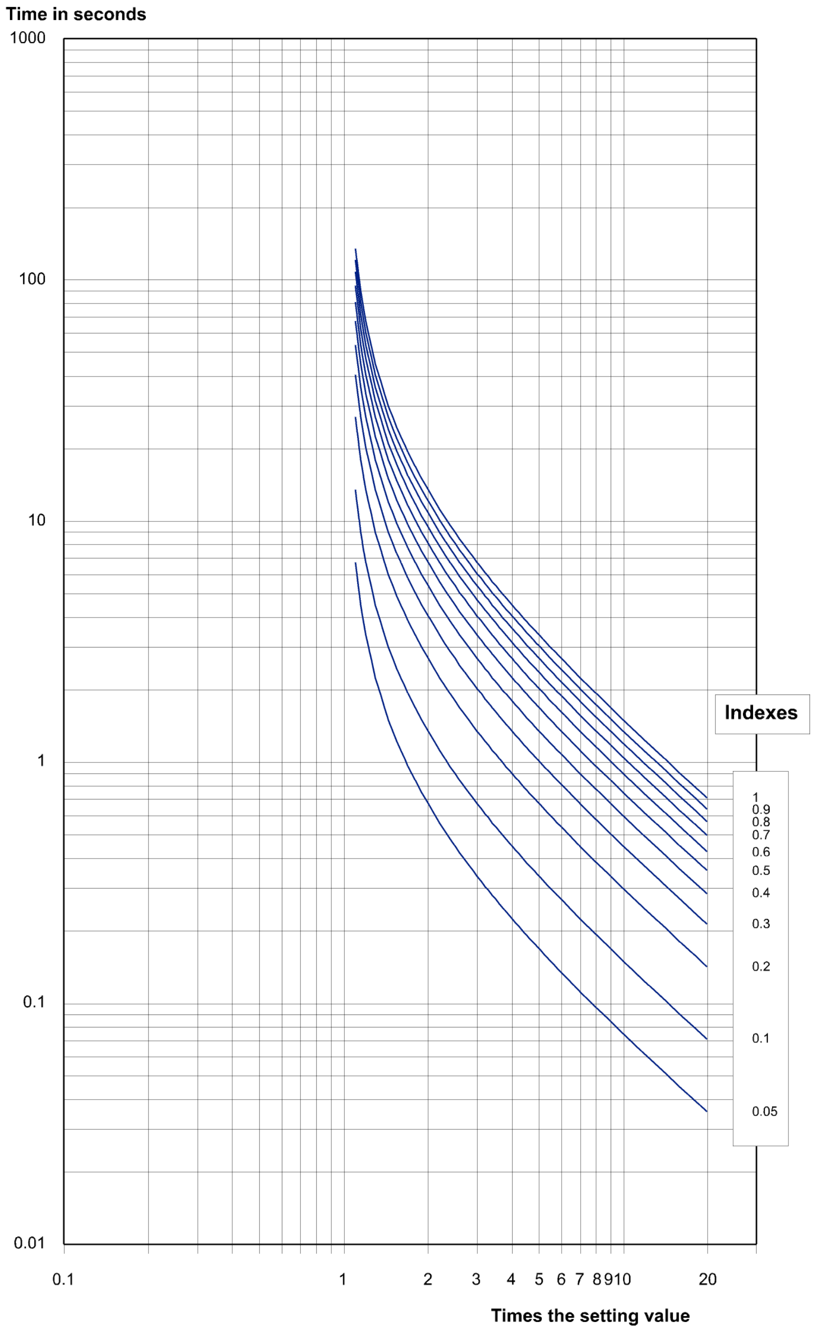


Figure 2.1.4 VERY INVERSE Time Curve (IEC).

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

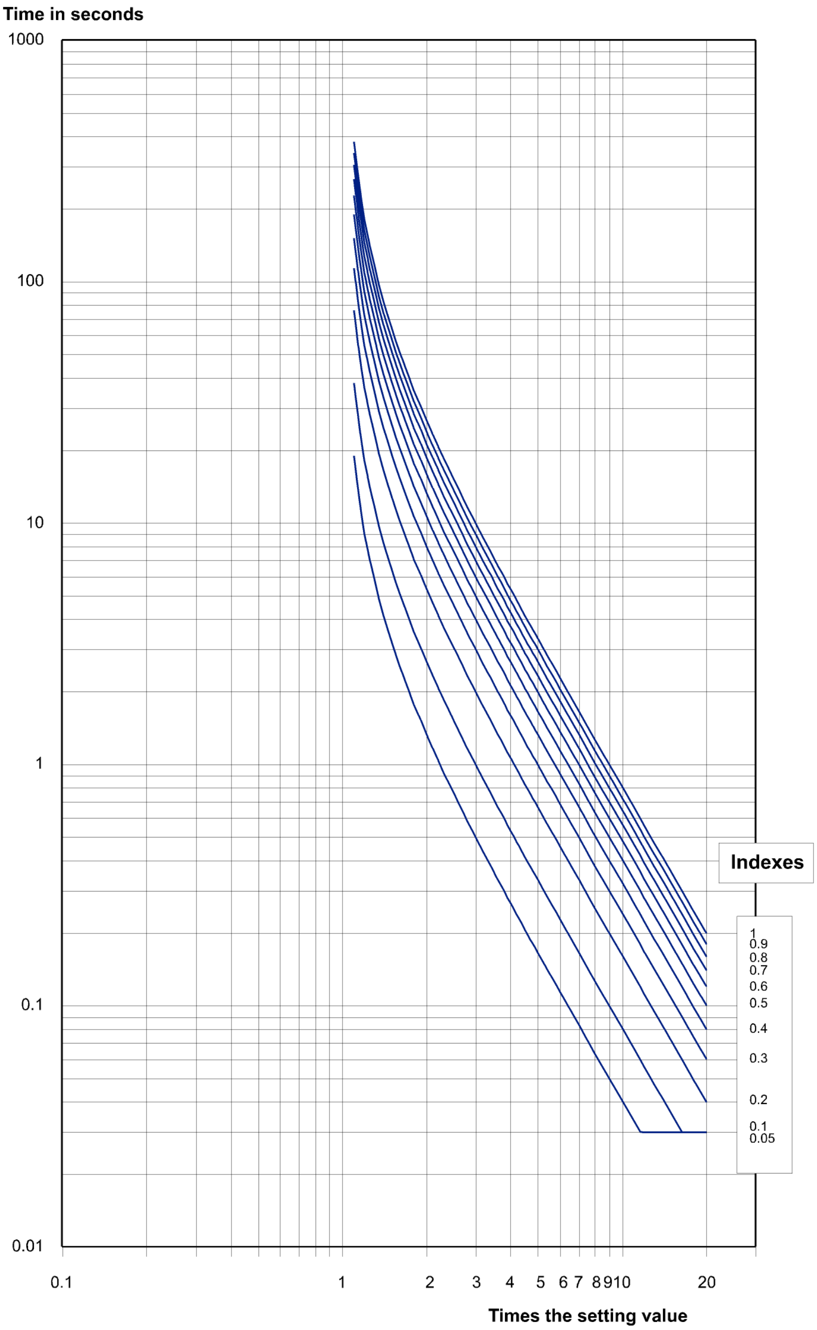


Figure 2.1.5 EXTREMELY INVERSE Time Curve (IEC).

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

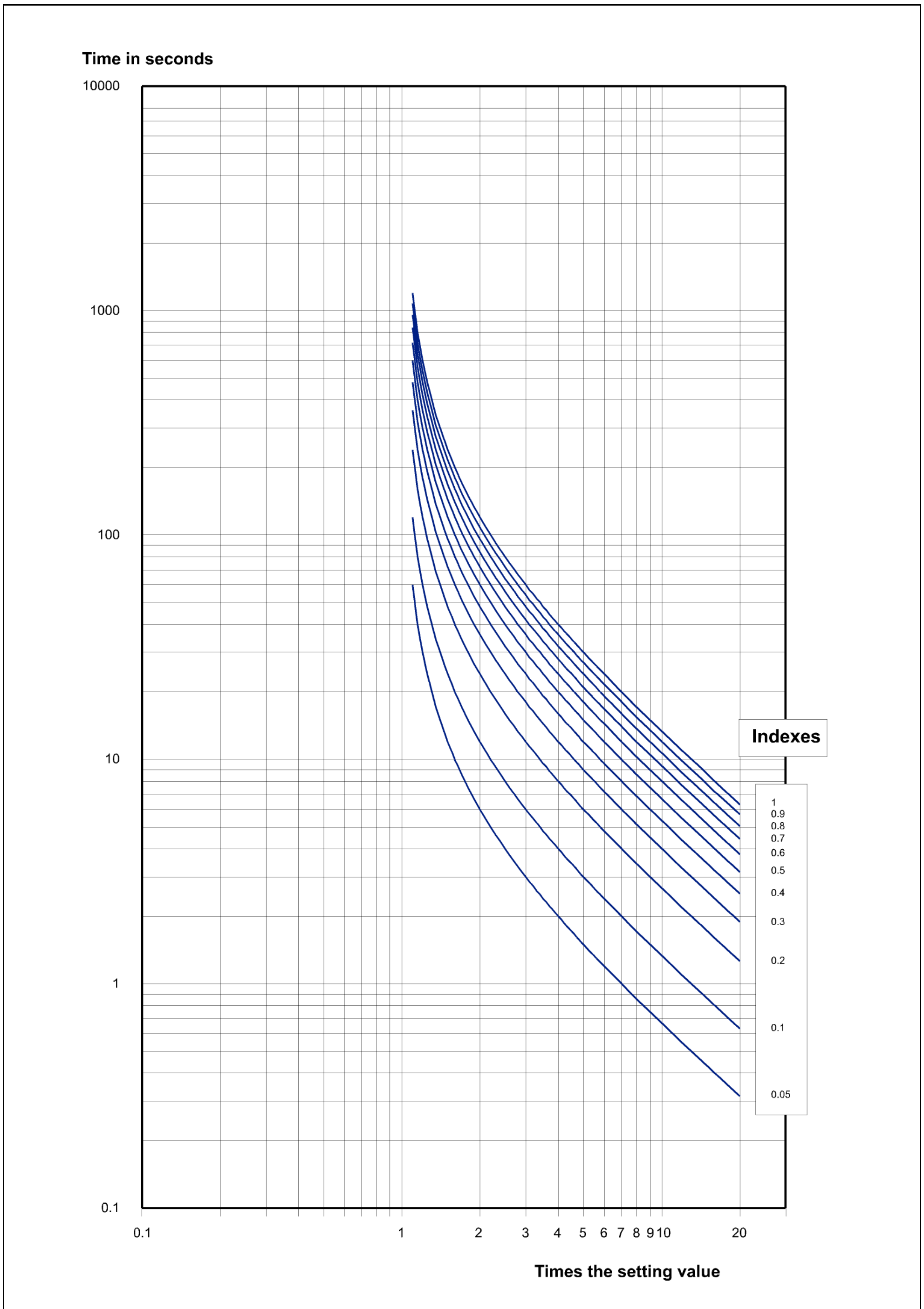


Figure 2.1.6 LONG TIME-INVERSE Curve (IEC).

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

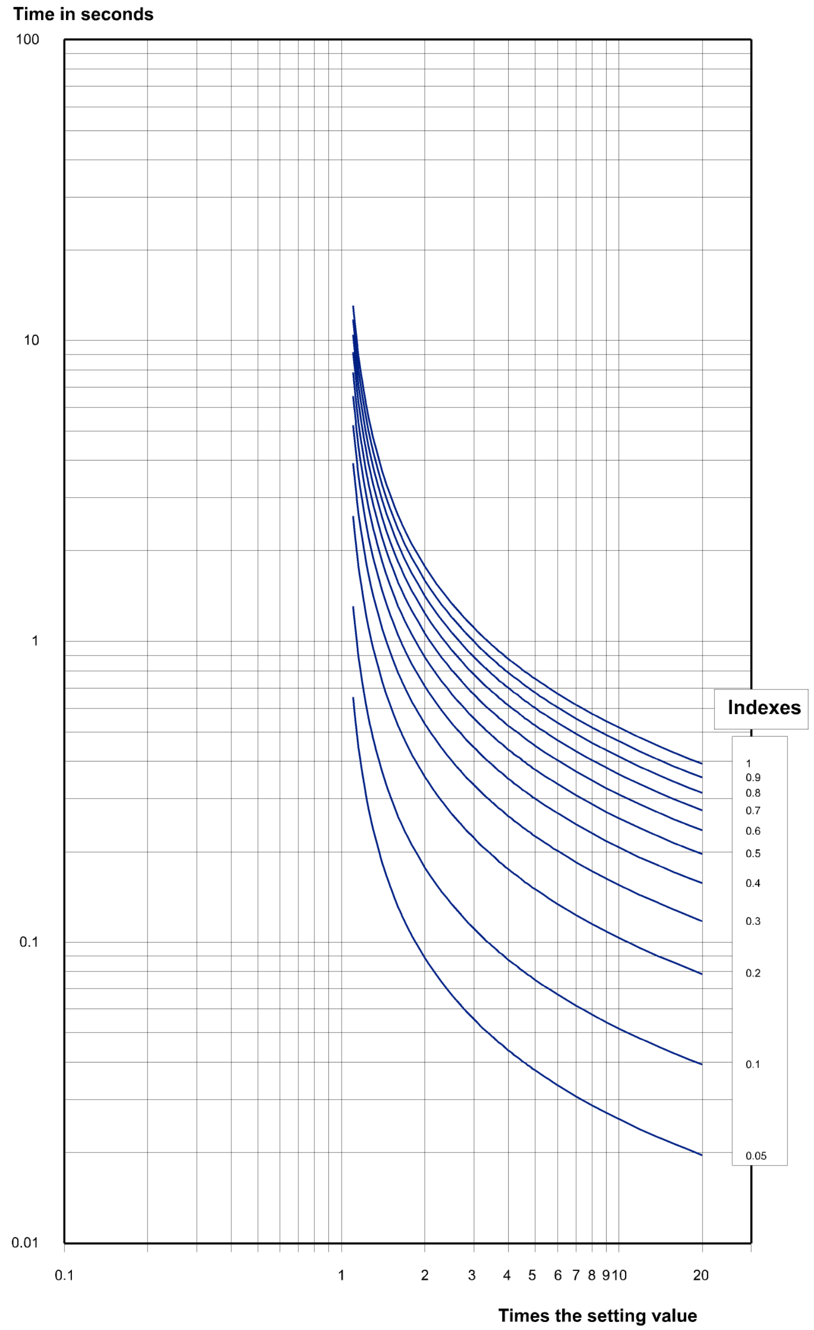


Figure 2.1.7 SHORT TIME-INVERSE Curve (IEC).

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

Figures 2.1.8, 2.1.9 y 2.1.10 present the inverse curves according to the **IEEE** Standards.

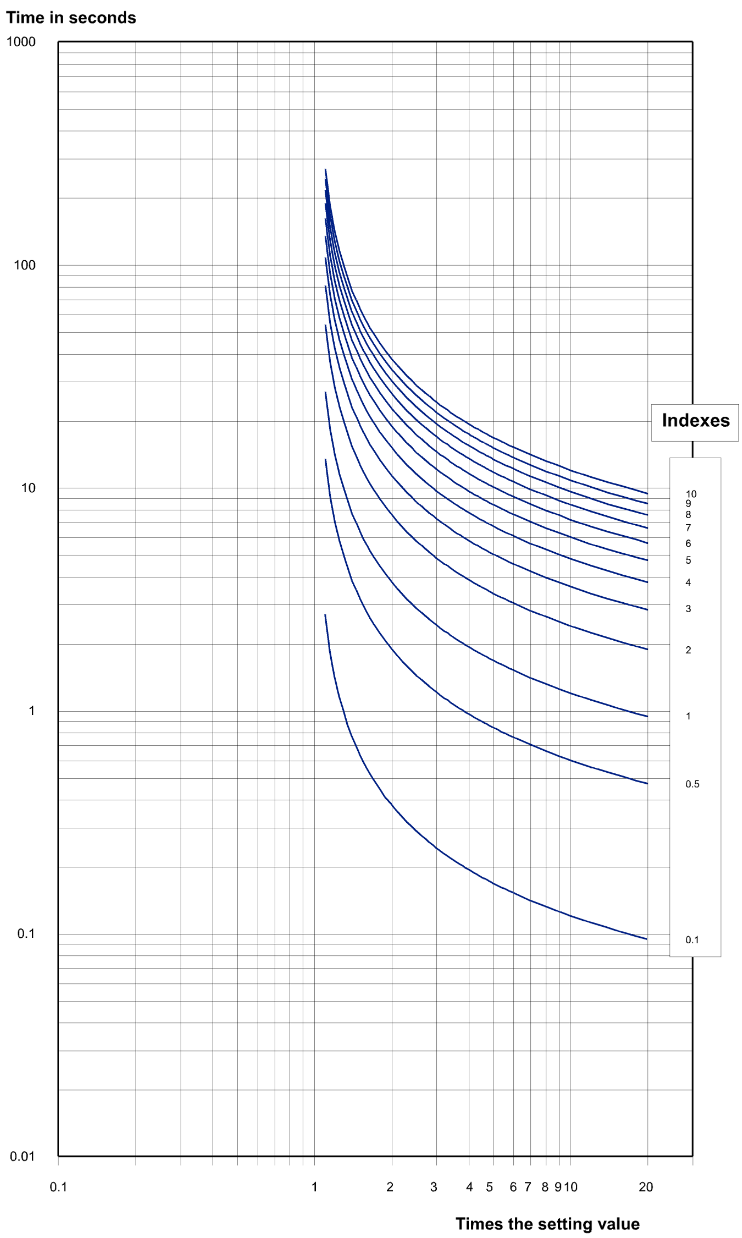


Figure 2.1.8 MODERATELY INVERSE Time Curve (IEEE).

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

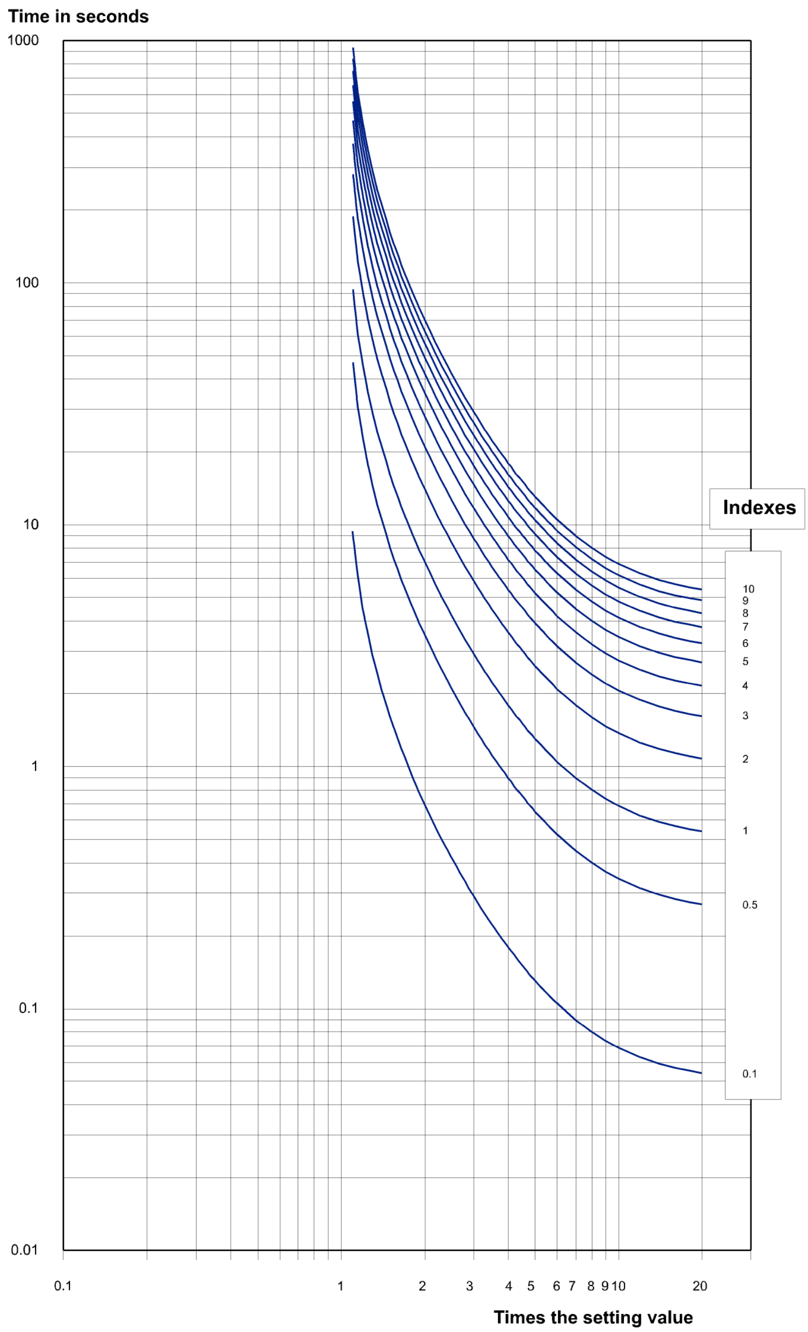


Figure 2.1.9 VERY INVERSE Time Curve (IEEE).

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

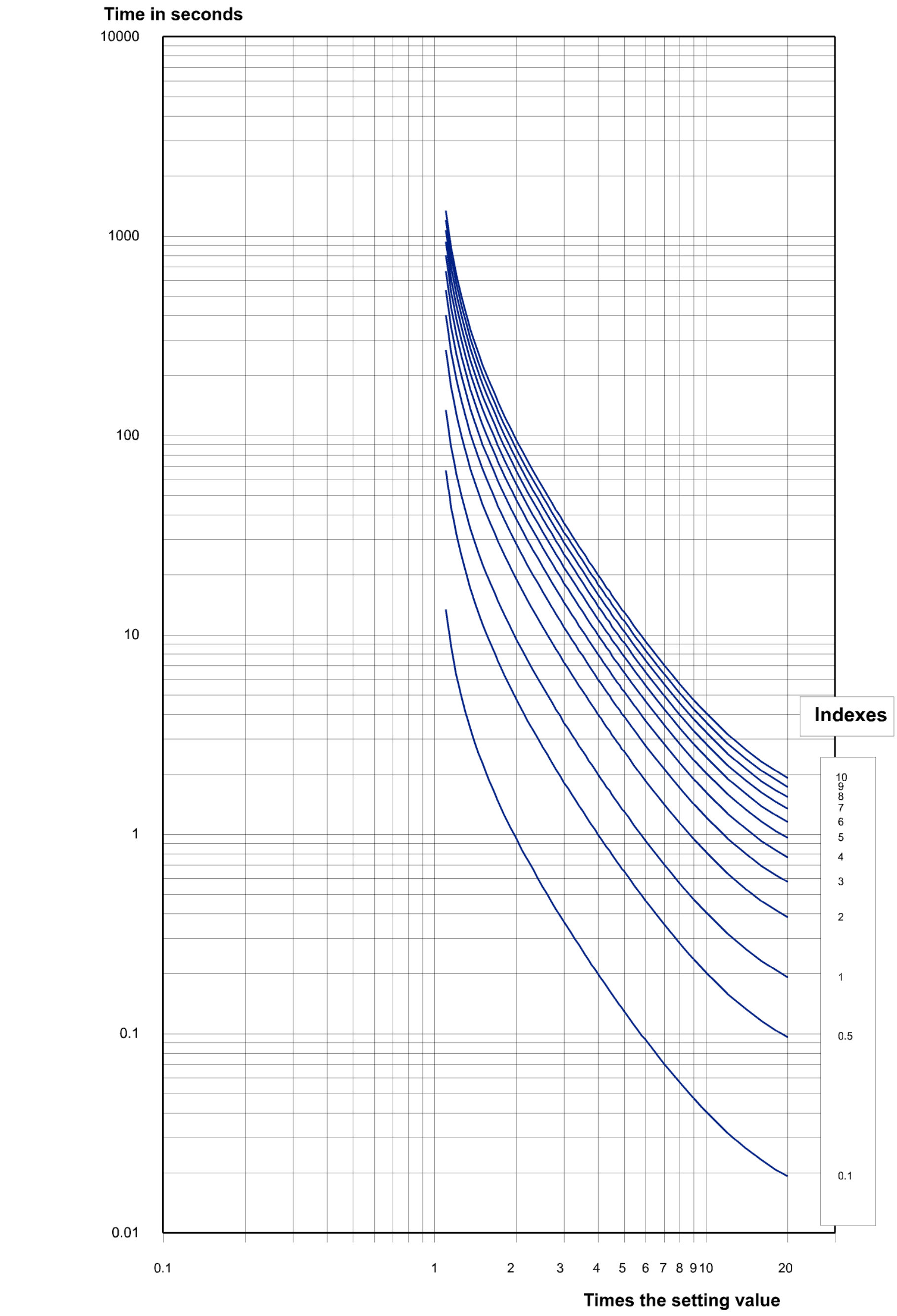


Figure 2.1.10 EXTREMELY INVERSE Time Curve (IEEE).

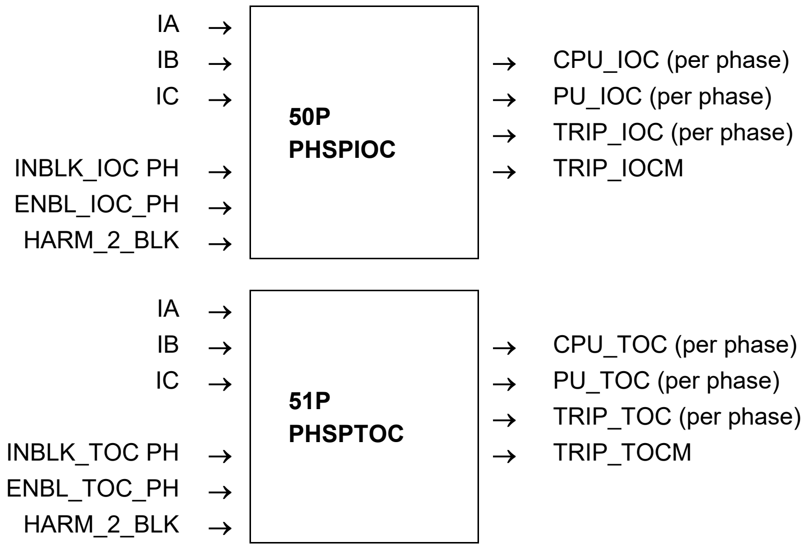
$t = \left(0.1217 + \frac{28.2}{I_S^2 - 1}\right)$ x Index	$I_S = \frac{I_{measured}}{I_{pickup}}$

2.1.2 Phase Overcurrent Elements

2.1.2.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Instantaneous Phase Overcurrent Element	PHSPIOCx	3I>>	50Px

2.1.2.b General Block



2.1.2.c Operation Principles and Block Diagram

The phase element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The current value of any phase exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section.

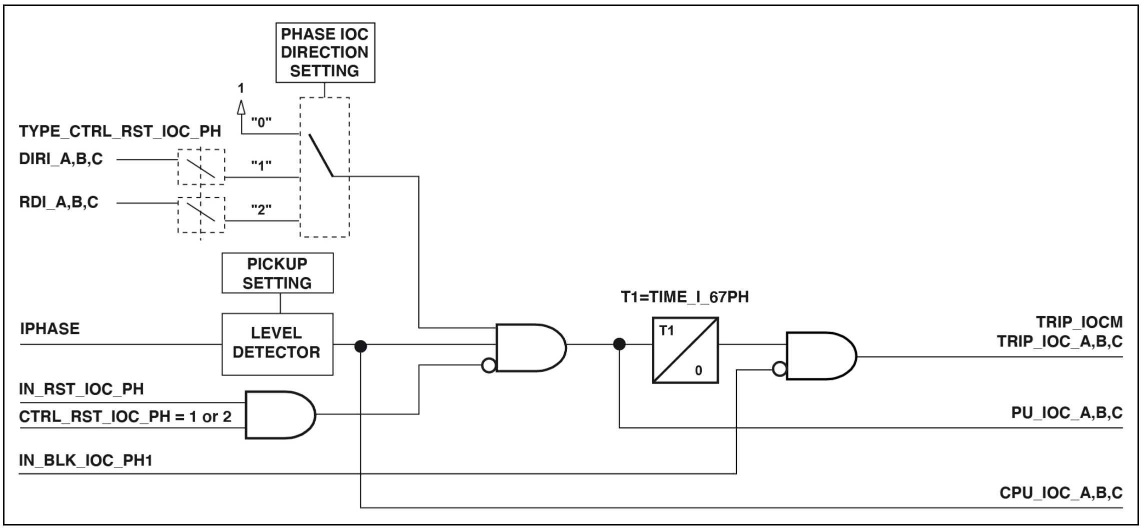


Figure 2.1.11 Block Diagram of a Phase Instantaneous Overcurrent Element.

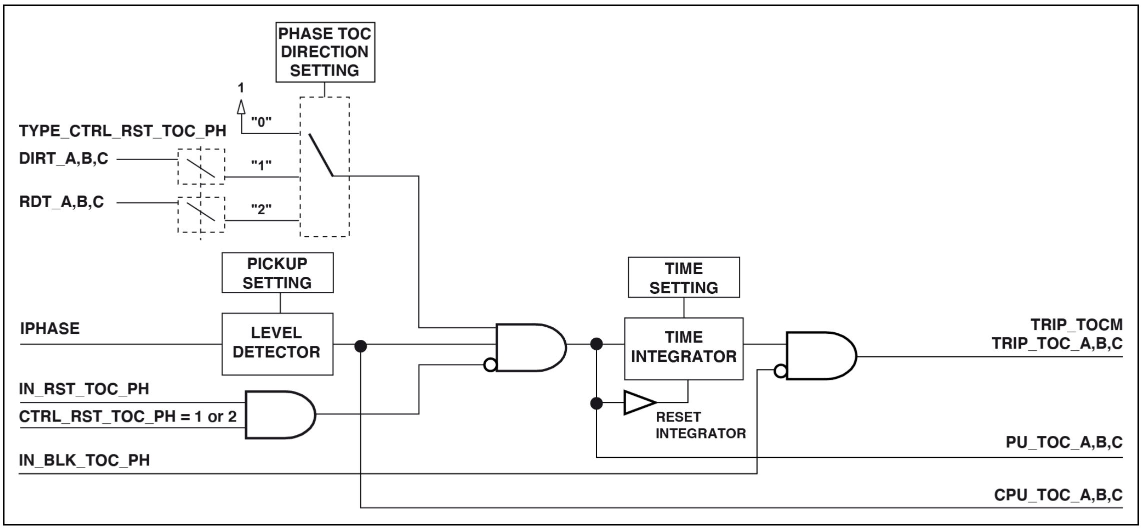


Figure 2.1.12 Block Diagram of a Phase Time-Delayed Overcurrent Element.

2.1.2.d Application

The phase overcurrent element is in charge of detecting fault currents flowing between two or more phases in three phase power systems. The fault current can flow between the conductors or between the conductors and ground, therefore, phase to phase, phase to ground and three phase faults can be detected, phase to phase faults being typically more severe.

An example of a fault detected by the phase overcurrent element could be the contact between two or more conductors due to a branch falling on a line.

The time set overcurrent element is of common use as backup for transformer differential and distance protections, although it is also used as main element in medium voltage lines and specific applications to detect close onto fault or in ring systems, among many others.

In parallel transformers and busbar coupling systems, the instantaneous overcurrent elements will be applied first with directionality in order to prevent the opening leaving the busbar without power supply upon faults in one of the transformers, the use of non directional elements with higher time delay being possible as backup.

In ring systems, as for airports or underground secondary substations, the current can flow in any direction so that directional elements are used to detect faults between bays.

2.1.2.e Example of Settings Calculation

For pickup current and trip time setting calculation of the instantaneous overcurrent element, the standard short circuit calculation principles should be taken into account. The example below shows a typical calculation.

Starting values:

- CT: 1500/5.
- Load current: 1470 A.
- Lowest protection downstream: 400 A.

Relay settings must take into account both the load current and the reset current, such that it operates only upon real faults. As the element picks up at 1.05 times the pickup setting, this being exactly the minimum fault current value, the element will be set directly with this value, referred to the secondary, as both the protection element and the settings are referred to the secondary. Therefore, the pickup setting value must a minimum of 4.9 A.

When the relay is to be coordinated with other protections, their trip times must match as much as possible, setting a proper definite time for each case.

2.1.2.f Setting Ranges

Parameters / Lx / DPF &AF / Phase Instantaneous				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Phase IOC Enable	PHSPIOC.LNInSvc	YES / NO		NO
Phase IOC Pickup	PHSPIOC.StrVal	10 - 3000 A	0.1 A	100.0 A
Phase IOC Delay	PHSPIOC.OpDlTmms	0 - 300 s	0.01 s	0 s

Parameters / Lx / DPF &AF / Phase Time Overcurrent				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Phase TOC Enable	PHSPTOC.LNInSvc	YES / NO		NO
Phase TOC Pickup	PHSPTOC.StrVal	10 - 3000 A	0.1 A	100.0 A
Phase TOC Curve	PHSPTOC.TmACrv	See list of curves		Fixed Time
Phase TOC Dial	PHSPTOC.TmMult	0.1-10 (IEEE)	0.01	1
		0.05 - 1 (IEC)	0.01	1
Phase TOC Curve	PHSPTOC.OpDlTmms	0.05 - 300 s	0.01 s	0.05 s

Fixed Settings in the Firmware

Parameters / Lx / DPF &AF / Phase Instantaneous		
Web Server	**IEC 61850**	**Value**
Phase IOC Direction	PHSPIOC.DirMod	NO

Parameters / Lx / DPF &AF / Phase Time Overcurrent		
Web Server	**IEC 61850**	**Value**
Phase IOC Direction	PHSPIOC.DirMod	NO

2.1.2.g Analog Inputs to the Unit

The operating magnitude of phase overcurrent elements will be the fundamental current IA, IB and IC. However, the relay will take into account the presence of harmonics, the relay being blocked when harmonic percentage exceeds the setting value.

Table 2.1-1: Analog Inputs of the Overcurrent Modules

Name	Description	IEC 61850
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC

2.1.2.h Digital Inputs to the Phase Overcurrent Unit

Table 2.1-2: Digital Inputs to the Phase Overcurrent Modules

Name	Group	IEC 61850	Description	Vis.	Function
IN_BLK_IOC_PHx	Logic Inputs to Protection	PHSPIOCx.Mod	Block Phase Instantaneous Unit x		Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_RST_IOC_PHx	Logic Inputs to Protection	PHSPIOCx.DirInh	Disable Torque Control Phase Instantaneous Unit x		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_PHx	Logic Inputs to Protection	PHSPTOCx.DirInh	Disable Torque Control Time Overcurrent Unit x		
ENBL_IOC_PHx	Enabling Commands	PHSPIOCx.Mod	Enable Phase Instantaneous Unit x		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."
IN_BPT_PH1	Logic Inputs to Protection	PHSPTOC1.OpDlInh	Phase Time Overcurrent Unit x Time Disable		It converts the set timing sequence of a given element to instantaneous.

2.1.2.i Auxiliary Outputs and Events of the Phase Overcurrent Modules

Table 2.1-3: Auxiliary Outputs and Events of the Phase Overcurrent Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_IOC_Ax	Pickup Protection Outputs	PHSPIOC1.Str	Phase A Instantaneous Unit x Pick Up		AND logic of the pickup of the current elements with the corresponding torque control input.
PU_IOC_Bx		PHSPIOC1.Str	Phase B Instantaneous Unit x Pick Up		
PU_IOC_Cx		PHSPIOC1.Str	Phase C Instantaneous Unit x Pick Up		
PU_TOC_Ax		PHSPTOC1.Str	Phase A Time Overcurrent Unit x Pick Up		
PU_TOC_Bx		PHSPTOC1.Str	Phase B Time Overcurrent Unit x Pick Up		
PU_TOC_Cx		PHSPTOC1.Str	Phase C Time Overcurrent Unit x Pick Up		
CPU_IOC_Ax		PHSPIOCx.Str	Phase A Instantaneous Unit x Pick Up Condition		Pickup of the current elements, unaffected by the torque control.
CPU_IOC_Bx		PHSPIOCx.Str	Phase B Instantaneous Unit x Pick Up Condition		
CPU_IOC_Cx		PHSPTOCx.Str	Phase C Instantaneous Unit x Pick Up Condition		
CPU_TOC_Ax		PHSPTOCx.Str	Phase A Time Overcurrent Unit x Pick Up Condition		
CPU_TOC_Bx		PHSPTOCx.Str	Phase B Time Overcurrent Unit x Pick Up Condition		
CPU_TOC_Cx		PHSPTOCx.Str	Phase C Time Overcurrent Unit x Pick Up Condition		
TRIP_IOC_Ax	Trip Protection Outputs	PHSPIOC1.Op	Phase A Instantaneous Unit x Trip		Trip of the current elements.
TRIP_IOC_Bx		PHSPIOC1.Op	Phase B Instantaneous Unit x Trip		
TRIP_IOC_Cx		PHSPIOC1.Op	Phase C Instantaneous Unit x Trip		
TRIP_TOC_Ax		PHSPTOC1.Op	Phase A Time Overcurrent Unit x Trip		
TRIP_TOC_Bx		PHSPTOC1.Op	Phase B Time Overcurrent Unit x Trip		
TRIP_TOC_Cx		PHSPTOC1.Op	Phase C Time Overcurrent Unit x Trip		
TRIP_IOC_x		PTRC1.Op	Instantaneous Unit x Trip		Trip of the grouped phase elements
TRIP_TOC_x		PTRC1.Op	Time Overcurrent Unit x Trip		

2.1.2.j IEC 61850 Logical Nodes

CLASS PHSPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirInh	EXT_SPC	Directional mode inhibition command
HBlkVal	EXT_ASG	Harmonic blocking value

CLASS PHSPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirInh	EXT_SPC	Directional mode inhibition command
HBlkVal	EXT_ASG	Harmonic blocking value

2.1.2.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end.

Table 2.1-4: Pickup and Reset of the Instantaneous Overcurrent Elements

Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.02 **x** X / RTTC	1.03 **x** X / RTTC	0.97 **x** X / RTTC	1.02 **x** X / RTTC

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

"RTTC" is the Transformer Ratio of Current Transformers, since the setting is made in primary current and the current injection is made in secondary current.

- **Operating Times**

Definite or Instantaneous Time

A current 20% above the selected pickup setting value shall be applied. Operating time should 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**

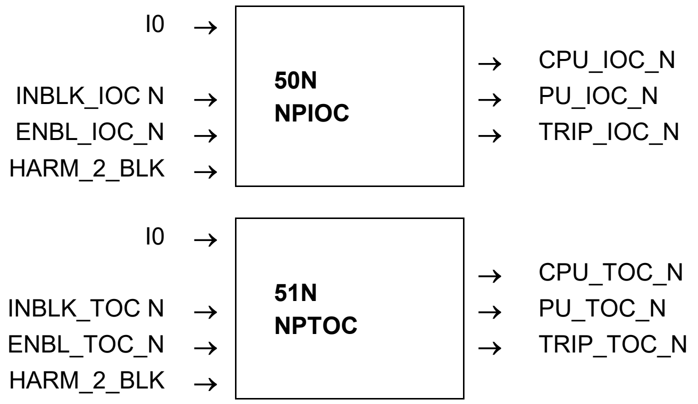
For a given curve, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

2.1.3 Neutral Overcurrent Element

2.1.3.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Neutral Instantaneous Overcurrent Unit x	NPIOCx	3Io>>	50Nx
Neutral Time-Delayed Overcurrent Unit X	NPTOCx	3Io>	51Nx

2.1.3.b General Block



2.1.3.c Operation Principles and Block Diagram

The neutral element pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The current value of neutral exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream.

The instantaneous element will be reset when the current value drops to 1 time the setting value and will operate in accordance with the blocking, enable, harmonics, saturation and direction signals explained in **Common Principles** section. Meanwhile, the time element will be reset either at 1 time the setting value or using a reset curve adequate to the trip characteristic used as a function of the ***Reset Type*** setting as has been explained in **Common Principles** section.

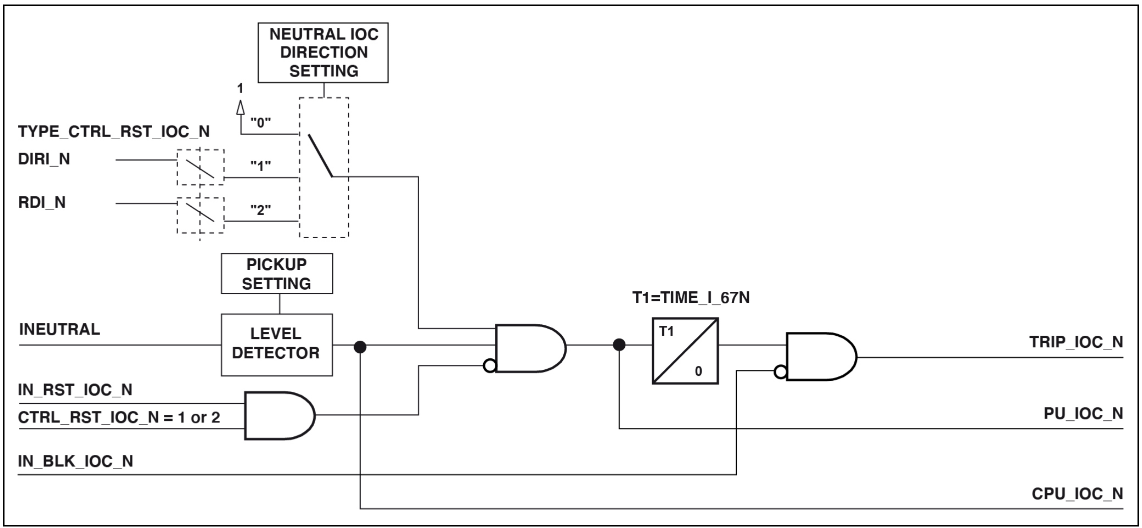


Figure 2.1.13 Block Diagram of a Neutral Instantaneous Overcurrent Element.

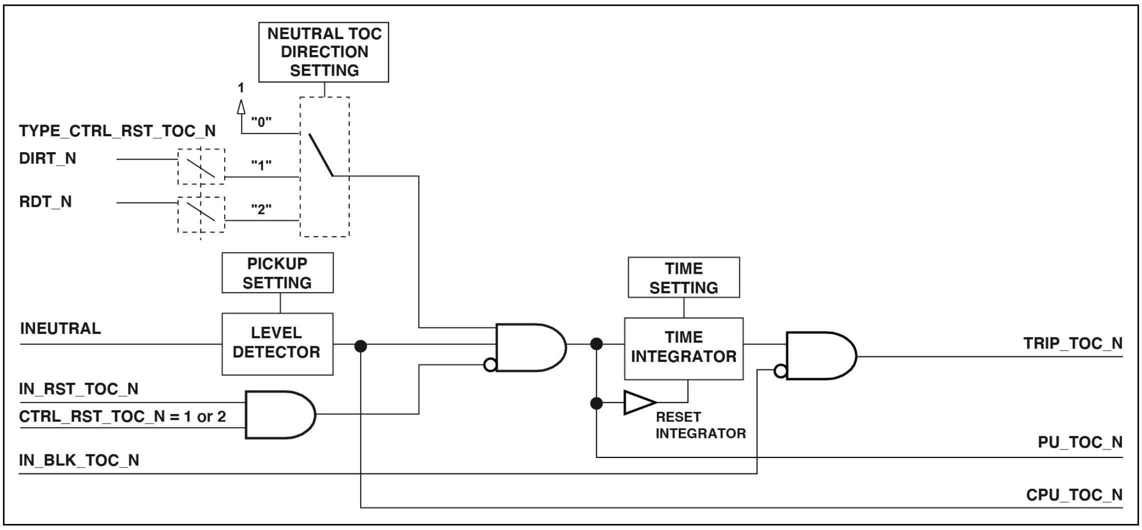


Figure 2.1.14 Block Diagram of a Neutral Time-Delayed Overcurrent Element.

2.1.3.d Application

Fault currents flowing to ground are detected by the neutral overcurrent element.

The neutral overcurrent element detects ground faults through the current calculated from the sum of phase currents, namely, it does not use a magnitude directly read by a measurement transformer as is the case for ground elements.

2.1.3.e Examples of Settings Calculation

For a totally balanced system, the residual current detected by the relay in the faulted bay equals the coil current minus the sum of the load currents flowing from the rest of the system. Also, the addition of the two sound phase load currents in each bay provides a total load current of a magnitude three times the phase stationary value. Therefore, for a totally balanced system, the detected unbalanced current equals three times the phase load current of the faulty circuit. In this way, a typical setting can be about 30% of this value, namely, equal to the phase load current of the faulty circuit. In practice, exact settings may be at the site, where system failures can be applied and adequate settings based on actual results can be adopted.

In most cases, the system will not be totally balanced and, thus, a small stable fault current flow is permitted. Therefore, the residual current observed by the IED at the faulty bay can be slightly higher, which implies that its settings must be based on actual current levels where possible.

2.1.3.f Setting Ranges

Parameters / Lx / DPF &AF / Neutral Instantaneous				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Gnd IOC Enable	NPIOC.LNInSvc	YES / NO		NO
Gnd IOC Pickup	NPIOC.StrVal	15 - 2000A	0.1 A	200 A
GND IOC Delay	NPIOC.OpDlTmms	0 - 5 s	0.01 s	0 s

Parameters / Lx / DPF &AF / Ground Time Overcurrent				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Ground TOC Enable	NPTOC.LNInSvc	YES / NO		NO
Ground TOC Pickup	NPTOC.StrVal	10 - 300A	0.01 A	25 A
Ground TOC Curve	NPTOC.TmACrv	See list of curves		Definite Time
Ground TOC Dial	NPTOC.TmMult	0.1-10 (IEEE)	0.01	1
		0.05 - 1 (IEC)	0.01	1
Ground TOC Dial	NPTOC.OpDlTmms	0 - 600 s	0.01 s	0 s

Fixed Settings in the Firmware

Parameters / Lx / DPF &AF / Neutral Instantaneous		
Web Server	**IEC 61850**	**Value**
Neutr IOC Direction	NPIOC.DirMod	NO

Parameters / Lx / DPF &AF / Neutral Instantaneous		
Web Server	**IEC 61850**	**Value**
Neutr IOC Direction	NPTOC.DirMod	NO

2.1.3.g Analog Inputs to the Unit

The operating magnitude of neutral overcurrent elements will be the sum of the fundamental currents IA, IB and IC. However, the relay will take into account the presence of harmonics, the relay being blocked when harmonic percentage exceeds the setting value.

Table 2.1-5: Analog Inputs to the Overcurrent Module		
Name	**Description**	**IEC 61850**
IN	Neutral calculated current	MMXU1.A.res

$$\bar{I}_N = \bar{I}_A + \bar{I}_B + \bar{I}_C$$

2.1.3.h Digital Inputs to the Neutral Overcurrent Element

Table 2.1-6: Digital Inputs to the Neutral Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_IOC_Nx	Logic Inputs to Protection	NPIOCx.Mod	Block Neutr Instantaneous Unit x		Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_BLK_TOC_Nx		NPTOC1.Mod	Block Neutr Time Overcurrent Unit 1		
IN_RST_IOC_Nx		NPIOCx.DirInh	Disable Torque Control Neutr Instantaneous Unit x		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_Nx		NPTOC1.DirInh	Disable Torque Control Neutr Time Overcurrent Unit 1		
IN_BPT_Nx		NPTOCx.OpDlInh	Neutr Time Overcurrent Unit x Time Disable		It converts the set timing sequence of a given element to instantaneous.
ENBL_IOC_Nx		NPIOCx.Mod	Enable Neutr Instantaneous Unit x		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_Nx		NPTOCx.Mod	Enable Ground Time Overcurrent Unit 1		

2.1.3.i Auxiliary Outputs and Events of the Neutral Overcurrent Modules

Table 2.1-7: Auxiliary Outputs of the Neutral Overcurrent Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_IOC_Nx	Pickup Protection Outputs	NPIOCx.Str	Neutr Instantaneous Unit x Pick Up		AND logic of the pickup of the current elements with the corresponding torque control input.
PU_TOC_Nx		NPTOCx.Str	Neutr Time Overcurrent Unit x Pick Up		
CPU_IOC_Nx		NPIOCx.Str	Neutr Instantaneous Unit x Pick Up Condition		Pickup of the current elements, unaffected by the torque control.
CPU_TOC_Nx		NPTOCx.Str	Neutr Time Overcurrent Unit x Pick Up Condition		
TRIP_IOC_Nx	Trip Protection Outputs	NPIOCx.Op	Neutr Instantaneous Unit x Trip		Trip of the current elements.
TRIP_TOC_Nx		NPTOCx.Op	Neutr Time Overcurrent Unit x Trip		

2.1.3.j IEC 61850 Logical Nodes

CLASS NPIOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirMod	ING_ENUM	Directional mode
DirInh	EXT_SPC	Directional mode inhibition command

CLASS NPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirInh	EXT_SPC	Directional mode inhibition command
HBlkVal	EXT_ASG	Harmonic blocking value

2.1.3.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time. Carry out the injection in one phase only, so that the injected current will be equal to the calculated neutral current.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end.

Table 2.1-8: Pickup and Reset of the Overcurrent Instantaneous Elements

Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X / RTTC	1.02 **x** X / RTTC	1.03 **x** X / RTTC	0.97 **x** X / RTTC

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

"RTTC" is the Transformer Ratio of Current Transformers, since the setting is made in primary current and the current injection is made in secondary current.

- **Operating Times**

Definite or Instantaneous Time

A current 20% above the selected pickup setting value shall be applied. Operating time should 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, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

2.1.4 Sensitive Ground Overcurrent Element

2.1.4.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Sensitive Ground Time-Delayed Overcurrent Unit	GNDSPTOCx	3Io>	51SG

2.1.4.b General Block

2.1.4.c Operation Principles and Block Diagram

The Sensitive Ground Instantaneous elements pickup is conditioned to the compliance with the conditions below:

- The element is enabled by protection setting.
- The sensitive ground current value of exceeds 1.05 times the element pickup setting value.
- If the element is set as directional, the current flow direction is in accordance with the selected setting.
- The blocking input is deactivated (if it is not configured, it is deactivated by default).
- The enable input is enabled (if it is not configured, it is always enabled by default).

Once the element has picked up, the trip can be instantaneous or timed if used is made of the applicable time setting so as to adjust its selectivity taking into account other protections or relays upstream or downstream. The time delayed unit will be reset at 1 time the setting value.

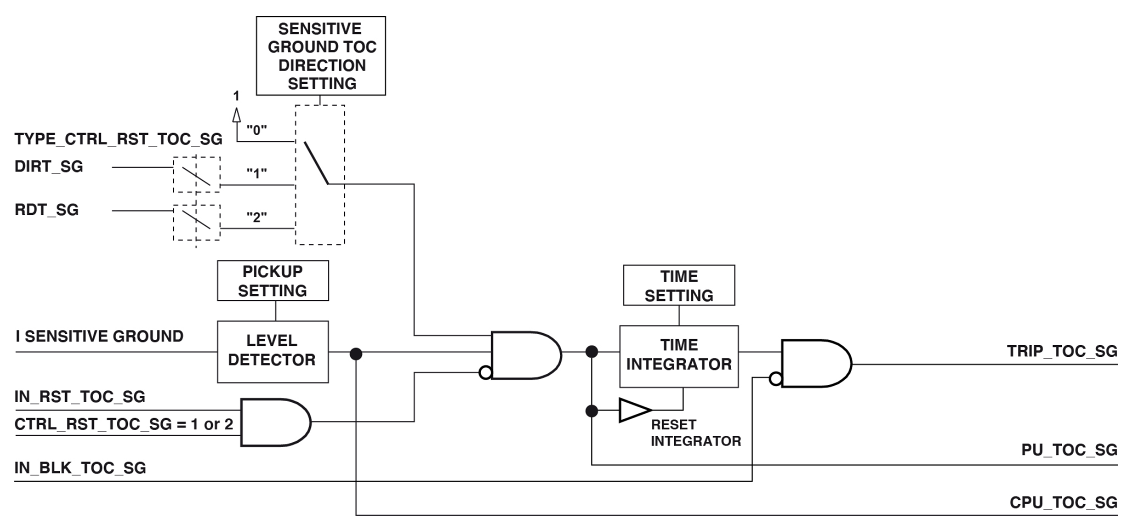


Figure 2.1.15 Block Diagram of a Sensitive Ground Time-Delayed Overcurrent Element.

2.1.4.d Application

The Sensitive Ground Overcurrent element is in charge of detecting fault currents to ground limited either by a resistor or by specific conditions.

Thus, the Sensitive Ground element is used for the protection by means of setting lower than usual. This element will use an operating magnitude coming from more sensitive transformers, normally toroidal transformers, mounted around the three phases, to detect small imbalances.

2.1.4.e Examples of Settings Calculation

As a fault residual current results from the sum of the load currents of the rest of the system and the sum of the sound phases could give a value close to three times the phase current, we could extrapolate that the total residual current equals three times the phase current.

A typical element setting would be around one third of the maximum residual current, although the best setting is based on actual relay readings when mounted on the bay.

2.1.4.f Setting Ranges

Parameters / Lx / DPF &AF / Sensitive Ground Time Overcurrent				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
SG TOC Enable	GNDSPTOC.LNInSvc	YES / NO		NO
SG TOC Pickup	GNDSPTOC.StrVal	0.1 - 30A	0.01 A	1 A
SG TOC Curve	GNDSPTOC.TmACrv	See list of curves		Definite Time
SG TOC Time Dial	GNDSPTOC.TmMult	0.1-10 (IEEE)	0.01	1
		0.05 - 1 (IEC)	0.01	1
SG TOC Time Dial	GNDSPTOC.OpDlTmms	0 - 600 s	0.01 s	0 s

Fixed Settings in the Firmware

Parameters / Lx / DPF &AF / Neutral Instantaneous		
Web Server	**IEC 61850**	**Value**
SG IOC Direction	GNDSPTOC.DirMod	NO

2.1.4.g Analog Inputs to the Unit

The operating magnitude of Sensitive Ground overcurrent elements will be the measured magnitude of the input channel IGS. However, the relay will take into account the presence of harmonics when harmonic blocking is enabled, the relay being blocked when harmonic percentage exceeds the setting value.

Table 2.1-9: Analog Inputs of the Overcurrent Module		
Name	**Description**	**IEC 61850**
IGS	Sensitive Ground Current	MMXU1.A.neut

2.1.4.h Digital Inputs to the Sensitive Ground Overcurrent Element

Table 2.1-10: Digital Inputs to the Sensitive Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
IN_BLK_IOC_SG	Logic Inputs to Protection	GNDSPTOC1.Mod	Block Sensitive Ground Time Overcurrent Unit		Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
IN_RST_IOC_SG	Logic Inputs to Protection	GNDSPTOC1.DirInh	Disable Torque Control Sensitive Ground Time Overcurrent Unit		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_BPT_SG1	Logic Inputs to Protection	GNDSPTOC1.OpDlInh	Sensitive Ground Time Overcurrent Time Disable		It converts the set timing sequence of a given element to instantaneous.
ENBL_IOC_SG	Enabling Commands	GNDSPTOC1.Mod	Enable Sensitive Ground Time Overcurrent Unit		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.”

2.1.4.i Auxiliary Outputs and Events of the Sensitive Ground Overcurrent Modules

Table 2.1-11: Auxiliary Outputs of the Sensitive Ground Overcurrent Modules					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
PU_IOC_SG	Pickup Protection Outputs	GNDSPTOC1.Str	Sensitive Ground Time Overcurrent Unit Pick Up		AND logic of the pickup of the current elements with the corresponding torque control input.
CPU_IOC_SG		GNDSPTOC1.Str	Sensitive Ground Time Overcurrent Unit Pick Up Condition		Pickup of the current elements, unaffected by the torque control.
TRIP_IOC_SG	Trip Protection Outputs	GNDSPTOC1.Op	Sensitive Ground Time Overcurrent Unit Trip		Trip of the current elements.

2.1.4.j IEC 61850 Logical Nodes

CLASS GNDSPTOC		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
TmACrv	CURVEc	Operating Curve characteristic
StrVal	ASG	Start value
TmMult	ASG	Time Dial Multiplier
OpDlTmms	ING	Delay time
DirMod	ING_ENUM	Directional mode
Extended Data		
LNInSvc	EXT_SPG	In service
OpDlInh	EXT_SPC	Operation delay inhibit command
DirInh	EXT_SPC	Directional mode inhibition command
Str	EXT_ACT	Start condition
HBlkEna	EXT_SPG	Harmonic blocking enable
HBlkVal	EXT_ASG	Harmonic blocking value

2.1.4.k Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time.

- **Pickup and Reset**

Set pickup setting values of the corresponding element and check pickup by activating any output configured to this end.

Table 2.1-12: Pickup and Reset of the Overcurrent Instantaneous Elements

Element Setting	Pickup		Reset	
	MAX	MIN	MAX	MIN
X	1.08 **x** X / RTTC	1.02 **x** X / RTTC	1.03 **x** X / RTTC	0.97 **x** X / RTTC

In low ranges pickup and reset interval can be extended up to X ± (5% x In) mA.

"RTTC" is the Transformer Ratio of Current Transformers, since the setting is made in primary current and the current injection is made in secondary current.

- **Operating Times**

Definite or Instantaneous Time

A current 20% above the selected pickup setting value shall be applied. Operating time should 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, operating time will be a function of the selected dial and the applied current (times pickup setting value). Tolerance will be given by the result obtained after applying ±1% offset to current measurement. This will result into ±2% or ±35ms (whichever is greater) offset in time measurement.

2.2 Directional Elements

The IEDs have the following Directional Units for the control of the Overcurrent Units and the detection of the fault direction indicated by the Fault Passage Detector:

Phase Directional Element (67).
Ground Directional Element (67N).
Sensitive Ground Directional Element (67Ns).
Isolated / Compensated Ground Directional Element (67Na).

2.2.1 Common Principles

The mission of the Directional Unit is to determine the direction in which the operating current is flowing in order to control its associated overcurrent element and to detect and indicate the direction of the fault. The direction is determined by comparing its phase with that of a reference value, the phase of which is maintained irrespective of the direction of the flow of the operating current.

Each directional element controls the corresponding overcurrent elements as long as the ***Torque Control*** setting is other than **Zero**. The control over the overcurrent element is carried out inhibiting the operation of the pickup elements in case the current flows in the reverse direction to that selected. If the directional element inhibits the operation of the overcurrent element, the timing function will not start. If the inhibition occurs once the timing has started, it will reset so that the timing will start again from zero if the inhibition disappears. In any case, a trip requires the timing function to be uninterrupted.

If the ***Torque Control*** is equal to **Zero**, the directional control is inhibited and allows the pickup of the overcurrent elements for current flows in both directions: **Direction** and **Reverse Direction**. This setting has no effect on the Fault Passage Detection Unit, which uses the outputs of the Directional Units to calculate the direction of the fault at all times when it is detected.

In all cases, the directional element can enable and block trips in both directions (direction and reverse direction) with the ***Torque Control*** setting (**1** for the direction and **2** for the reverse direction). With **Torque Annulment** input activated, the corresponding directional element is not allowed to pick up.

The **Trip Direction Reversal** input (**IN_INV_TRIP**) changes, if activated, the direction of operation of all the directional elements.

All the directional elements generate direction and reverse direction outputs, instantaneous as well as timed, which exercise directional control over the instantaneous and time overcurrent elements, respectively. The timing of the timed outputs of the directional elements is given by the ***Coordination Time*** setting.

2.2.2 Phase Directional Element

2.2.2.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Phase Directional Overcurrent Unit	PHSRDIR1	3I →	67P

2.2.2.b General Block

IA, IB, IC →	**67P PHSRDIR1**	→ RDI (per phase)
VA, VB, VC →		→ RDT (per phase)
INH_DIR_PH →		→ DIRI (per phase)
IN_INV_TRIP →		→ DIRT (per phase)

2.2.2.c Operation Principles and Block Diagram

There is one directional element per phase. Phase operate magnitude is phase current and polarization magnitude is phase-to-phase voltage corresponding to the other two phases memorized 2 cycles before pickup.

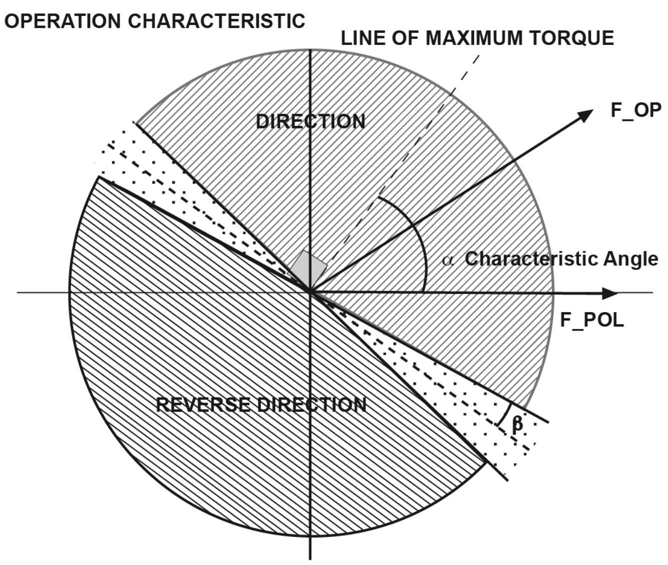


Figure 2.2.1 Vector Diagram of the Phase Directional Element.

Table 2.2-1 shows operation and polarization magnitudes applied to each of three phases.

The aim of directional phase elements is to check whether phase currents and voltages exceed a given value. This value is settable for voltage (**Maximum Voltage** setting) and has 10 A of primary for current. If current or voltage do not exceed the threshold values the **Lack of Polarization Blocking** setting is checked. If set to **NO** proceed as for the case of directional inhibition, but if set to **YES** indicates lack of polarization blocking and trips in both directions are blocked.

Following table shows the operating and polarization values applied to each of the three phases.

Table 2.2-1: Phase Directional Element

ABC Phase Sequence			Criteria
Phase	**Fop**	**Fpol**	
A	I_A	$U_{BCM} = (V_B - V_C)_M$	Direction
B	I_B	$U_{CAM} = (V_C - V_A)_M$	$-(90^o - ANG\_67 - \beta) \leq [\arg(Fop) - \arg(Fpol)] \leq (90^o + ANG\_67 - \beta)$
C	I_C	$U_{ABM} = (V_A - V_B)_M$	
ACB Phase Sequence			
Phase	**Fop**	**Fpol**	Reverse Direction
A	I_A	$U_{CBM} = (V_C - V_B)_M$	$(90^o + ANG\_67 + \beta) \leq [\arg(Fop) - \arg(Fpol)] \leq -(90^o - ANG\_67 + \beta)$
B	I_B	$U_{ACM} = (V_A - V_C)_M$	
C	I_C	$U_{BAM} = (V_B - V_A)_M$	

The operate characteristic, drawn on a polar diagram, is a straight line, the perpendicular of which (maximum torque line) is rotated a given angle counter clockwise, known as phase characteristic angle, with respect to polarization magnitude. Said straight line divides the plane into two half planes. In addition, there is an area, delimited by two straight lines turned at an angle β to one and the other side of the mentioned straight line and called **Dead Zone** in which the directional characteristic is not taken into account due to the inaccuracies that could have the measurement and the capture sensors. It is worth highlighting that said characteristic angle is complementary to the angle of the line positive sequence impedance (see the following application example).

When the directional element is set **Direction**, the overcurrent element is enabled when the above 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). As mentioned above, directional control is made phase after phase.

The logic diagram of operation of the phase directional element is shown in Figure 2.2.2.

The activation of the **Phase Directional Element Inhibition** (**INH_DIR_IN**) input converts the element to **Non-directional**.

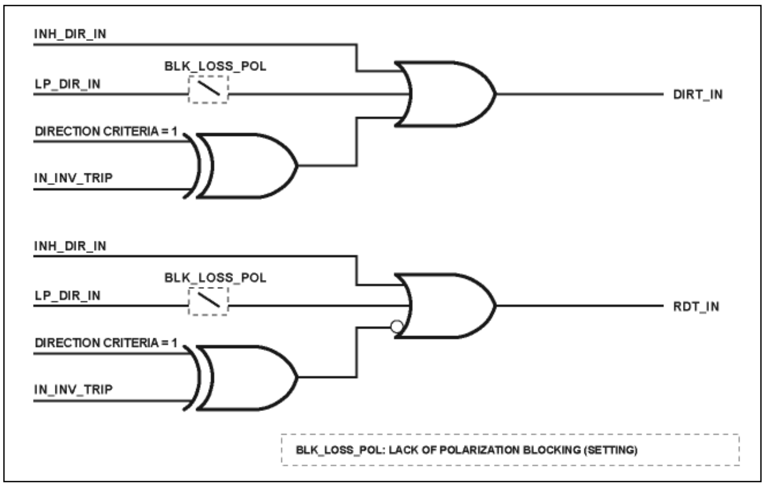


Figure 2.2.2 Block Diagram of a Phase Directional Element.

The **Inversion of the Trip Direction** (**IN_INV_TRIP**) input changes, if activated, the direction of operation of the directional element.

2.2.2.d 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.

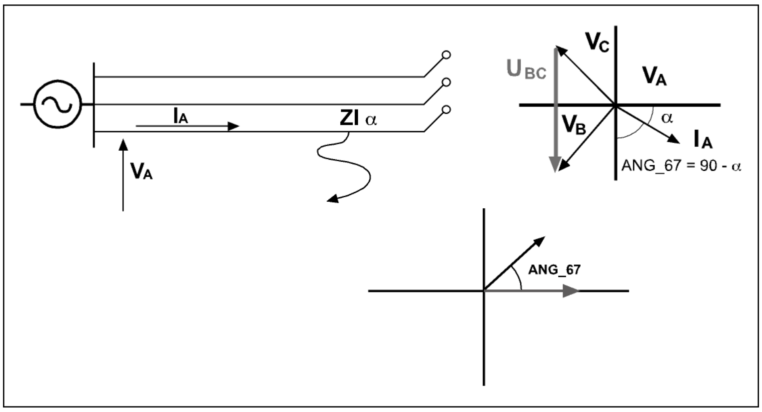


Figure 2.2.3 Graphics for the Application Example.

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 2.2-1).

As shown in the above graphics, for an A-phase to ground fault as described above, the polarization magnitude used by the relay in order to decide tripping or not, is voltage $U_{BC} = V_B - V_C$, with a phase lag of 90º with respect to the phase to neutral voltage of the faulted phase V_A .

As the **Phase Characteristic Angle** (**ANG_67**) set at the relay is the angle between **Operate Magnitude** and **Polarization Magnitude** (see Figure 2.2.1), the value to be assigned is the complementary angle to the “line impedance” angle.

All comments made so far for phase A can be directly extrapolated to phases B and C.

Summarizing, if $\mathbf{Z_{l\theta}}$ is line impedance, phase characteristic angle (**ANG_67**) setting is:

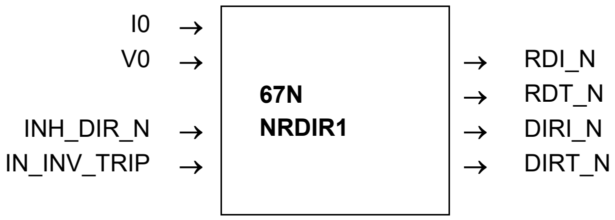
$$\mathbf{ANG\_67 = 90 - \alpha}$$

2.2.3 Neutral Directional Element

2.2.3.a Identification

Description of the protection unit	**IEC 61850 Node**	**IEC 60617**	**ANSI/IEEE C37.2**
Neutral Directional Overcurrent Element	NRDIR1	3Io →	67N

2.2.3.b General Block



2.2.3.c Operation Principles and Block Diagram

Ground and Sensitive Ground Directional element operation is based on zero-sequence magnitudes. Calculated zero-sequence current is taken as operate magnitude. The origin of both polarization and operation magnitudes is as follows:

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

$$\overline{V_0} = \frac{\overline{V_A} + \overline{V_B} + \overline{V_C}}{3}$$

Zero Sequence Current.
The zero sequence current (I0) is calculated from the phase currents as follows:

$$\overline{I_0} = \frac{\overline{I_A} + \overline{I_B} + \overline{I_C}}{3}$$

2.2.3.d Voltage Polarization

In this case Ground Directional Element operating principle rests on finding the angle difference between the zero-sequence current and zero-sequence voltage. Figure 2.2.4 diagrams the elements used to explain how polarization by voltage works

Ground Directional element checks that ground current and voltage exceed a given value.

This value is adjustable for the polarization phasor (***Minimum Neutral Voltage*** setting: since the setting refers to the ground voltage, the zero sequence voltage must exceed the adjusted value divided by three) and **10A** and **4A** in primary values for the ground and sensitive ground currents (operating phasors) respectively.

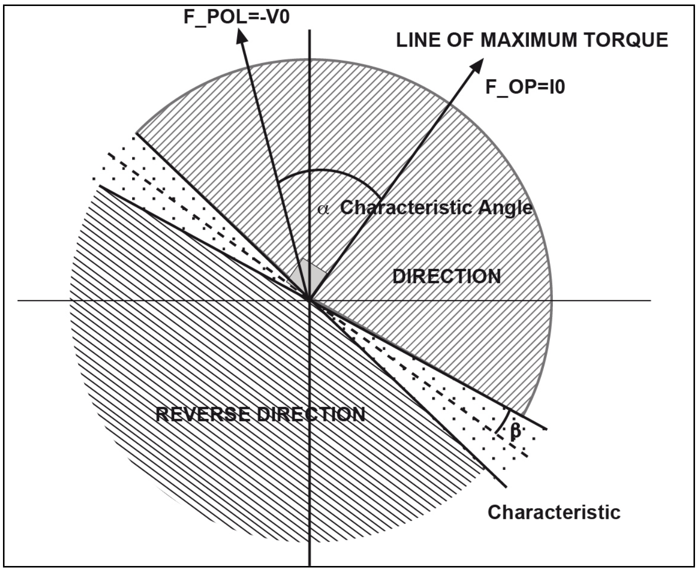


Figure 2.2.4 Vector Diagram of the Ground Directional Element (Polarization by Voltage).

If current or voltage do not exceed the threshold values the ***Lack of Polarization Blocking*** setting is checked. If set to **NO** proceed as for the case of directional inhibition, but if set to **YES** indicates lack of polarization blocking and trips in both directions are blocked.

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

Table 2.2-2: Ground Directional Element (polarization by voltage)

Fop	Fpol	Criteria
I0	$-V0$	Direction $-\left(90^\circ + ANG\_67N - \beta\right) \leq \left[\arg\left(Fop\right) - \arg\left(Fpol\right)\right] \leq \left(90^\circ - ANG\_67N - \beta\right)$ Reverse Direction $\left(90^\circ - ANG\_67N + \beta\right) \leq \left[\arg\left(Fop\right) - \arg\left(Fpol\right)\right] \leq -\left(90^\circ + ANG\_67N + \beta\right)$

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).

Figures 2.2.5 and 2.2.6 show the zero sequence network for a ground fault (single phase or two phase) in a forward and reverse direction, respectively.

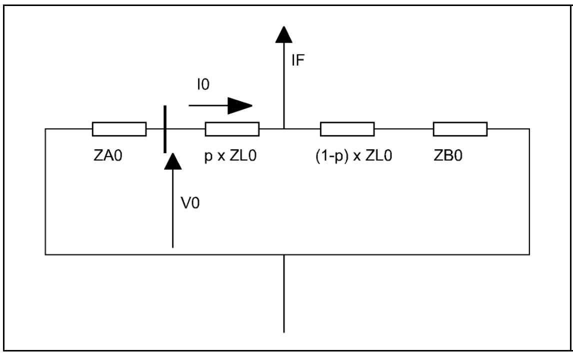


Figure 2.2.5 Zero Sequence Network for Forward Fault.

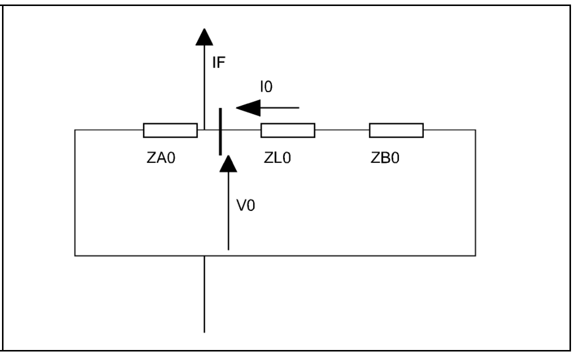


Figure 2.2.6 Zero Sequence Network for Reverse Fault.

If the fault is in **Direction**, it can be deduced that $V0 = ZA0 \cdot (-I0)$, where $ZA0$ is the zero sequence impedance of the local source. It is seen, consequently, that the angle between $-V0$ and $I0$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the ground directional element (**ANG_67N** setting).

If the fault is in the **Reverse Direction**, the following expression will be obtained: $V0 = (ZL0 + ZB0) \cdot I0$, where $ZL0$ and $ZB0$ are the zero sequence impedance of the line and the remote source, respectively. Consequently, the angle between $-V0$ and $I0$ will be supplementary of the angle of $ZL0 + ZB0$ impedance (which will be similar to the $ZA0$ angle).

Through the relative phase difference between $-V0$ and $I0$, the directionality of the fault can be deduced.

The activation of the **Directional Ground Element Inhibit** (**INH_DIR_N**) input converts the element to non-directional.

The logic diagram of operation of the ground directional element is shown in Figures 2.2.7 and 2.2.8 respectively.

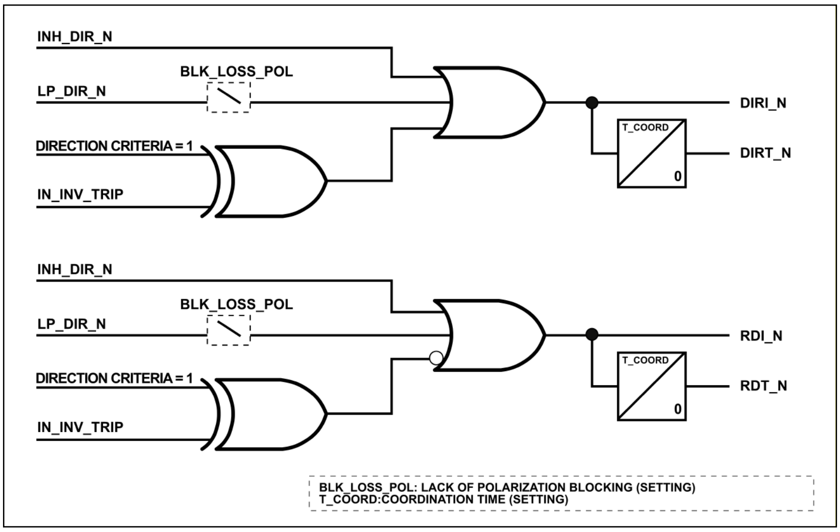


Figure 2.2.7 Block Diagram of a Directional Ground Element.

LP_DIR_N and **LP_DIR_SG** signals show **Lack of Ground Directional Polarization** and **Lack of Residual Ground Directional Polarization**, respectively.

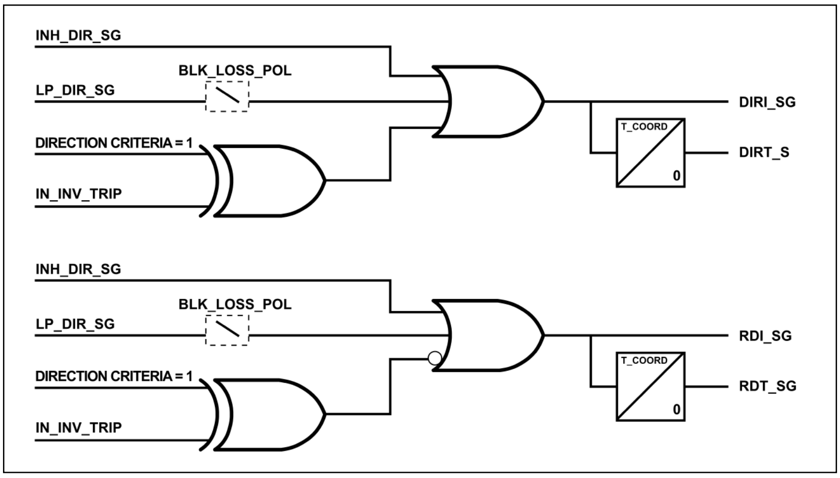


Figure 2.2.8 Block Diagram of a Sensitive Ground Directional Element.

2.2.4 Negative Sequence Directional Unit

2.2.4.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Negative Sequence Directional Overcurrent Unit	NSRDIR1	I2 →	67Q

2.2.4.b General Block

Inputs		67Q NSRDIR1		Outputs
I2	→		→	RDI_NS
V2	→		→	RDT_NS
INH_DIR_NS	→		→	DIRI_NS
IN_INV_TRIP	→		→	DIRT_NS

2.2.4.c Operation Principles and Block Diagram

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

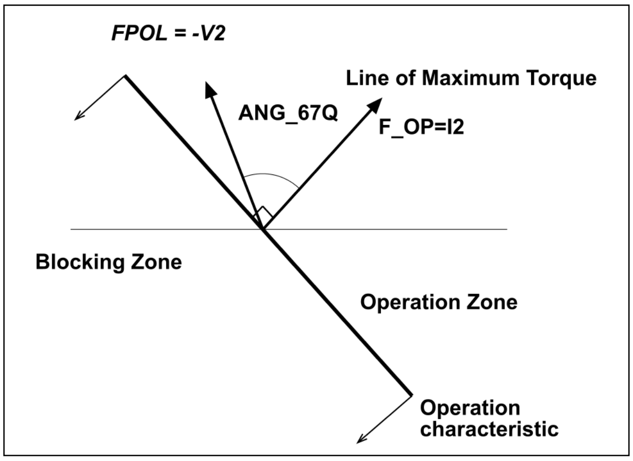


Figure 2.2.9 Vector Diagram of the Negative Sequence Directional Element.

Negative Sequence Directional elements check if negative sequence currents and voltages exceed a given value. This value is adjustable for the polarization phasor (***Minimum Negative Sequence Voltage*** setting) and **10/3 A** in primary values for the operating phasor If the operation or polarization phasors do not exceed their threshold values, the ***Lack of Polarization Blocking*** setting is checked. If this setting indicates **NO** blocking, it acts as in the case of directional inhibition, but if it indicates blocking due to lack of polarization, the trips are blocked in both directions.

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

Table 2.2-3: Directional Negative Sequence Element

Fop	Fpol	Criteria
I2	$-V2$	$-\left(90^{\circ}+ANG\_67Q\right)\leq\left[\arg\left(Fop\right)-\arg\left(Fpol\right)\right]\leq\left(90^{\circ}-ANG\_67Q\right)$

The directional element, if configured in **Direction**, enables the Overcurrent Element when the above criteria is fulfilled (operation zone indicated in the diagram), while if configured in **Reverse Direction**, enables the Overcurrent Element when this criteria is not fulfilled (blocking zone indicated in the diagram).

Figures 2.2.10 and 2.2.11 show the negative sequence network for a forward and reverse unbalanced fault (single phase or two phase), respectively.

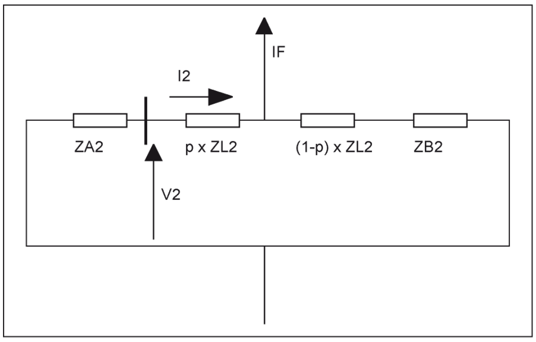


Figure 2.2.10 Negative Sequence Network for Forward Fault

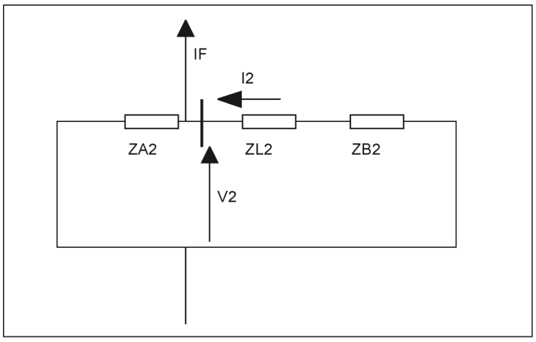


Figure 2.2.11 Negative Sequence Network for Reverse Fault

If a forward fault, it can be deduced that $-V2 = ZA2\cdot(-I2)$, where $ZA2$ is the negative sequence impedance of the local source. Consequently, it can be seen that the angle between $-V2$ and $I2$ will be that corresponding to this impedance. For this reason, this should be the characteristic angle of the directional negative sequence element (**ANG_67Q** setting).

The logic diagram of operation of the directional negative sequence element is shown in Figure 2.2.12.

If the **Inversion of Directionality** (**IN_INV_TRIP D**) input is active, the direction of calculated direction is changed.

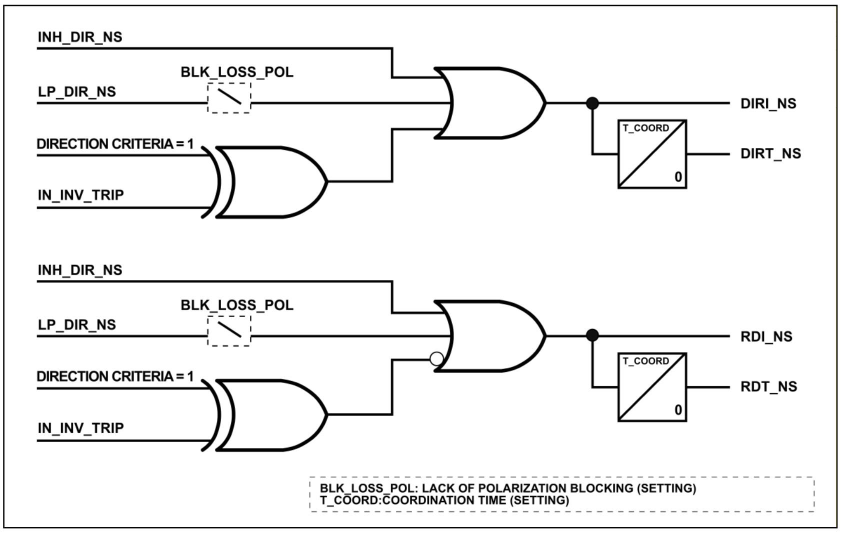


Figure 2.2.12 Block Diagram of a Directional Negative Sequence Element.

The activation of the **Ground Directional Element Inhibit** (**INH_DIR_NS**) input converts the element into non-directional.

The logic diagram of operation of the Positive Sequence Directional element is shown in Figure 2.2.13.

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

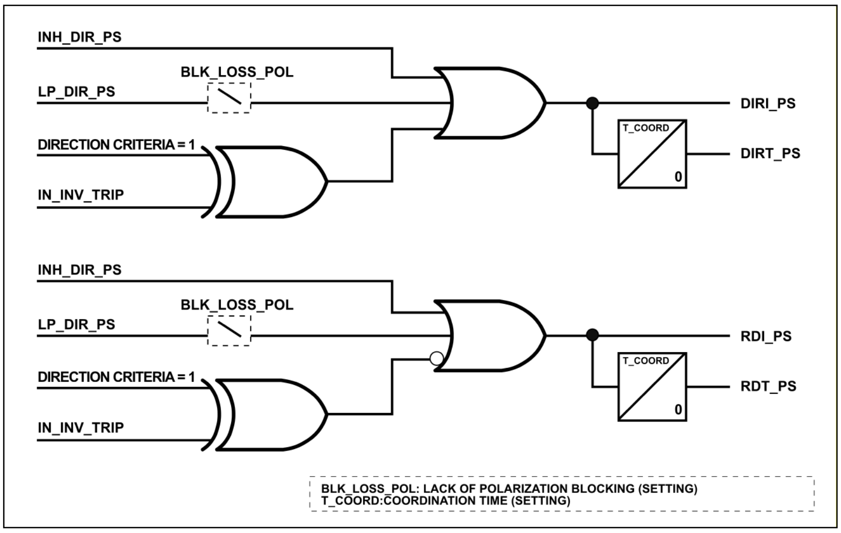


Figure 2.2.13 Block Diagram of a Directional Positive Sequence Element.

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

2.2.4.d Directional Unit of Zero Sequence Impedance Module

The use of a purely inductive neutral earthing in certain MV networks prevents the use of Zero Sequence Directional Units based on the angular relationship between the zero sequence voltage and current, since this is the same for forward and reverse faults. The discrimination of the direction of the fault will be made through the calculated zero sequence impedance module (**Z0=V0/I0**), rather than through the angle of this impedance (**ang(V0)-ang(I0)**).

In a healthy line, the calculated **Z0** will be equal to the capacitive reactance to ground of the line itself (disregarding the inductive reactance of zero sequence of this line since it will be much smaller than the capacitive reactance) taking into account all its ramifications (**XCL**). However, in a fault line, the **Z0** calculated will be equal to the inductive reactance of the grounding (**3*XL_pat** since it is a zero sequence impedance) in parallel with the capacity of the rest of the system, connected in parallel with the fault line (**XCS**). Figures 2.2.14 and 2.2.15 show the zero sequence network for a forward and reverse fault respectively, where:

XCLF	Represents the capacitive reactance of the faulty line.
XCLS	Represents the capacitive reactance of the healthy line.
X0LF	Represents the zero sequence inductive reactance of the faulty line.
XCS	Represents the capacitive reactance of the system connected in parallel with the faulted line in Figure 2.2.14 and of the system connected in parallel with the faulted and healthy lines in Figure 2.2.15.

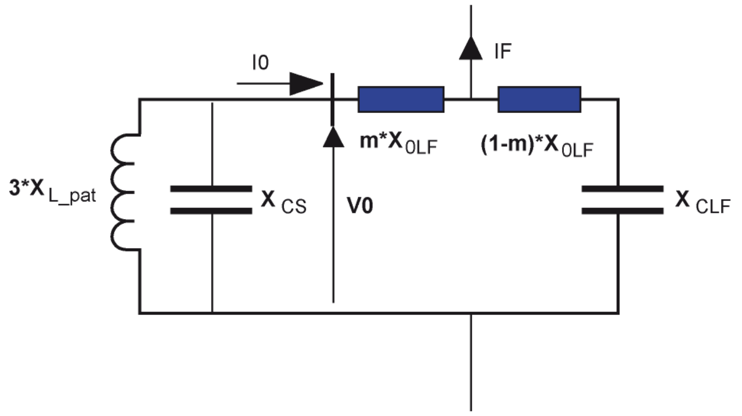


Figure 2.2.14 Zero Sequence Network for Forward Fault.

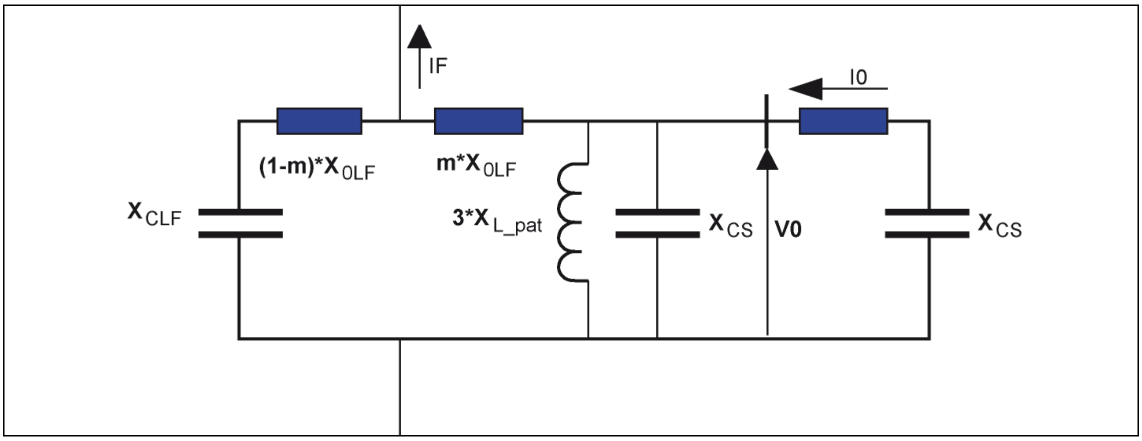


Figure 2.2.15 Zero Sequence Network for Reverse Fault.

- **Principle of Operation**

In general, **3*XL**_pat in parallel with **XCS** will be much smaller than **XCLS**, which will allow to distinguish the direction of the fault. There will be a zero sequence impedance level setting below which the fault will be considered forward. This setting must be less than the minimum capacitive reactance of the line, taking into account all its ramifications. The advantage of using **Z0** over **I0** is that the former is not affected by the fault resistance, so if, in the worst case, **3*XL_pat** in parallel with **XCS** is less than **XCLS**, coordination is assured.

The Directional Unit based on the **Z0** module will present the following algorithm:

- Forward fault: **Z0<LEVEL_Z0**.
- Reverse fault: **Z0≥LEVEL_Z0**.

If there is a resistance in series with the earthing inductance of the ground, the Directional Unit based on the angular relation between **V0** and **I0** (**Z0** angle) will be maintained but the range of the characteristic angle will be extended, whose minimum value will now be **-90º**.

On the other hand, a Negative Sequence Directional Unit will be implemented which will operate only if **V2** exceeds an adjustable minimum threshold. When operating this Directional Unit, it will have preference over the Ground Directional Unit, so only the decision of the first one will be taken into account.

The Directional Unit for Neutral Overcurrent will be selected based on the ***Directional Unit Type*** setting:

1- **Z0 angle**: it will be based on the angular relationship between V0 and I0.
2- **Z0 magnitude**: it will be based on the Z0=V0/I0 magnitude.
3- **Z0 magnitude + Z2 angle**: it will be based on the Z0 magnitude if V2 does not exceed the minimum threshold; if V2 is above the threshold, the directional will be based exclusively on the angular relation of V2 and I2 (Negative Sequence Directional Unit).

The **Z0** based directional will only operate when **I0** exceeds **0.02*Inom** and **V0** exceeds the adjustable minimum level.

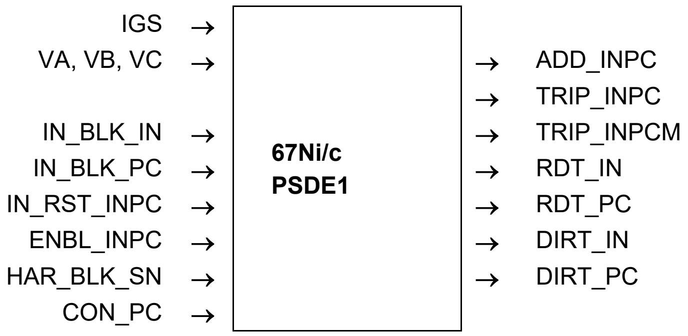
The adjustments of the levels of **Z0**, **V0** and **V2** will be given in primary values.

2.2.5 Isolated Ground Directional Element

2.2.5.a Identification

Description of the protection unit	IEC 61850 Node	IEC 60617	ANSI/IEEE C37.2
Positive Sequence Directional Overcurrent Unit	PSDE1		67Ni/c

2.2.5.b General Block



2.2.5.c Operation Principles and Block Diagram

Isolated Ground Directional Elements consist of a measuring element that operates according to voltage / current characteristic, as represented in figure 2.2.16. It differs from the above in that it does not include ***Coordination Time*** setting and the ***Characteristic Angle*** setting is capacitive.

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** (**PU_IN**) output.

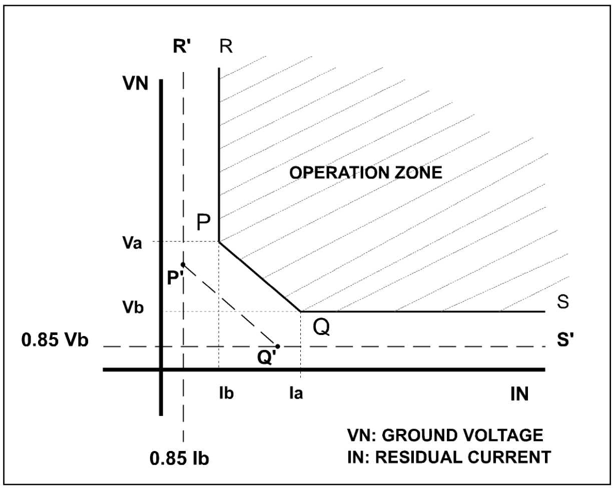


Figure 2.2.16 Diagram of the Characteristic of Isolated Ground Directional Element.

The element picks up at 100% of the operate zone limit value, marked as R-P-Q-S (±5%) in figure 2.2.16, 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 calculated from the phase voltages by means of vector sum of them. The residual current (INA) for isolated ground systems is another analog input of extraordinary measurement accuracy for very low current values. The current transformer used will be a toroidal covering all three phases.

This unit can be monitored by the Isolated Ground 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 figure 2.2.17).

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 (Figure 2.2.17).

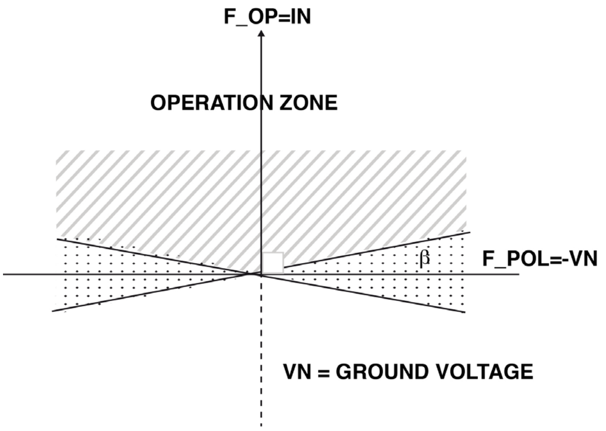


Figure 2.2.17 Vector Diagram of the Characteristic of the Isolated Ground Directional Element.

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.

The Isolated Ground Directional unit checks that the neutral current and voltage exceed certain values. This value is adjustable for the voltage and **20 mA** for the isolated ground current. If the voltage or the current do not exceed their threshold values, the ***Lack of Polarization Blocking*** setting is checked. If this setting indicates **NO** blocking, it acts as in the case of directional inhibition, but if it indicates blocking due to lack of polarization, the trips are blocked in both directions.

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.

In isolated ground networks, default currents are mainly capacitive so the characteristic angle (α) for this type of networks is usually 90º capacitive. In the figure the characteristic angle takes a fixed value of 90º capacitive with respect to the polarization magnitude F_POL.

The blind spot (**β**) determines the area of the directional characteristic in which it is not possible to precisely determine the direction of the fault current. This angle is determined by the ANG_IDLE setting, common to all the directional units of the equipment.

2.2.5.d Isolated Ground Protection Element Logic

Figure 2.2.18 shows the overcurrent protection element block diagram. Mention is made of two elements:

- Voltage / current characteristic generator.
- Directional element.

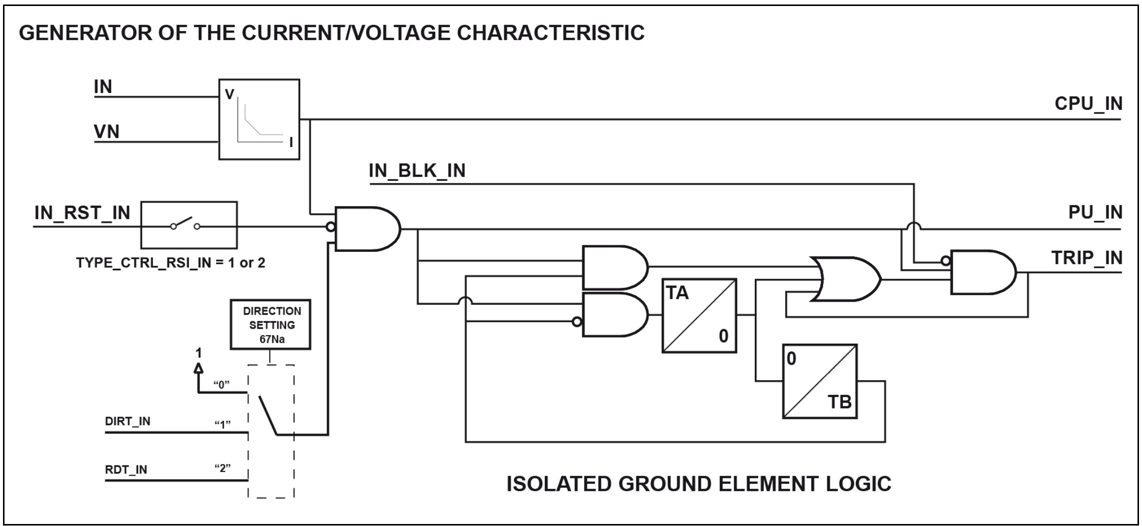


Figure 2.2.18 Isolated Ground Protection Element Logic.

2.2.5.e 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 Isolated Ground elements and Compensated Ground elements are operated simultaneously and share the same voltage / current characteristic. Nevertheless, they are provided with separate timers (isolated ground time and compensated ground time) and separate directional characteristics.

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

Table 2.2-4: 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.

Figure 2.2.19 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 ground 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.

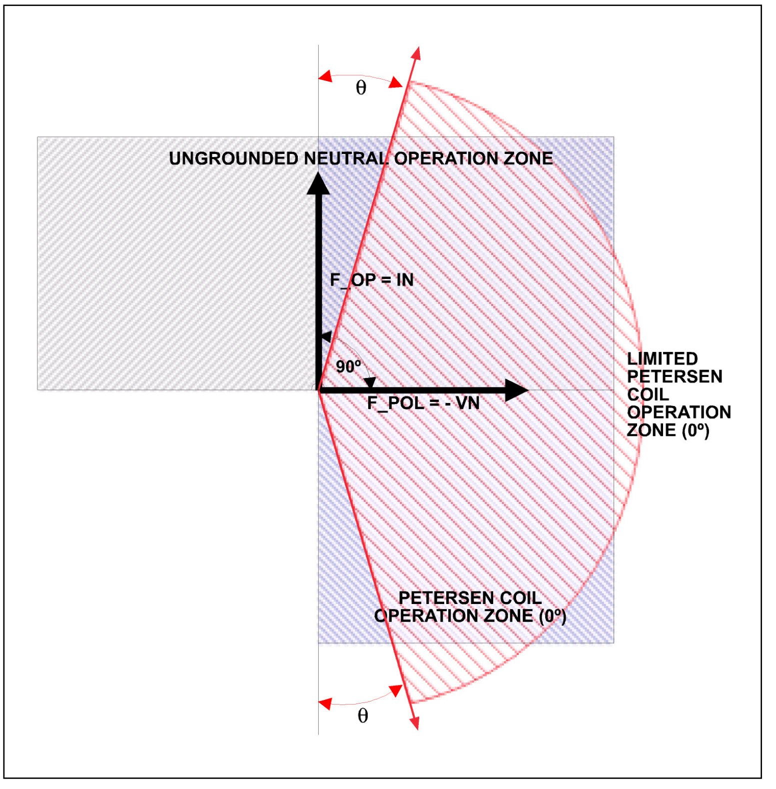


Figure 2.2.19 Vector Diagram of the Characteristic of Directional Ungrounded and Compensated Ground (Petersen Coil) Element.

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 isolated ground element.

2.2.6 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.

2.2.7 Setting Ranges

Directional Elements			
Setting	**Range**	**Step**	**Default**
Phase Characteristic Angle	-90º - 90º	1º	45º
Gnd Characteristic Angle	-90º - 90º	1º	45º
Negative Sequence Characteristic Angle	0 - 90º	1º	45º
Blind Spot	0 - 30º	0.1º	10º
Lack of direction blocking	YES / NO		NO
Min. Phase Voltage	10 – 50,000 V	1 V	100 V
Min. Gnd Voltage	10 – 50,000 V	1 V	100 V
Min. Negative Sequence Voltage	10 – 50,000 V	1 V	100 V
Coordinating Time	0 - 30 ms	1 ms	0 ms
Level Z0 for Forward Fault	0.1 ohm – 10,000 ohm	0.1 ohm	100 ohm
Direction Type for Ground	0: Z0 angle 1: Z0 magnitude 2: Z0 magnitude + Z2 angle		2: Z0 magnitude + Z2 angle

Isolated Ground Directional Unit			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Low Current	100 mA - 10 A	10 mA	100 mA
High Current	1.0 - 3.0 x Ib	0.01	2 x Ib
Low Voltage	100 - 10,000 V	1 V	100 V
High Voltage	100 - 20,000 V	1 V	200 V
Isolated Ground 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
Ground Direction	0: None 1: Direction 2: Reverse		0: None
Petersen Coil Supervision	YES / NO		NO
Angle Limit Petersen Coil	0º - 60º	1º	0º
Petersen Coil Time	0.05 - 300 s	0.01 s	0.1 s

2.2.8 Digital Inputs of the Directional Modules

Table 2.2-5: Digital Inputs of the Directional Modules[(1)]

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_IN	Isolated / Compensated Ground directional element inhibit	
IN_INV_TRIP_PH	Phase polarization inversion	When the input is quiescent, the operation zones are those indicated in this section 2.2. If it is activated, the operation zone of all the directional elements is inverted.
IN_INV_TRIP_N	Ground polarization inversion	
IN_INV_TRIP_SG	Sensitive Ground polarization inversion	
IN_INV_TRIP_IN	Isolated / Compensated Ground polarization inversion	
IN_BLK_IN	Isolated / Compensated Ground 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_IN	Isolated / Compensated Ground 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_IN	Isolated / Compensated Ground 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. The default value of this logic input signal is a “1.”
CON_PC	Connected Petersen Coil input	This input is used to select isolated ground or compensated ground elements.

[(1)] For the second analog board the signals are identified in the same way, but with the prefix "U1_".

2.2.9 Auxiliary Outputs and Events of the Directional Modules

Table 2.2-6: Auxiliary Outputs and Events of the Directional Modules[1]

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_C	Phase C instantaneous element reverse direction	
RDI_G	Ground instantaneous element reverse direction	
RDT_A	Phase A time element reverse direction	
RDT_B	Phase B time element reverse direction	
RDT_C	Phase C time element reverse direction	
RDT_G	Ground time element reverse direction	
RDT_SG	Sensitive Ground time element reverse direction	
RDT_IN	Isolated / Compensated Ground time 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_C	Phase C instantaneous element direction	
DIRI_G	Ground instantaneous element direction	
DIRT_A	Phase A time element direction	
DIRT_B	Phase B time element direction	
DIRT_C	Phase C time element direction	
DIRT_G	Ground time element direction	
DIRT_SG	Sensitive Ground time element direction	
DIRT_IN	Isolated / Compensated Ground time element direction	
INHD_PH	Phase directional element inhibit	Same as for Digital Inputs.
INHD_N	Ground directional element inhibit	
INHD_SG	Sensitive ground directional element inhibit	
INHD_IN	Isolated / Compensated Ground directional element inhibit	
IN_INV_TRIP_PH	Phase polarization inversion	Same as for Digital Inputs.
IN_INV_TRIP_N	Ground polarization inversion	
IN_INV_TRIP_SG	Sensitive Ground polarization inversion	
IN_INV_TRIP_IN	Isolated / Compensated Ground polarization inversion	
PU_IN	Isolated / Compensated Ground directional element pickup.	AND logic of the pickup of the current element with the corresponding torque-control input.
CPU_IN	Isolated / Compensated Ground directional element pickup conditions	Element pickup unaffected by torque control.
TRIP_IN	Isolated / Compensated Ground directional element trip	Trip of the isolated ground element.

Table 2.2-6: Auxiliary Outputs and Events of the Directional Modules(1)		
Name	**Description**	**Function**
IN_BLK_IN	Isolated / Compensated Ground directional element block input	Same as for Digital Inputs.
IN_RST_IN	Isolated / Compensated Ground directional element torque annulment input	Same as for Digital Inputs.
ENBL_IN	Isolated / Compensated Ground directional element enable input	Same as for Digital Inputs.
IN_ENBLD	Isolated / Compensated Ground directional element enabled	Indication of enabled or disabled status of the unit.
CON_PC	Connected Petersen coil input	This input is used to select isolated ground or compensated ground elements.

(1) For the second analog board the signals are identified in the same way, but with the prefix "U1_".

2.2.10 Directional Elements Test

Prior to testing check that **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. following Tables show the angles between which relay directional control is enabled. To check if the relay directional control is enabled or not one or more outputs or LEDs must be configured and check the state of flags corresponding to the tested phase.

Table 2.2-7: Phase Directional Control	
V APPLIED	I APPLIED
Vb = 2.3V ⌊0º	Ia = 0.4A ⌊(270º-α charact. to 90º + α charact.) ± 2º
Vc = 2.3V ⌊0º	Ib = 0.4A ⌊(270º-α charact. to 90º + α charact.) ± 2º
Va = 2.3V ⌊0º	Ic = 0.4A ⌊(270º-α charact. to 90º + α charact.) ± 2º

Table 2.2-8: Ground Directional Control	
Ground Directional and Sensitive Ground Directional by Z0 angle	
V APPLIED	I APPLIED
Va = 2.3V ⌊0º	In = 0.4A ⌊ (90º - α charact. to 270º - α charact.) ± 2º
Ground Directional and Sensitive Ground Directional by Z0 magnitude	
V APPLIED	I APPLIED
Va = 2.3V ⌊0º	In > 0.12A ± 3% ⌊ (0º - 360º)
Ground Directional and Sensitive Ground Directional by Z2 angle	
V APPLIED	I APPLIED
Va = 2.3V ⌊180º	In = 0.4A ⌊ (270º - α charact. to 90º - α charact.) ± 2º

2.2.10.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 following Table, 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 2.2-9: 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	$\dfrac{V_b + mI_a - V_{ap} \cdot 0.99}{m} \bullet 1.01$	$\dfrac{V_b + mI_a - V_{ap} \cdot 1.01}{m} \bullet 0.99$

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

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

- **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 following Table, trip times are within the stated margins.

Table 2.2-10: 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 following Table with an error of ±1º:

Table 2.2-11: 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

2.3 Harmonic Blocking

2.3.1 Identification

Description of the Protection Unit	**Node IEC 61850**	**IEC 60617**	**ANSI/IEEE C37.2**
Harmonic Blocking	OCPHAR1	3I2f>	68

2.3.2 General Block

IA, IB. IC → **68 OCPHAR** → HAR_2_BLK_X

2.3.3 Operation Principles

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

Under overexcitation conditions of the transformer, as a result of overvoltage and under frequency, important magnetizing currents can also be produced. In order to avoid the operation of overcurrent elements under the mentioned magnetizing currents, the Harmonic Blocking function is included in the **2TCA-E** family.

All overcurrent elements include the setting ***Second Harmonic Blocking***. When the measured harmonic value exceeds the value of the setting, the applicable overcurrent element will be blocked by the corresponding blocking by harmonics signal.

2.3.4 Setting Ranges

Parameters / Lx / DPF &AF / Harmonic Blocking				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Second Harmonic Blocking	OCPHAR1.BlkValPct1	0% - 200%	0.01%	0%

2.3.5 Auxiliary Outputs and Events of the Harmonic Blocking

Tabla 2.2-1: Auxiliary Outputs of the Harmonic Blocking					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
HAR_2_BLK_A	Harmonic Blocking and Saturation Detector	OCPHAR1.Str1	Phase A Blocking by 2nd Harmonic		Phase, Neutral, Sensitive Ground and Isolated Ground Harmonic Blocking.
HAR_2_BLK_B		OCPHAR1.Str1	Phase B Blocking by 2nd Harmonic		
HAR_2_BLK_C		OCPHAR1.Str1	Phase C Blocking by 2nd Harmonic		
HAR_2_BLK_N		OCPHAR1.Str2	Neutral Blocking by 2nd Harmonic		
HAR_2_BLK_SN		OCPHAR1.Str3	Sensitive Ground Blocking by 2nd Harmonic		

2.3.6 IEC 61850 Logical Node

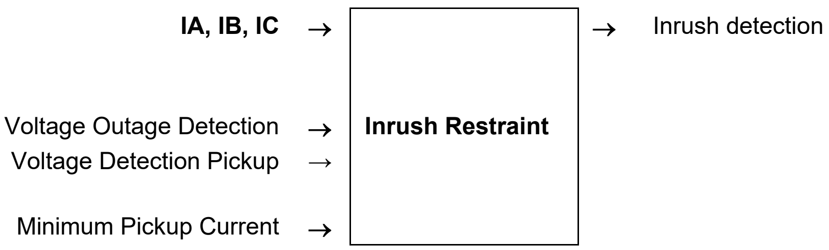
CLASS PHAR		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str1	ACD	Second harmonic blocking phase pickup
Str2	ACD	Second harmonic blocking neutral pickup
Str3	ACD	Second harmonic blocking ground/sensitive ground pickup
Str4	ACD	Second harmonic blocking ungrounded neutral pickup
Extended Data		
BlkValPct1	EXT_ASG	Second harmonic blocking pickup

2.4 Inrush Restraint

2.4.1 Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Inrush Restraint	-	-	68

2.4.2 General Block



2.4.3 Operation Principles

To prevent maloperations during the energization of big loads, transformers, generators or motors, caused by the inrush current, the IED will provide an Inrush Restraint unit that will ignore the inrush current and so it will not trip under that condition.

The unit will determine that there could be a possible inrush condition when normal voltage conditions appear after a voltage outage. Therefore, the Inrush Restraint unit will work just during a certain time (***Inrush Detection Time***) after the IED detects a normal voltage level (activation of the **Voltage Detection Pickup** signal of the open phase unit) coming from a voltage outage status (deactivation of the **Voltage Outage Detection** signal of the open phase unit). This way the IED will not delay possible real fault conditions not generated by an inrush.

When the unit is enabled, the IED detects that the breaker has closed (change in the voltage measurements as explained before) and the IED detects a high current value (the setting is defined as a multiple value of the pickup current of the phase instantaneous overcurrent unit), the **Inrush Detection** signal will be activated during the time defined in the ***Inrush Restraint Time*** setting. While the **Inrush Detection** signal is in active status, the IED will block the overcurrent units so that the inrush current value will be ignored and so the overcurrent units will not operate and no fault indication will be generated. The **Inrush Detection** signal will deactivate after the ***Restraint Time*** even if the Inrush conditions persist.

The overcurrent units will take into account the Inrush Detection condition not to operate under such conditions.

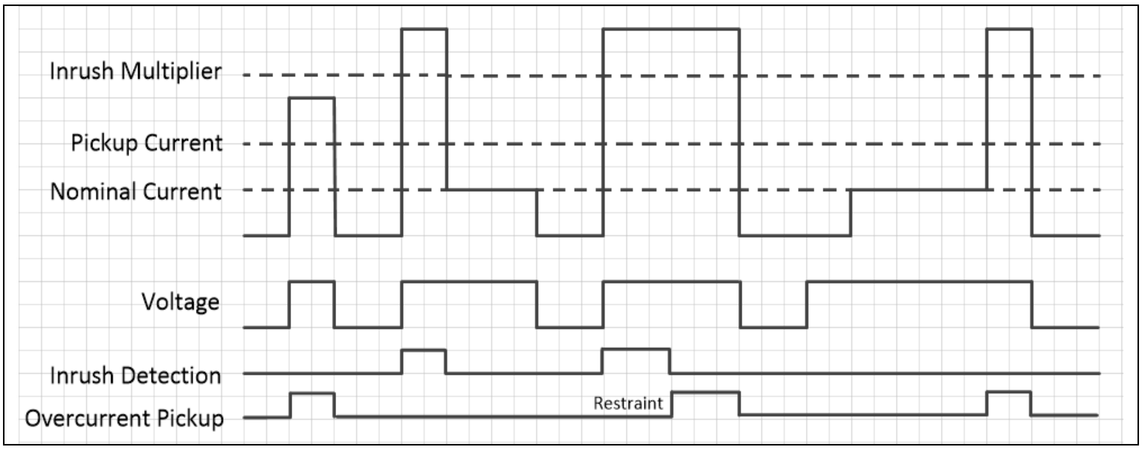


Figura 2.4.1 Overcurrent Pickup depending on the Inrush Condition Detection.

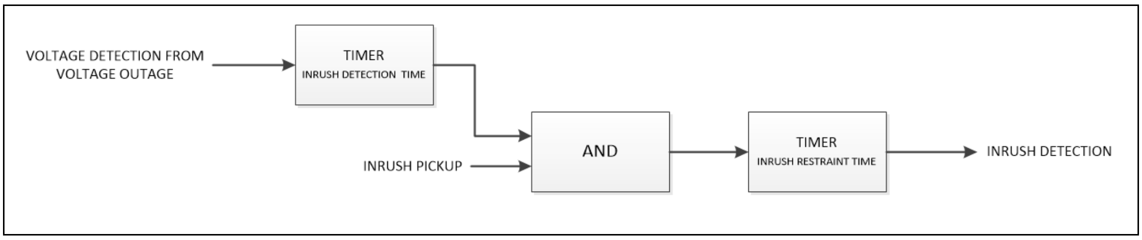


Figura 2.4.2 Block Diagram of the Inrush Retraint Unit.

2.4.4 Application

The Inrush Restraint unit is used to prevent malfunctions or trips caused by the inrush current when energizing a transformer, generator, motor, big loads, etc.

By this way the relay will ignore the inrush condition filtering the trip of the IED and so ensuring a correct complete switching operation of the breaker.

2.4.5 Setting Ranges

Parameters / Lx / Inrush Restraint				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Inrush Restraint Enable		YES/NO	-	YES
Multiple of Minimum Pickup Current		2-20	1	2
Inrush Restraint Time		0.1-3s	0.1s	0.1s
Inrush Detection Time		0.5-5s	0.1	1s

2.4.6 Analog Inputs to the Unit

Analog Inputs of the Inrush Restraint Module		
Name	**Description**	**IEC 61850**
IA	Phase A Current	MMXU1.A.phsA
IB	Phase B Current	MMXU1.A.phsB
IC	Phase C Current	MMXU1.A.phsC

2.4.7 Digital Inputs to the Inrush Restraint Unit

Table 2.4-1: Digital Inputs to the Inrush Restraint Module

Name	Group	IEC 61850	Description	Vis.	Function
ENBL_INRUSH	Enabling Commands	-	Enable Inrush Restraint Unit x	E	Activation of this input puts the element into service. It can be assigned to status contact inputs by level. The default value of this logic input signal is a "1" (unit enabled).

Note: Vis column, will indicate where the signal is going to appear: SLD Diagram (S), Details (D), Event (E), IEC 104 (I).

2.4.8 Auxiliary Outputs and Events of the Inrush Restraint Module

Table 2.4-2: Auxiliary Outputs and Event of the Inrush Restraint Module

Name	Group	IEC 61850	Description	Vis.	Function
INRUSH_ACT	Harmonic Blocking and Saturation Detector	-	Inrush Detection	S D E	Activation of the inrush detection signal.

Note: Vis column, will indicate where the signal is going to appear: SLD Diagram (S), Details (D), Event (E), IEC 104 (I).

2.4.9 Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time.

Instantaneous Overcurrent Unit	**Ranges**	**Test Settings**
Phase IOC Enable	YES / NO	YES
Phase IOC Pickup	10 - 3000 A	400A
Phase IOC Delay	0 - 300 s	0 s
Inrush Restraint	**Ranges**	**Test Settings**
Inrush Restraint Enable	YES / NO	YES
Multiple of Minimum Pickup Current	2-20	2
Inrush Restraint Time	0.1-3s	0.1s
Inrush Detection Time	0.5-5s	2s
Open Phase	**Ranges**	**Test Settings**
Open Phase Enable	YES / NO	YES
Voltage off level	0.5-0.75pu	0.5pu
Voltage on level	0.7-0.85pu	0.8pu
Delay time	0 – 60s	4s

- **Inrush restraint**

Start injecting nominal voltage and 900A for 50ms and then keep on injecting 200A. The IED will not trip and the **Inrush Detection** event is generated.

Start injecting nominal voltage and 200A. Wait for 1 second. Inject 900A for 50ms and then keep on injecting 200A. The IED will not trip and the **Inrush Detection** event is generated.

- **Trip not blocked**

Start injecting nominal voltage and 900A for 120ms. The **Inrush Detection** event is generated for 100ms and the IED trips. Once the signal deactivates the instantaneous overcurrent unit trips.

Start injecting nominal voltage and 600A during 50ms. The IED will trip due to the instantaneous overcurrent unit. The **Inrush Detection** event is not generated.

Start injecting nominal voltage and 200A. Wait for 3 seconds. Increase the current to 900A. The IED will trip due to the instantaneous overcurrent unit. The **Inrush Detection** event is not generated.

Chapter 3.

Voltage Protection Elements

3.1 Voltage Elements

Voltage Protection Elements		
1 / 2	Phase Overvoltage Elements	59-1, 59-2
1 / 2	Phase Undervoltage Elements	27-1, 27-2

3.1.1 Common Principles

3.1.1.a Operation and Reset

For a given voltage unit, pickup occurs when the measured value is equal to or greater / less than the set value, and the resets with a selectable percentage value (lower / upper) on the setting.

For the voltage units (voltage presence and absence) to work, the Fault Passage Detector automatism must be enabled.

The Phase Voltage elements have an **associated logic** (see Figure 3.1.1):

- **AND**: the element trips when the three associated overvoltage elements comply with the trip condition. Used to detect the absence of voltage (undervoltage).
- **OR**: the element trips when one or more of the three associated overvoltage elements comply with the trip condition. Used to detect the presence of voltage (overvoltage).

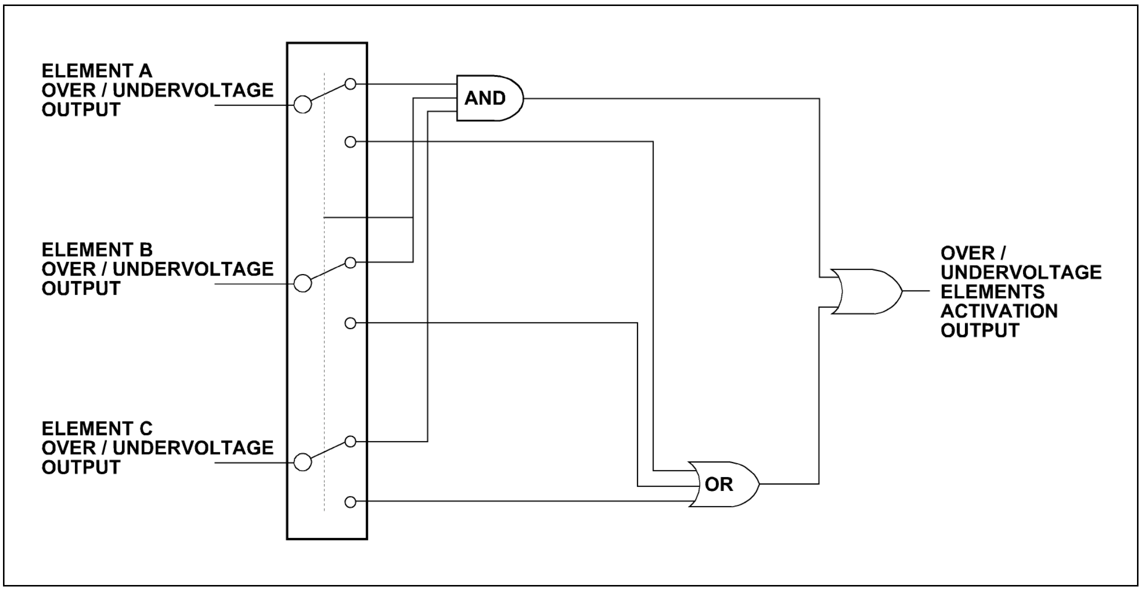


Figura 3.1.1 Block Diagram of the AND/OR Operation for the Voltage Elements.

3.1.1.b Trip Blocking

Voltage Elements can program block trip inputs, which prevents the operation of the element if this input is activated before the trip is generated. If activated after the trip, it resets. Even if the element is blocked it remains operative so that if the relay is under trip conditions at the moment when the blocking input deactivates, the relay will issued a trip command instantaneously.

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

3.1.1.c Enabling and Disabling the Unit

All elements include an enable and disable input in such a way that, the element being enabled by protection settings, it may be disabled through logic upon given circumstances. In this way, when the enable input is disabled, the element is not operative and the element starts operation from zero the moment the enable input is activated.

3.1.1.d Restoration Setting

The reset value of each set of voltage elements (phase overvoltage and phase undervoltage) is settable and one setting per set is provided to this end. A common setting called ***Hysteresis*** of the Voltage Absence and Presence units is available for this purpose

Parameters / Lx / DPF &AF / Voltage Absence and Presence				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Hysteresis (AUT_DPF_HT) (%)	PHSPTUV.PhVRs	0 - 100 %	0.1 %	5 %

3.1.2 Phase Undervoltage Elements

3.1.2.a Identification

Description of the Protection Unit	Node IEC 61850	IEC 60617	ANSI/IEEE C37.2
Phase Undervoltage Unit 1	PHSPTUV1	3U<	27-1
Phase Undervoltage Unit 2	PHSPTUV2	3U<	27-2

3.1.2.b General Block

VA →	**27**	→ PU_IUV (per phase)
VB →	**PHSPTUV**	→ PU_IUV_3PH
VC →		→ TRIP_UV (per phase)
INBLK_UV PH →		→ TRIP_UV_3PH
ENBL_UV_PH →		

3.1.2.c Operation Principles and Block Diagram

The equipment has one or two phase undervoltage units, depending on the model selected, and as many indications as lines are available in the equipment. Each unit is associated to the three analog voltage inputs of each board.

The units are always enabled by protection setting, but to be operational, the Fault Passage Detector automatism must be enabled.

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 included time setting is fixed at 40ms and is not configurable. The unit has an extra setting to allow timing of the voltage absence signal for recording in the event log and for the sectionalizer automatism.

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.

In addition, the phase undervoltage units have an associated AND type logic (see Figure 3.1.1) so that it is necessary for the equipment to detect absence of voltage in all three phases to activate the general trip. The unit will activate the absence signal corresponding to each phase independently.

For the unit to be operational, the Fault Passage Detector automatism must be enabled.

The pickup- and trip condition of the unit is subject to no current detection. If the unit is measuring phase current (value greater than 4A primary), the undervoltage unit and therefore the voltage absence signals will not activate. The status of the breaker (open/closed) is not taken into account for the operation of the unit.

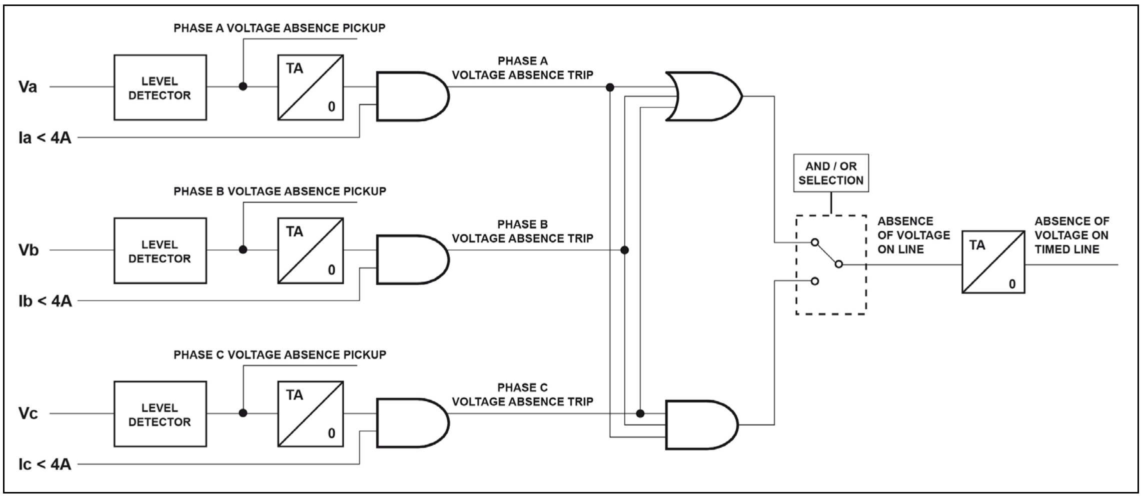


Figura 3.1.2 Block Diagram of the Phase Undervoltage Element.

3.1.2.d Application

The Phase Undervoltage element detects undervoltage in system elements. These low voltage conditions can be caused by different factors:

- Malfunction of voltage regulation equipments.
- Power system overloads that imply a voltage supply drop, which cannot be compensated by the voltage regulation equipments.
- Trips causing phase voltage drop under fault conditions.
- Total absence of a busbar voltage caused by operation of the transformer or busbar protection scheme.

In this way, the phase undervoltage element can be used to disconnect from the network any equipment that could be damaged when working under low voltage conditions or under conditions that could produce overheating.

3.1.2.e Recommendation of Unit Settings

The pick-up setting of the unit should be somewhat below the nominal voltage of the system, taking into account the usual variations that may occur when regulation equipments are operated. This percentage will depend on each system, although a standard value could be around 15%.

3.1.2.f Setting Ranges

Parameters / Lx / DPF &AF / Voltage Absence				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Pickup (AUT_DPF_VAT) (%)	PHSPTUV.StrVal	10 - 120 V	0.1 V	40 V
Voltage Absence Time for Logs (AUT_TAT)	PHSPTUV.OpDlTmms	0 - 60 s	0.1 s	5 s

Fixed Settings in the Firmware

Parameters / Lx / DPF &AF / Voltage Absence		
Web Server	**IEC 61850**	**Value**
Enable	PHSPTUV.LNInSvc	YES
Delay	PHSPTUV.OpDlTmms	0.04s
Trip Logic	PHSPTUV.EvTyp	AND
Maximum Current	PHSPTUV.MaxCur	4A
Hysteresis (A)	PHSPTUV.HysVal	1A

3.1.2.g Analog Inputs to the Unit

Table 3.1-1: Analog Inputs to the Phase Undervoltage Modules		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

3.1.2.h Digital Inputs to the Phase Undervoltage Modules

Table 3.1-2: Digital Inputs to the Phase Undervoltage Modules

Name	Group	IEC 61850	Description	Vis.	Function
IN_BLK_UVx	Logic Inputs to Protection	PHSPTUVx.Mod	Line Voltage Absence Unit Ux Block Input		Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_UVx	Enabling Commands	PHSPTUVx.Mod	Line Voltage Absence Unit Ux 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."

3.1.2.i Auxiliary Outputs and Events of the Phase Undervoltage Modules

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

Name	Group	IEC 61850	Description	Vis.	Function
PU_IUVx_A	Pickup Protection Outputs	PHSPTUVx.Str	Phase A Absence of Voltage Ux Pickup		Pickup of the undervoltage units and start of the time count.
PU_IUVx_B		PHSPTUVx.Str	Phase B Absence of Voltage Ux Pickup		
PU_IUVx_C		PHSPTUVx.Str	Phase C Absence of Voltage Ux Pickup		
TRIP_UVx_A	Trip Protection Outputs	PHSPTUVx.Op	Phase A Absence of Voltage U1 Trip		Trip of the undervoltage elements. The three-phase trips are those that are generated after the chosen AND or OR algorithm.
TRIP_UVx_B		PHSPTUVx.Op	Phase B Absence of Voltage U1 Trip		
TRIP_UVx_C		PHSPTUVx.Op	Phase C Absence of Voltage U1 Trip		
TRIP_UVx		PHSPTUVx.Op	Phase A Absence of Voltage Trip		

3.1.2.j IEC 61850 Logical Nodes

CLASS PHSPTUV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
VTyp	EXT_ENG	Type of voltage
EvTyp	EXT_ENG	Trip logic
OpDlTmmsLog	ING	Delay time for logs
MaxCur	ASG	Maximum current
HysVal	ASG	Hysteresis

3.1.2.k Protection Element Test

- **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. The table takes into account an adjustment of 5% for reset.

Table 3.1-4:Pickup and Reset of the Undervoltage Elements				
Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	1.02 x X or +10mV	0.98 x X or -10mV	X x 1.05 x 1.02 or (X x 1.05) + 10mV	X x 1.05 x 0.98 or (X x 1.05) - 10mV

It should be noted that the unit setting is a percentage of the nominal voltage of the equipment and that the nominal voltage of the equipment is phase-to-phase voltage . For example, for a nominal voltage of 2V, a pick-up setting of 40% and a reset setting of 5%, the theoretical pick-up value of the unit will be 462.43mV and the reset will occur at 485mV.

No current will be injected.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time

A 20% less than the selected pick-up setting will be applied. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz) or 28ms (for 60Hz), so the accepted range will be 72 to 8 ms at 50Hz and 68 to 12 ms at 60Hz.

3.1.3 Phase Overvoltage Elements

3.1.3.a Identification

Description of the Protection Unit	**Node IEC 61850**	**IEC 60617**	**ANSI/IEEE C37.2**
Phase Overvoltage Unit 1	PHSPTOV1	3U>	59-1
Phase Overvoltage Unit 2	PHSPTOV2	3U>	59-2

3.1.3.b General Block

VA →	**59**	→ PU_OV (per phase)
VB →	**PHSPTOV**	→ PU_OV_3PH
VC →		→ TRIP_OV (per phase)
INBLK_OV PH →		→ TRIP_OV_3PH
ENBL_OV_PH →		

3.1.3.c Operation Principles and Block Diagram

The equipment has one or two phase overvoltage units, depending on the model selected, and as many indications as lines are available in the equipment. Each unit is associated to the three analog voltage inputs of each board.

The units are always enabled by protection setting, but to be operational, the Fault Passage Detector automatism must be enabled.

Pickup occurs for a given overvoltage element when the value measured is equal to or greater than one times the set value, and resets at a selectable percentage (lower) over the setting.

The overvoltage element pickup enables the timing function. This is done by applying increments on a meter that picks up the element when it times out. The included time setting is fixed at 40ms and is not configurable. The unit has an extra setting to allow timing of the voltage presence signal for recording in the event log and for the sectionalizer automatism.

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.

In addition, the phase overvoltage units have an associated OR type logic (see Figure 3.1.1) so that it is necessary for the equipment to detect presence of voltage in all three phases to activate the general trip.

The status of the breaker (open/closed) and the phase current level are not taken into account for the operation of the unit.

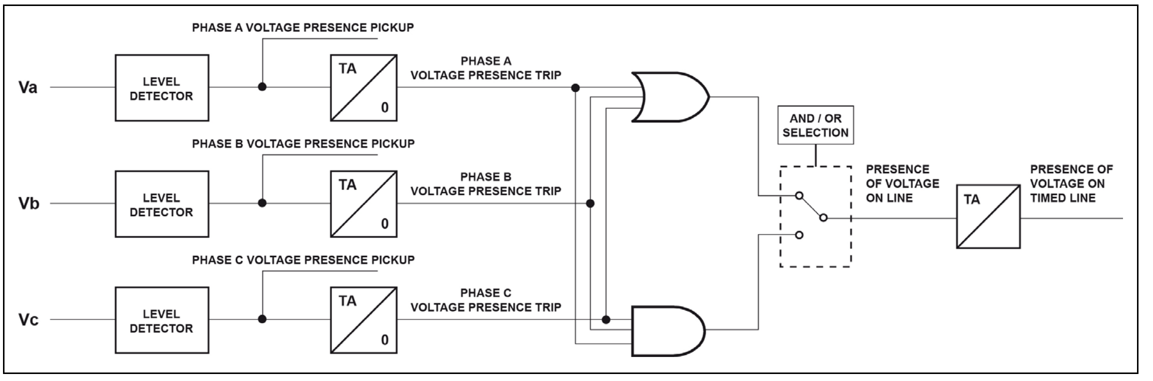


Figura 3.1.3 Block Diagram of the Phase Overvoltage Element.

3.1.3.d Application

The Phase Overvoltage Element detects overvoltage conditions in system elements such as generators, transformers, transmission and distribution lines, motors, etc. that can cause insulation damage in the protected equipment. These overvoltage conditions can be caused by different factors such as:

- Voltage drop not compensated by regulators.
- Bad operation of voltage regulators.
- Phase overvoltage derived from ground faults, even through the system should be designed to support them.
- Sudden voltage drop due to line bay trips.

In this way, the phase overvoltage element can be used to disconnect from the network any equipment that could be damaged when working under high voltage conditions.

3.1.3.e Recommendation of Unit Settings

The overvoltage unit should be properly coordinated with voltage units located in other bays that are part of the protection scheme.

It is common to use one unit as an alarm without having, therefore, permission to trip, and a second with a higher pick-up value as a protection unit itself. In both cases, the units will be timed. In those cases where it is important that the trip time is gradual and dependent on the severity of the overvoltage, the unit will be set with an inverse curve.

3.1.3.f Setting Ranges

Parameters / Lx / DPF &AF / Voltage Presence				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Pick-up (AUT_DPF_VPT) (%)	PHSPTOV.StrVal	10 - 120 V	0.1 V	40 V
Voltage Absence Time for Logs (AUT_TPT)	PHSPTOV.OpDlTmms	0 - 120 s	0.1 s	10 s

Fixed Settings in the Firmware

Parameters / Lx / DPF &AF / Voltage Presence		
Web Server	**IEC 61850**	**Value**
Enable	PHSPTOV.LNInSvc	YES
Delay	PHSPTOV.OpDlTmms	0.04s
Trip Logic	PHSPTOV.EvTyp	OR

3.1.3.g Analog Inputs to the Unit

The operating magnitude of the Phase Overvoltage Elements will be VA, VB and VC voltage.

Table 3.1-5: Analog Inputs of the Phase Overvoltage Modules		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

3.1.3.h Digital Inputs to the Phase Overvoltage Unit

Table 3.1-6: Digital Inputs to the Phase Overvoltage Modules

Name	Group	IEC 61850	Description	Vis.	Function
IN_BLK_OVx	Logic Inputs to Protection	PHSPTOVx.Mod	Line Voltage Presence Unit Ux Block Input		Activation of the input before the trip is generated prevents the element from operating. If activated after the trip, it resets.
ENBL_OVx	Enabling Commands	PHSPTOVx.Mod	Line Voltage Presence Unit Ux 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."

3.1.3.i Auxiliary Outputs and Events of the Phase Overvoltage Modules

Table 3.1-7: Auxiliary Outputs and Events of the Phase Overvoltage Modules

Name	Group	IEC 61850	Description	Vis.	Function
PU_OVx_A	Pickup Protection Outputs	PHSPTOVx.Str	Phase A Presence of Voltage Ux Pickup		Pickup of the overvoltage units and start of the time count.
PU_OVx_B		PHSPTOVx.Str	Phase B Presence of Voltage Ux Pickup		
PU_OVx_C		PHSPTOVx.Str	Phase C Presence of Voltage Ux Pickup		
TRIP_OVx_A	Trip Protection Outputs	PHSPTOVx.Op	Phase A Presence of Voltage U1 Trip		Triggering of the overvoltage units. The three-phase trips are those generated after the OR logic.
TRIP_OVx_B		PHSPTOVx.Op	Phase B Presence of Voltage U1 Trip		
TRIP_OVx_C		PHSPTOVx.Op	Phase C Presence of Voltage U1 Trip		
TRIP_OVx		PHSPTOVx.Op	Phase A Presence of Voltage Trip		

3.1.3.j IEC 61850 Logical Nodes

CLASS PHSPTOV		
Data Object Name	**Common Data Class**	**Explanation**
LNName		The name shall be composed of the class name, the LN-Prefix and LN-Instance-ID according to IEC 61850-7-2, Clause 22
Data Objects		
Status information		
Str	ACD	Pickup
Op	ACT	Trip
Settings		
StrVal	ASG	Start value
OpDlTmms	ING	Delay time
Extended Data		
LNInSvc	EXT_SPG	In service
VTyp	EXT_ENG	Type of voltage
EvTyp	EXT_ENG	Trip logic
OpDlTmmsLog	ING	Delay time for logs

3.1.3.k Protection Element Test

- **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. The table takes into account an adjustment of 5% for reset.

Table 3.1-8:Pickup and Reset of the Undervoltage Elements				
Setting of the unit	Pickup		Reset	
	Maximum	Minimum	Maximum	Minimum
X	1.02 x X or +10mV	0.98 x X or -10mV	X x 1.05 x 1.02 or (X x 1.05) + 10mV	X x 1.05 x 0.98 or (X x 1.05) - 10mV

It should be noted that the unit setting is a percentage of the nominal voltage of the equipment and that the nominal voltage of the equipment is phase-to-phase voltage . For example, for a nominal voltage of 2V, a pick-up setting of 80% and a reset setting of 5%, the theoretical pick-up value of the unit will be 924.85mV and the reset will occur at 867mV.

No current will be injected.

- **Operating Times**

To verify the operating times use an output configured with the trip signal of the unit.

Fixed Time

A 20% less than the selected pick-up setting will be applied. Operating time should be the selected time setting ±1% or ±32 ms (for 50Hz) or 28ms (for 60Hz), so the accepted range will be 72 to 8 ms at 50Hz and 68 to 12 ms at 60Hz.

3.2 Voltage in Bus Bars

3.2.1 Introduction

In the case of Ring Main Units (RMU) and modular assemblies with several lines, the equipment has a specific unit for calculating the bus voltage. It is based on the measurements of the voltages present on each line and the state of the circuit breakers/switches. Figure 3.2.1 shows the single-line diagram of a center in 3L2P configuration.

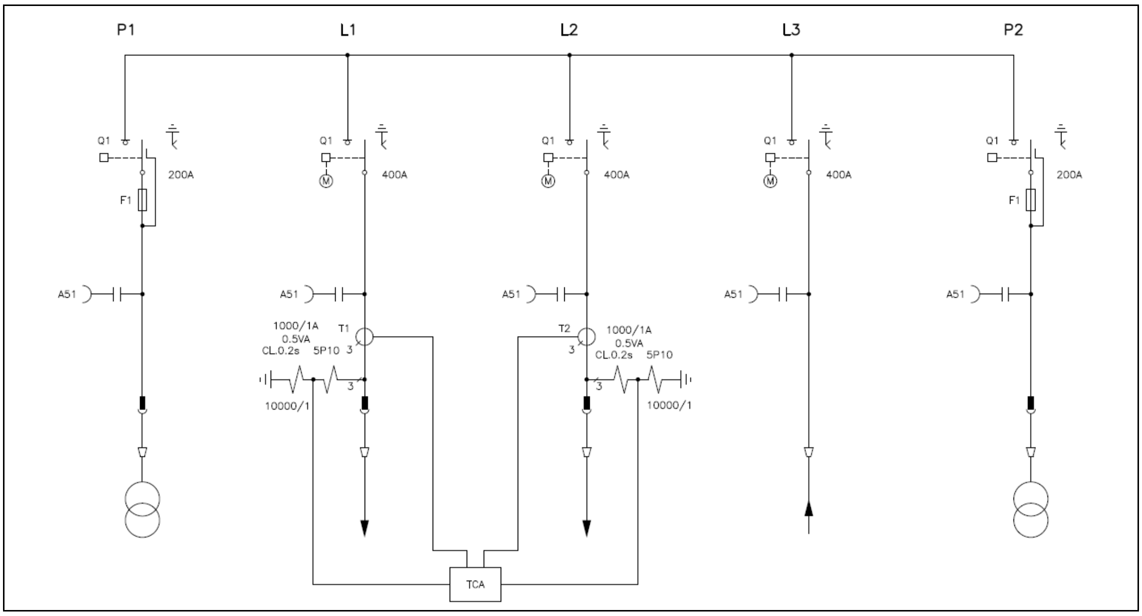


Figure 3.2.1 Voltage in Bus Bars.

3.2.2 Calculation of Voltage in Bus Bars

For the Bus Voltage calculation unit, it is necessary to indicate to the equipment which measures it must take into account in this calculation. The equipment can have up to a maximum of two analog input modules, each of them associated to a RMU line bay. They are identified as AI1 and AI2.

The Bus Voltage will be calculated as the arithmetic average of all the line voltages that have the breaker/switch associated with their line in a closed state. Therefore, lines with the switch open or in an unknown or invalid state will not participate in this calculation.

- If the state of all switches is open or unknown, the bus voltage value will be null, and the quality bit of the bus voltage measurement will be sent invalid.
- Similarly, if any of the monitored line voltages differs from the calculated bus voltage by more than 10%, the quality bit will also be invalid.

In addition, the status of circuit breakers/switches for which no analog measurement is available is taken into account. In distribution centers it is usual to have directional fault passage detector functions in N-1 available bays. The line without measurement or fault passage detection function is supervised by another equipment installed upstream.

The Bus Voltage Unit can consider these lines without measurement, monitoring the state of the line breaker / switch by an internal signal called **Possible Voltage in Bus Bars**. It will be necessary to define by means of the programmable logic, on which switch the monitoring is carried out and to which the Possible Voltage on Bus Bars signal is associated.

The Voltage on Bus Bars calculation unit considers the status of these breakers, so that, if the **Possible Voltage in Bus Bars** signal is active, they consider it possible that the last measurement stored will continue to be present on the bus. Its quality bit will be set to "Invalid" as it is not a real measurement refreshed in real time.

3.2.3 Setting Ranges

Voltage in Bus Bars Settings			
Setting	**Range**	**Step**	**Default**
EA1 Voltage Enable	YES / NO		YES
EA2 Voltage Enable	YES / NO		NO

3.2.4 Digital Inputs of the Voltage in Bus Bars Module

Table 3.2-1: Digital Inputs of the Voltage in Bus Bars Module

Name	Description	Function
POSS_BB_VOLTAGE	Possible Voltage in Bus Bars	It allows redirecting the state of a switch from a position from which no analog measurements are available to the bus voltage calculation module. If the rest of the circuit breakers are open and the unmonitored is in a closed or unknown state, the bus voltage will be equal to the last stored value and the quality bit will be invalid.

3.3 Open Phase

3.3.1 Identification

Description of the Protection Unit	**Node IEC 61850**	**IEC 60617**	**ANSI/IEEE C37.2**
Open Phase	-	3U<	27

3.3.2 General Block

Inputs		Block		Outputs
VA, VB, VC	→	**27**	→	Pickup of Open Phase
			→	Pickup Three-phase Voltage detection
Delay Time	→			
Voltage off level	→			
Voltage on level	→		→	Open Phase Detection
			→	Voltage Outage Detection

3.3.3 Operation Principles and Block Diagram

This unit will check the voltage values in order to determine if there are open phase conditions.

The pickup of the open phase unit occurs when the voltage measured in any of the phases (OR) is equal to or less than one time the value defined in the ***Voltage off level*** setting and it will reset when the voltage measured in all phases is equal or greater than the ***Voltage on level*** setting. The open phase pickup activation and deactivation enables the timing function so that the trip and reset of the open phase unit signal will take place once the time defined in the ***Delay Time*** setting has passed.

The open phase unit will also generate the **Voltage Outage Detection** signal. In this case the unit will also check if the voltage measured in the three phases (AND) is equal or less than one time the value defined in the ***Voltage off level*** setting, taking also into account the delay time, resetting when the three phase voltages are equal or greater than the value defined in the ***Voltage on level*** setting.

The off and on level settings are defined in values per unit based on the nominal voltage of the device (compound voltage).

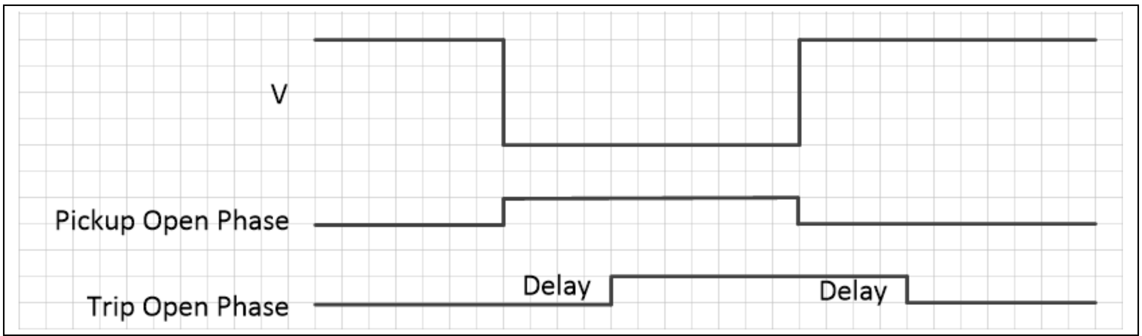


Figura 3.3.1 Signal Generation of Open Phase Unit.

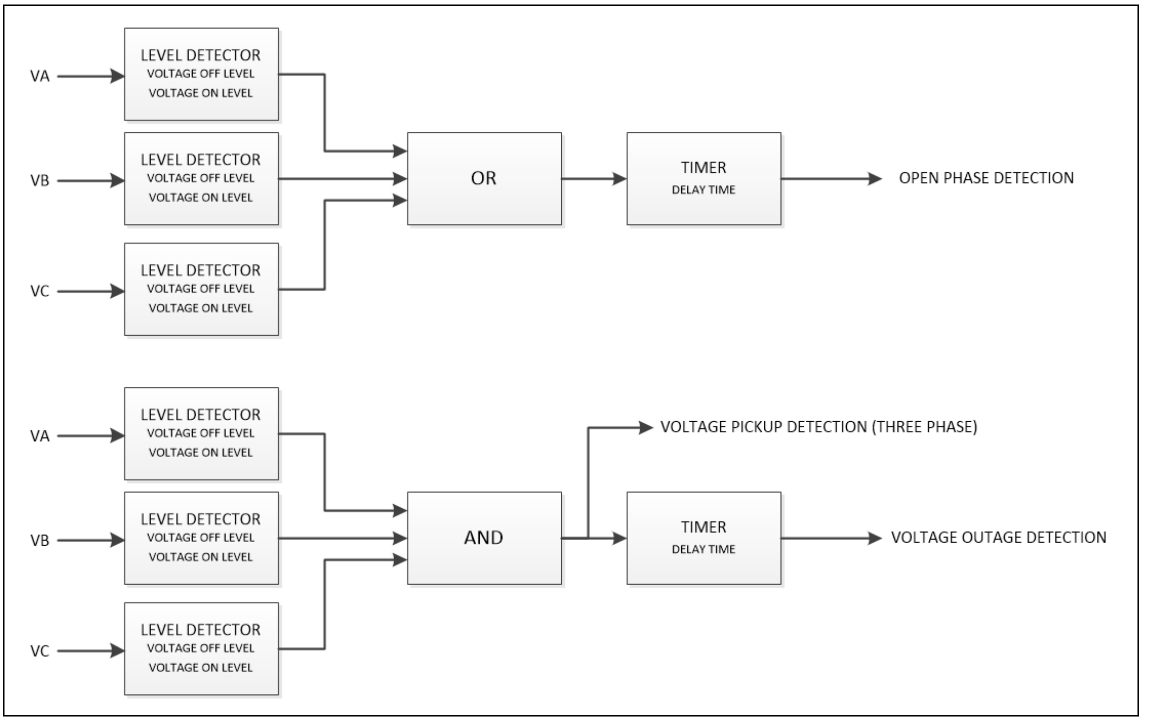


Figura 3.3.2 Block Diagram of the Open Phase Element.

3.3.4 Application

The open phase element detects undervoltage in system elements. These low voltage conditions can be caused by different factors:

- Malfunction of voltage regulation equipments.
- Power system overloads that imply a voltage supply drop, which cannot be compensated by the voltage regulation equipments.
- Trips causing phase voltage drop under fault conditions.
- Total absence of a busbar voltage caused by operation of the transformer or busbar protection scheme.

In this way, the open phase element can be used to disconnect from the network any equipment that could be damaged when working under low voltage conditions or under conditions that could produce overheating.

On the other hand, the open phase element also detects normal voltage conditions and cero voltage conditions, and this information is used by other units for their correct operation.

3.3.5 Setting Ranges

Parameters / Lx / DPF &AF / Voltage Absence				
Web Server	**IEC 61850**	**Range**	**Step**	**Default**
Open Phase Enable	-	Yes/No	-	Yes
Voltage off level	-	0.5-0.75pu	0.05pu	0.5pu
Voltage on level	-	0.7-0.85pu	0.05pu	0.8pu
Delay time	-	0 – 60s	0.1s	4s

3.3.6 Analog Inputs to the Unit

Analog Inputs to the Open Phase Module		
Name	**Description**	**IEC 61850**
VA	Phase A Voltage	MMXU1.PhV.phsA
VB	Phase B Voltage	MMXU1.PhV.phsB
VC	Phase C Voltage	MMXU1.PhV.phsC

3.3.7 Digital Inputs to the Open Phase Module

Table 3.3-1: Digital Inputs to the Open Phase Module					
Name	**Group**	**IEC 61850**	**Description**	**Vis.**	**Function**
ENBL_OP	Enabling Commands	-	Open Phase Enable Input	E	Activation of this input puts the unit into service. It can be assigned to status contact inputs by. The default value of this logic input signal is a “1” (unit enabled).

Note: Vis column, will indicate where the signal is going to appear: SLD Diagram (S), Details (D), Event (E), IEC 104 (I).

3.3.8 Auxiliary Outputs and Events of the Open Phase Module

Table 3.3-2: Auxiliary Outputs and Events of the Open Phase Module

Name	Group	IEC 61850	Description	Vis.	Function
OP_PICKUP	Pickup Protection Outputs	-	Pickup Open Phase Unit	E	Pickup of the open phase unit
OP_3PHPICKUP			Three-phase Voltage Detection Pickup Open Phase Unit	E	Pickup of the three-phase detection voltage
OP_PICKUPRESET			Pickup Voltage Reposition	E	Pickup of the voltage reposition signal before resetting the Open Phase Unit
OP_ACT	Trip Protection Outputs	-	Trip Open Phase	S D E	Trip of the open phase unit. Undervoltage in any phase.
OP_OUTAGE		-	Voltage Outage Detection	E	No voltage detection in any phase.

Note: Vis column, will indicate where the signal is going to appear: SLD Diagram (S), Details (D), Event (E), IEC 104 (I).

3.3.9 Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time.

Open Phase Unit	Ranges	Test Settings
Open Phase Enable	YES / NO	YES
Voltage off level	0.5-0.75pu	0.5pu
Voltage on level	0.7-0.85pu	0.8pu
Delay time	0 – 60s	4s

- **Open Phase Trip**

Inject nominal voltage values in the three phases. Decrease one or two phases below 0.5pu and check the activation of the **Pickup Open Phase Unit** signal and the activation of the **Trip Open Phase** signal 4 seconds later.

- **Open Phase Reset**

Being in the previous situation, increase the voltage of the phase or phases to the nominal value. Check that the **Pickup Voltage Reposition** signal activates at 0.8pu and that the **Trip Open Phase** signal deactivates 4 seconds later. At this time the **Pickup Voltage Reposition** signal will also deactivate.

- **Voltage Outage Detection**

Inject nominal voltage values in the three phases. Decrease the three of them below 0.5pu and check the activation of the **Trip Open Phase Detection** signal and the **Voltage Outage Detection** signal after 4 seconds.

Chapter 4.

Automatisms, Supervision and Control

4.1 Directional Fault Passage Detector

4.1.1 Introduction

One of the main functions of the **TCA** equipment is Fault Passage Detection (FPD). The equipment has as many DPF units as analog input modules. The detection mechanism is based on the sequence of changes in the magnitudes of current and voltage that occurs when a fault occurs in the system and is cleared by the overcurrent protection of the header substation.

This sequence consists of the appearance of an overcurrent in all or some of the phases followed by a drop in voltage and current once the fault clearing time has elapsed and the circuit breaker has tripped.

In addition, the direction of the fault should be known in order to help determine its location. For this purpose, directional algorithms are applied based on the angular relations between currents and voltages at the moment of the fault. If the above criterion is not adequate due to the specific grounding topology of the line, the impedance magnitude that is "seen" by the equipment will be applied.

The equipment shall incorporate the following auxiliary protection units to carry out the fault passage detection functionality:

- **Overcurrent Units**
    - 3 Phase Instantaneous Overcurrent Units (3 x 50), one for each phase (50A, 50B and 50C).
    - 3 Phase Time Overcurrent Units (3 x 51), one for each phase (51A, 51B and 51C).
    - 1 Neutral Instantaneous Overcurrent Unit (50N).
    - 1 Neutral Time Overcurrent Unit (51N).
    - 1 Sensitive Ground Time Overcurrent Unit (51Ns).
- **Directional Units**
    - 3 Phase Directional Units (3x67), one for each phase.
    - 1 Ground Directional Unit (67N).
    - 1 Sensitive Ground Directional Unit (67Ns).
- **Voltage Units**
    - 1 Line Voltage Absence Unit.
    - 1 Line Voltage Presence Unit.

When the equipment is switched on, an internal check will be carried out to determine whether it is able to operate correctly (there is voltage, currents within the operating ranges, no discordance or invalidity of any element). If all the checks are successful, the detection logic will start working, leaving an indication of all this in the event log.

Pickup of any overcurrent detection unit (phase, neutral or sensitive neutral) must not block the operation of the others.

All of these overcurrent functions may be activated/deactivated by setting. The direction of the fault must be indicated in order to determine the line segment where the fault occurred.

4.1.2 Operation Principle

The fault passage detection will have local indication. There will also be a local event register detailing the action of each of the overcurrent logics, timings and threshold values in each case, in order to allow a posteriori analysis of the correct action of the FPD logic.

Once the activation of an Overcurrent Unit has been detected, the Direction and Reverse Direction indications of each of the Overcurrent Units begin to be recorded. Their purpose is to be used to determine the direction of the fault passage using the logic described as follows.

When the fault is cleared by the header breaker, all Overcurrent Units will be deactivated. From that moment, the time to consider that this fault must be communicated (**Tact-pf**) begins. Once this time expires, and only if the Voltage Absence Unit has been activated (indicating that the substation header has tripped), will the fault detection be reported as true.

- The pulse duration of the Fault Passage Detector signals that are sent to the Remote Control (**FALT** and **RNEUTRO**) is determined by the ***Tpul-pf*** time setting.

- The duration of the address and address validity signals (**DIRDPF** and **VALDIR**) sent to the Remote Control, in turn, is determined by the ***Tdes-pf*** setting.

The purpose of indicating the fault passage by means of a pulse is to guarantee the signaling to the Remote Control of all fault passages that occur during a reclosing cycle. If a new fault occurs before the **Tdes-pf** timeout expires, the **DIRDPF** and **VALDIR** signals are reset (they return to their default state) and then activated again with the value corresponding to the new fault.

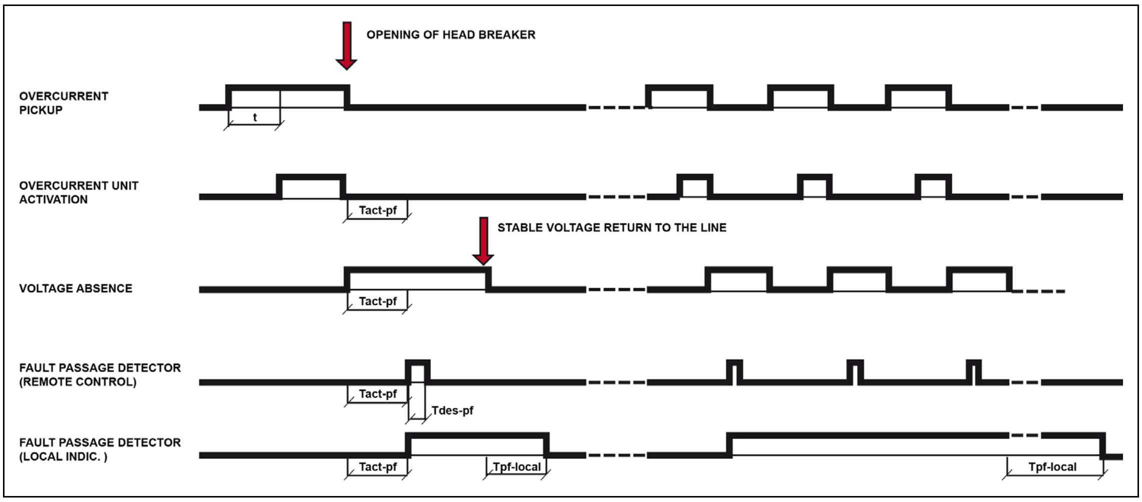


Figure 4.1.1 Fault Detection.

In addition, there is a local indication, which is normally connected by means of programmable logic to one or more of the LED indicators, which is activated at the same time as that of the remote control and is reset once the ***Tpf-local*** time has elapsed, which begins to count on the activation of the Voltage Presence Unit.

If any of the times expires and the conditions have not been met, the initial situation will be reset without indicating a fault passage.

In addition, the direction of the fault must be indicated, which will be calculated from the Direction and Reverse Direction signals delivered by the respective Directional Units.

- A fault in **Direction** will activate the direction (**DIRDPF**) and validity (**VALDIR**) signals.
- If it is in the **Reverse Direction**, **DIRDPF** will be equal to zero and **VALDIR** will be equal to one.
- If the address cannot be determined, the lack of validity will be indicated by making **VALDIR** and **DIRPF** equal to zero.

4.1.3 Fault Passage Detector for Sensitive Ground

The Sensitive Ground Overcurrent Unit is used as an input to a Fault Passage Detector independent of the general FPD. The behavior of this unit is identical to the one described above, with the only differences being that the fault direction is not calculated and that the signal sent to Remote Control to indicate the fault step is the **RNEUTRO**, equivalent to the **FALT**.

4.1.4 Fault Direction Determination Logic

The direction indication of the fault sent to the Remote Control and to the Local indication will be the result of the combination of the different indications derived from the Directional Units associated with the Overcurrent Units that are activated throughout the duration of the fault, from the moment when the first unit is activated until all of them are reset. To do this, the Direction and Reverse Direction signals of the units will be memorized as they are tripping. This information will be used when the ***Tact-pf*** time expires to determine if and how a valid direction can be given.

If a given Directional Unit has both Direction and Reverse Direction outputs with the same value, they are considered to contain no valid information. Therefore, they cannot enter into the calculation of the direction of the fault. From this moment on, three cases can occur:

1. There is no Directional Unit containing valid information. In this case the validity (**VALDIR**) and direction (**DIRDPF**) indications are set to zero.
2. There is a discrepancy between the directions indicated by the Directional Units. In this case it is not possible to determine which is the correct direction and proceed as in the previous case.
3. All units indicate the same direction. In this case the validity indication (**VALDIR**) will be set to one and the direction indication (**DIRDPF**) will be set to one if the fault is in Direction and to zero if it is in Reverse Direction.

Indication of the fault direction to the Remote Control is subject to being allowed by the ***Phase Fault Indication*** and ***Ground Fault Indication*** settings.

4.1.5 Indication of the Fault Passage to the Remote Control

All of the Overcurrent Units trips will be combined with an OR indicating the trip of any one of them. When this signal is deactivated by resetting all units that have fired, the Tact-pf time begins to be counted, after which the status of the Voltage Absence Unit is examined. If this unit is active, which indicates that there is no voltage or passage of current on the line, it is considered that there has been a fault passage and it is indicated with a pulse in the telecontrol signal (**FALT** and **RNEUTRO**) of duration **Tpul-pf**. Once this time has elapsed, the equipment returns to the initial waiting state for a new fault. The **DIRDPF** and **VALDIR** remote control signals will be activated together with the previous telecontrol signals and will remain active for a time ***Tdes-pf*** or until the reset and absence of voltage of a new fault. As a minimum, the rest time of these remote control signals will be 2 msg, delaying the same time the pulse indication of the new fault passage.

4.1.6 Local Indication of the Fault Passage

At the same time as the indication for the Remote Control is activated, the local indication is also activated by means of three signals analogous to those sent to the Remote Control but with different timings. These signals are as follows:

- Fault Detected.
- Valid Direction.
- Fault direction.

The local indication will remain active from the moment the fault passage is detected until a ***Tpf-local*** time has elapsed after the line voltage has been restored, a condition obtained from the output of the Voltage Presence Unit.

4.1.7 Validity of FPD Signals Transmitted to the Remote Control

The FPD signals transmitted to the Remote Control will only be valid if the settings of the protection units involved in detecting the fault passage contain values that do not block its operation. As an example, if the ***Enable*** setting of the fault passage unit is set to **NO**, the four fault passage signals that are transmitted to the Remote Control will be sent as **"0" + INV** (zero plus invalid). The rest of the validity conditions are indicated in the following table:

Table 4.1-1: FPD Validity Conditions

Settings Status	Remote Control Signals			
	FALT	DIRDPF	VALDIR	RNEUTRO
FPD disabled by adjustment or decalibration	"0" + INV	"0" + INV	"0" + INV	"0" + INV
Voltage presence detector disabled	"0" + INV	"0" + INV	"0" + INV	"0" + INV
Voltage absence detector disabled	"0" + INV	"0" + INV	"0" + INV	"0" + INV
Sensitive Ground Unit (51NS) disabled				"0" + INV
No overcurrent unit (50PH, 51PH, 50N, 51N, 67NA) enabled	"0" + INV	"0" + INV	"0" + INV	
FPD disabled by adjustment or decalibration	"0" + INV	"0" + INV	"0" + INV	"0" + INV

4.1.8 Setting Ranges

Fault Passage Detection			
Setting	**Range**	**Step**	**Default**
Enable	YES / NO		NO
Phase Faults Direction Indication	YES / NO		YES
Ground Faults Direction Indication	YES / NO		YES
Activation delay (Tact-pf)	0 - 60 s.	0.001 s.	1 s.
Remote indication pulse duration (Tpul-pf)	0 - 60 s.	0.001 s.	0.001 s.
Local indication time (Tpf-local)	0 - 150 min.	0.001 min.	10 min.
Remote indication time (Tdes-pf)	0 - 3600 s.	0.001 s.	600 s.

4.2 Fault Isolation Automatism

4.2.1 Introduction

One of the main functions of the **2TCA-E** equipment is Fault Isolation Automation, also known in some areas as Sectionalization Automation. This function is associated with each of the analog input modules.

The Fault Isolation Automation (FI) is a local automation, available at cell level or line bay , which performs the necessary operations after a fault detection, to isolate and minimize the reach of the fault zone.

The mechanism of this automation is fed by the signals provided by the Fault Passage Detection Unit (FPD) and the Voltage Presence and Absence Units, as well as by the status information on the position of the breakers.

4.2.2 Operation Principle

The protection breakers located at the head of the line can perform reclosings, after opening due to a fault, to try to re-establish the voltage in the line. A typical example of an actuation is shown in the figure below.

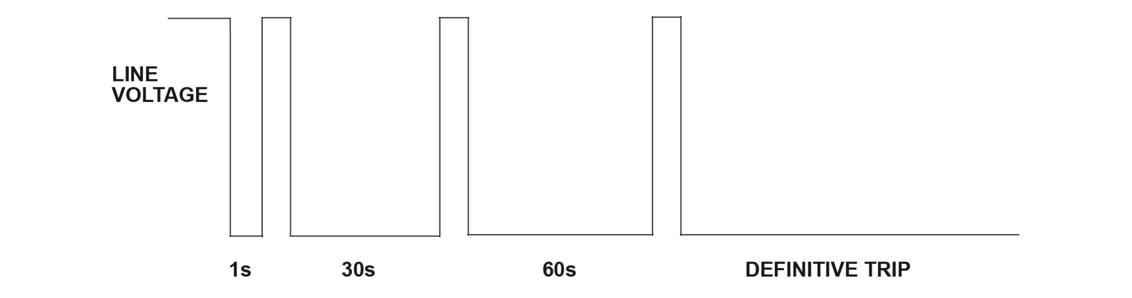


Figure 4.2.1 Example of Header Breaker Reclosures.

Since the breakers are not ready for a faulted opening, the long zeros without voltage in the example (between first and second reclosing and between second and third reclosing in Figure 4.2.1) are used to clear the fault and restore service by operating the no-voltage breakers.

The first voltage zero (1 s in the example) between trip and first reclosing is too fast to implement any type of automatic fault clearing sequence. It is for this reason that long zeros are used for the fault isolation sequence, which would imply that only 2 AF in series could be activated in this line, in the case of a head breaker with 3 reclosings.

The number of voltage zeros depends on the setting of the equipment and is the order counting upstream, as shown in the following figure.

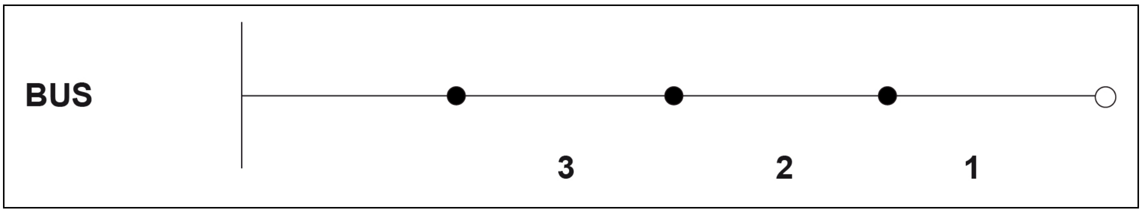


Figure 4.2.2 Parameterization of Line Elements.

As a reference, a series of general criteria are defined for the parameterization of the Fault Isolation Automatism:

1. For each line there will be 2 automated elements normally parameterized at 2 and 3 reclosures (3 the upstream element and 2 downstream) to open at the longest voltage zeros. There may be more elements if they are in parallel branches, parameterized in the same way.
2. Other automated elements of the line, interspersed between the previous ones, must be in Manual and parameterized (number of long voltage zeros, etc.) such as those downstream.
3. Parameterization depends on the MV topology, so when modifying it, the parameters must be adapted to the new situation.

The Fault Isolation Automatism can be enabled and disabled by means of the ***Enable*** setting, this circumstance being indicated by the digital **Fault Isolation Enabled** signal. When the automatism is enabled by means of adjustment, it remains in default and in **Manual** state, being the operator the one who passes it to **Automatic** state by means of a Local or Remote command.

Remote commands to Automatic or Manual are received through the IEC 60870-5-104 Remote Control protocol, provided that the Local/Remote Control input is in **Remote Control**. The automatism can also be controlled by means of the local commands of the equipment that control the inputs **Switch to Automatic Local Command** and **Switch to Manual Local Command** internal of the module, as long as the Local/Remote Control status is in **Local**.

In both cases the status of the automatism is indicated by the **Fault Isol. Auto Mode**, which remains active in the Automatic state and inactive in the Manual state. This signal is available for transmission to the control center by means of the Remote Control protocol. The status of the automatism is reflected in the optical signals of the device together with the local control command (**AUT / MAN**).

With each fault passage detection performed by the FPD unit an internal counter is increased. When the set ***Number of Faults*** is reached, it will examine whether the fault that caused the first trip of the header protection is in any of the directions allowed for the execution of the automatism. If it is, and once the ***Voltage Absence Time*** has elapsed, it will give the order to open the breaker. This time is necessary to avoid that the breaker operation is carried out with a short voltage zero.

If the opening operation is successful, the Fault Isolation Automatism returns to the default state, waiting for a new cycle of reclosings.

If the opening operation is not carried out for any reason, the automatism will return to default and to the **Manual** state, remaining in this state until it is returned to **Automatic** by means of a local or remote command.

In any case, the activation of the automatism causes the activation of the digital **Fault Isolation Operation** signal, which can be communicated to the dispatch of operations by means of the Remote Control protocol.

In the event of a stable voltage return to the line that is maintained for a time longer than the ***Maximum Waiting Time***, which is determined by the activation of the Voltage Presence Unit, the reclosing cycle will be considered completed and the automatism will return to the default condition, in the event that a fault has already been recorded.

4.2.3 Indication of Fault Isolation to The Remote Control

There are two digital signals that can be transmitted to the dispatch of operations by means of the Remote Control protocol through which the status of the automatism is indicated:

- **Fault Isolation Auto mode**. This signal remains active when the automatism is enabled and in the Automatic state, and inactive otherwise.
- **Fault Isolation Operation**. This signal is activated momentarily when the automatism generates a command to open the breaker.

The Remote Control can send commands from switch to Manual or Automatic to the FI Automatism, which will be executed if the automatism is enabled and the equipment has the Local/Remote Control input activated. Otherwise, the commands will be rejected.

4.2.4 Validity of FI signals Transmitted to the Remote Control

The FI signals transmitted to the remote control will only be valid if the settings of the protection units involved in the fault passage automatism contain values that do not block its operation. As an example, if the ***Fault Isolation Automatism Enable*** setting is set to NO, the two signals that are transmitted to the Remote Control will be sent as "0" + INV (zero plus invalid). The rest of the invalidity conditions are indicated in the following table:

Table 4.2-1: Conditions of Invalidity of FI Signals

Settings Status	Remote Control Signals
FI automatism disabled by setting	"0" + INV
FPD disabled by adjustment or decalibration	"0" + INV
Voltage Presence Detector disabled	"0" + INV
Voltage Absence Detector disabled	"0" + INV
No Overcurrent Unit (50PH, 51PH, 50N, 51N, 51NS 67NA) enabled	"0" + INV

4.2.5 Setting Ranges

Fault Isolation Automatism		
Setting	**Range**	**Default**
Enable	YES / NO	YES
Number of Faults	1 - 4	2
Absence Voltage Time	0 - 120 s.	5
Maximum Waiting Time	0 - 120 s.	10
Outgoing to Bus	YES / NO	YES
Incoming to Bus	YES / NO	
Unknown Direction	YES / NO	YES

4.2.6 Digital Inputs of the Fault Isolation Automatism

Table 4.2-2: Digital Inputs of the Fault Isolation Automatism(1)

Name	Function
Switch to Manual Local Command Switch to Automatic Local Command	The activation of these inputs controls the switch to Manual or Automatic of the Automatism. These inputs **can be connected** to other equipment signals by means of configurable logic.
Switch to Manual Remote Command Switch to Automatic Remote Command	The activation of these inputs controls the switch to Manual or Automatic of the Automatism. These inputs are **permanently connected** to the command output of the Remote Control protocol.

4.2.7 Auxiliary Outputs and Events of the Fault Isolation Automatism

Table 4.2-3: Auxiliary Outputs and Events of the Fault Isolation Automatism(1)

Name	Function
Fault Isolation Enabled	Fault Isolation Enable Indication
Fault Isolation Pickup	Indication that the automatism is carrying out a cycle.
Fault Isolation Check Error	Indication that there is some condition that prevents the Automatism from operating.
Opening Command due to Fault Isolation	Indication that an Opening Command has been made.
Fault Isolation Auto Mode	Indication for the Remote Control that the automatism is in Automatic mode
Fault Isolation Operation	Indication to the Remote Control that the automatism has carried out a Fault Isolation operation.

(1) For the second analog board the signals are identified in the same way, but with the prefix "U1_".

4.3 Analog Measurements Supervision

4.3.1 Introduction

The **2TCA-E** models have a supervision system for the set of elements that make up the system for measuring phase voltages and currents, from the voltage dividers and external current transformers, through the copper cables that connect them to the relay, to the equipment's own internal measurement modules.

This supervision provides an output that can be used to activate an LED indication to facilitate installation in the Secondary Substation, to disable the functions deemed appropriate or to notify the anomaly through communications.

Additionally, this output may cause the invalidity bit of all the analog signals to be activated and consequently deactivate the protection functions. This behavior can be enabled by means of its corresponding setting, and if activated, all the measurement signals sent by Remote control will have their invalidity bit activated. This setting can be seen in the following Figure.

4.3.2 Operation Principles

This supervision function is based exclusively on the own measurement of the phase voltages and currents, being able to consider that it is formed by three subunits, each one of which supervises a different functionality.

4.3.2.a Voltage Sequence Supervision Unit

In order to monitor that all voltage inputs are correctly connected, both in all phases and in the appropriate sequence, it is checked that the negative sequence voltage **V2** is less than 20% of the positive sequence voltage **V1**. Higher values of V2 would indicate that one or two of the phases are not measuring voltage, that the phase sequence is reversed or that the ground connection has been exchanged with any of the phases.

4.3.2.b Current Monitoring Unit

If the negative sequence voltage **V2** is too small and it is not possible to compare it with **V1**, there is an additional supervision that checks that there is no current passage in the absence of voltage of the corresponding phase. For this purpose, fixed thresholds of 5 A and 100 V respectively are established in primary values.

4.3.2.c Phase Concordance Unit

Finally, for the phases that exceed the set thresholds, the concordance of each of them between the voltage and the current is checked. Valid phase shifts between -40º and +20º for outgoing phases and between +140º and +200º for incoming phases are considered. The equipment checks that none of the phases is out of these ranges and that all the phases are either incoming or outgoing.

If none of the three phases exceeds the thresholds, no phase matching error will be generated. Such is the case of a line or center that is not in operation, in which the voltages are correct, but the measured currents are very low and below the thresholds.

The outputs of the three units are combined with an OR function, so that the activation of any of them for more than 10 seconds activates the **Input Connection Error** output.

The following figure shows the supervision logic of analog measurements:

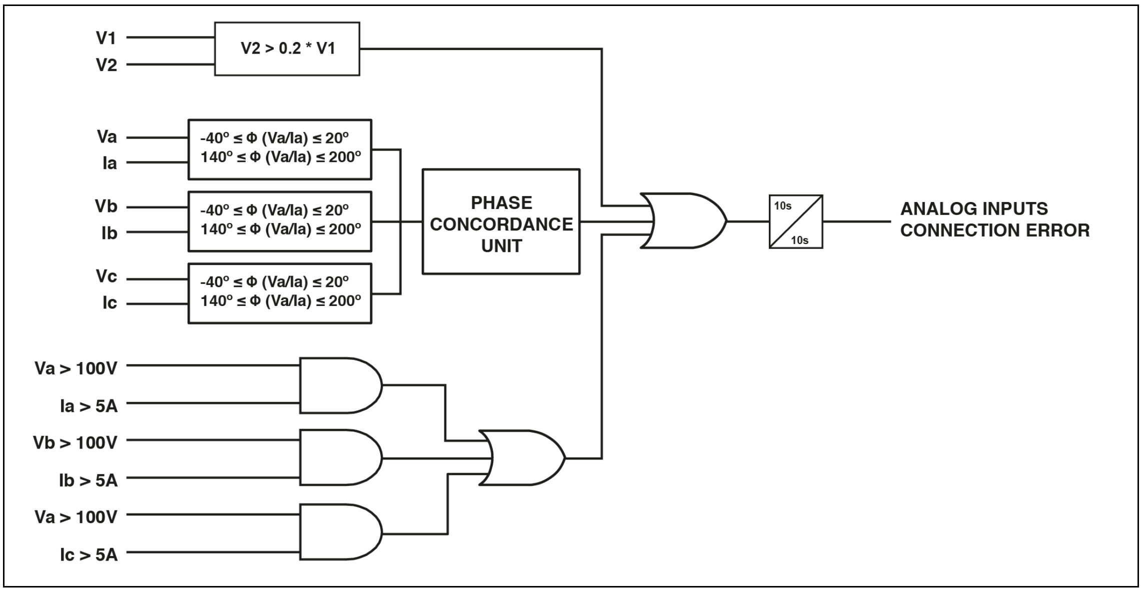


Figure 4.3.1 Analog Measurement Supervision Logic.

The detection of a fault in one of the measurement circuits only generates the activation of the **FAIL_EA** signals. The visual indications or by communications and the blocking of the trip of protection units that are affected by a bad function in the measurement of phase voltages and currents, must be programmed in the logic.

4.3.3 Digital Outputs of Analog Measurement Supervision

Table 4.3-1: Digital Outputs and Events of the Current Measurement Supervision[1]

Name	Description	Function
FAIL_EA	Analog Measurements Supervision Unit Activation	Its activation indicates the existence of a failure in the measuring system of any of the phases.

[1] For the second analog board the signals are identified in the same way, but with the prefix "U1_".

4.4 Phase Sequence

4.4.1 Introduction

In many occasions, in Secondary Substations it is not possible to make the connection of the phases so that the sequence of these is the standard (ABC). It is also not possible to know beforehand which phases the power cables physically correspond to, which means that the sequence of phases resulting from the installation will not be known.

In order to avoid problems due to the erroneous calculation of the Sequence Magnitudes and in the determination of the Polarization Magnitudes to be used by the Directional Units, a ***Phase Sequence*** setting has been provided that informs the relay of the real rotation of the system and, maintaining the same connections of the analog current and voltage inputs indicated for phases A, B and C in the external connection scheme, the correct operation of all the functions is obtained.

There are three selectable values for this setting: **ABC**, **ACB** and **Calculated**. In the latter case, the sequence of phases is automatically recognized by the relay from the assumption that the direction of rotation of the voltages under normal and stable conditions generates much more positive sequence voltage V1 than negative sequence V2. This function is instantiated as many times as the equipment has analogue cards.

4.4.2 Phase Sequence Detection

When the phase sequence setting has the Calculated value, the **2TCA-E** determines the actual phase sequence of the power system from the values of the positive sequence V1 and negative sequence V2 voltage magnitudes.

For this purpose, the voltage of each phase is first compared with an adjustable threshold voltage, and only if all phase voltages exceed it, the calculation of the direction of rotation is continued.

If this threshold has been exceeded, it is checked if the ratio between V2 and V1 is higher than a ratio configurable by setting. If this is the case, a timer also adjustable in time is started, at the expiry of which the phase rotation indicator that was in force for the calculations at that time is reversed.

The following Figure shows the logic that controls this Phase Sequence Detection Unit.

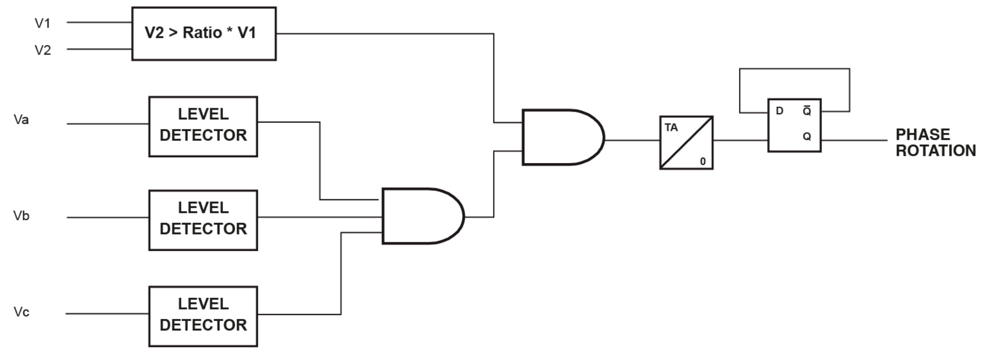


Figure 4.4.1 Phase Sequence Detection Unit Logic.

4.4.3 Setting Ranges

Phase Rotation Detection Settings			
Setting	**Range**	**Step**	**Default**
Phase Sequence	0: ABC 1: ACB 2: Calculated		2: Calculated
Minimum Voltage	100 V - 36,000 V	1 V	2000 V
V2/V1 Ratio	1.05 - 5	0.01	1.2
Time	0.1 s - 60 s	0.01	5 s

4.4.4 Digital Outputs and Events of the Phase Rotation Detection Module

Table 4.4-1: Digital Outputs and Events of the Phase Rotation Detection Module

Name	Description	Function
ROT_ABC	Direction of phase rotation ABC	Phase rotation direction indication outputs.
ROT_ACB	Direction of phases rotation ACB	

4.4.5 Phase Sequence Unit Test

4.4.5.a Setting Values

Adjust the equipment with the values in Table 4.4-2.

Table 4.4-2: Settings for Testing the Phase Sequence Unit

Setting	Value
Phase Sequence	2: Calculated
Minimum Voltage	2000 V
V2/V1 Ratio	1.2
Time	5 s

Apply a balanced three-phase voltage with ABC rotation sequence equivalent to a primary voltage higher than 3.5 kV phase-to-phase to the equipment voltage measurement inputs. After 5 seconds, check that the equipment indicates that the phase sequence is "ABC" on the Statistics page.

Exchange any two phases, e.g. A with B. Similarly, after 5 seconds, check that the equipment indicates that the phase sequence is "ACB" on the Statistics page.

4.5 Breaker Monitoring

4.5.1 Introduction

Each measuring unit has the capacity to manage the operations of one or two circuit breakers or switches. The command can be carried out by actuating the motorization or by means of trip and closing coils.

To do this, it has a logic that performs the following functions:

- Minimum and maximum Open Command activation time.
- Minimum and maximum Close Command activation time.
- Time delay for failure to open and close the circuit-breaker.
- Duration of motor protection switch trip.
- Maximum transition time of the circuit breaker contacts.

The two breakers are functionally identical, with the only difference that breakers 1 and 2 can be operated by means of a local command or a command from the remote control, while the opening of breaker 1 can also be carried out by the fault isolation automatism.

This chapter only describes the breaker 1, and it also applies to breaker 2 with the exception mentioned above.

4.5.2 Identifier

Each of the two switches has an identification text of between 0 and 20 characters that will appear in the list of events to help its interpretation.

4.5.3 Breaker Position Transition State

The position of the breaker is determined by the status of two signals coming from the breaker's auxiliary contacts: 52/a indicating breaker closing and 52/b indicating breaker opening. Both signals are complementary and combinations "00" and "11" are considered invalid. During the operation there will be a transition time, the duration of which will depend on the breaker mechanism, during which both signals may remain with the same logic value, being considered a valid condition as long as the time defined by the ***Position Transition Maximum Time*** setting is not exceeded. During this time, the status of the breaker position will not be updated while it remains in any of the invalid combinations "00" or "11”.

4.5.4 Duration of Commands

The close and open commands will remain active as long as the fact that it produces them remains active and until the corresponding change in the position of the breaker is detected. However, a minimum order duration can be defined by the ***Minimum Open Command Activation Time*** and ***Minimum Close Command Activation Time*** settings, which will extend the active command time up to the set value, even if the command has been executed.

In addition, there are two settings: ***Maximum Open Command Activation Time*** and ***Maximum Close Command Activation Time*** which limits the time during which the corresponding commands are active, proceeding to its reset even if the command has not been executed yet.

4.5.5 Breaker Open and Close Failure Time

Both in the case of manual operations and those generated by protection automatisms, 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.

Associated with the command failure signals is a motor protection output that can be used to instantly trip the magnetothermic circuit breaker that protects the motor or an auxiliary relay, if this function is available in the motor. The duration of this signal is determined by the ***Motor Protection Trip Duration*** setting, with a range between 0.1 and 10 seconds.

Open and close commands are active during the activation time setting even if Open or Close Command Failure is produced.

4.5.6 Digital Inputs and Events of the Breaker Supervision Module

Table 4.5-1: Digital Inputs and Events of the Breaker Supervision Module (1)

Name	Description	Function
BLK_BRK	Breaker Blocking Input	Prevents execution of the order.
BRK_OPEN	Open Breaker Input	Indicate the position of the breaker.
BRK_CLS	Closed Breaker Input	
LOCAL_OPEN	Local command to open the breaker	Inputs for local commands.
LOCAL_CLS	Local command to close the breaker	

4.5.7 Auxiliary Outputs and Events of the Breaker Supervision Module

Table 4.5-2: Auxiliary Outputs and Events of the Breaker Supervision Module(1)

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	

(1) For each breaker supervision unit, up to a maximum of four units. Each AI(i) board has two breaker controls.

4.5.8 Setting Ranges

Common Logic Settings(1)			
Setting	**Range**	**Step**	**Default**
Identifier	0 - 20 characters		
Position Transition Maximum Time	0 - 30 s	0.001 s	0.05 s
Fail to Open and Close Time	0.1 - 30 s	0.001 s	0.1 s
Fail to Open and Close Time	0.1 - 30 s	0.001 s	0.1 s
Motor Protection Trip Duration	0.1 - 10 s	0.001 s	0.2 s

Individual Logic Settings(1)			
Setting	**Range**	**Step**	**Default**
Identifier	0 - 20 characters		
Motor Protection Trip Duration	0.1 - 10 s	0.001 s	0.2 s

(1) For each breaker supervision unit, up to a maximum of four units. Each AI(i) board has two breaker controls.

4.6 Analog Inputs Settings

4.6.1 Introduction

There are two groups of settings within the Analog Inputs Settings group: **Nominal Values** and **Transformation Ratios**.

4.6.2 Nominal Values

These settings are used to select the nominal operating values. The selectable parameters are:

- ***Frequency***. It allows to choose the nominal frequency of the network, which determines the sampling frequency used for the calculations of the analog magnitudes.
- ***Voltage***. It adjusts the nominal value of the primary voltage in phase-phase value, being the reference for all those settings that are expressed in percentage of the nominal voltage.

4.6.3 Transformation Ratios

These settings define the transformation ratios of the current transformers, the division factors of the resistive dividers for voltage measurement and the magnitude and phase corrections of all sensors.

- ***Toroidal Transformer Ratio***. There is a common setting for all phases, the value of which is multiplied by the current measured in the secondary to obtain the phase current of the primary.
- ***Resistive Divider Transformation Ratio***. There is also a common setting for all phases. The output voltage of the resistive divider measured by the relay is multiplied by this setting to obtain the phase-ground voltage of the line.
- ***Resistive Divider Factor***. This is an adjustment, independent for each phase, which serves to compensate for the magnitude error that the resistive divider may present with respect to its nominal value. The result of multiplying the measured voltage by the transformation ratio is divided by this setting to obtain the corrected phase-ground voltage measurement.

$$Phase-Ground\_Voltage = \frac{Measured\_Voltage * Transformation\_Ratio}{Divider\_Factor}$$

- ***Offset Divider Factor***. This is a setting, independent for each phase, which serves to compensate for the phase shift that can present the resistive divider and the connection cable. The value of this setting is subtracted from the angle value calculated by the IED.

$$Voltage\_Angle = Calculated\_Angle - Offset$$

- ***Toroidal Factor***. This is an adjustment, independent for each phase and for each bay, which serves to compensate for the magnitude error that the toroidal transformer may present with respect to its nominal value. The result of multiplying the measured current by the current transformation ratio is divided by this setting to obtain the corrected phase-ground current measurement.

$$Phase-Ground\_Current = \frac{Measured_{current} * Current\_Transformation\_Ratio}{Divider\_Factor}$$

- **Offset Toroidal Factor:** This is a setting, independent for each phase and for each bay, which serves to compensate for the phase shift that can present the current toroidal sensor and the connection cable. The value of this setting is subtracted from the angle value calculated by the IED.

$$Current_{Angle} = Calculated_{Angle} - Offset_{toroidal}$$

4.6.4 Setting Ranges

Nominal Values			
Setting	**Range**	**Step**	**Default**
Nominal Frequency *	50 Hz / 60 Hz		50 Hz
Nominal Voltage	0 - 72 kV	0.1 kV	20 kV

*Depending on the model.

Transformation Ratios			
Setting	**Range**	**Step**	**Default**
Toroidal Transformer Ratio*	1:1 / NA(A:A) or (A/V)		1000:1
Resistive Divider Transformation Ratio	1:1 / NA (kV:V)		20:2
Resistive Divider Factor*	0.5 – 1.5	0.0001	1
Offset Divider Factor*	-90º – 90º	0.01º	0º
Toroidal Factor*	0.5 – 1.5	0.0001	1
Offset Toroidal Factor*	-90º – 90º	0.01º	0º

*Depending on the model.

- **Analog Inputs Settings by Web Page**

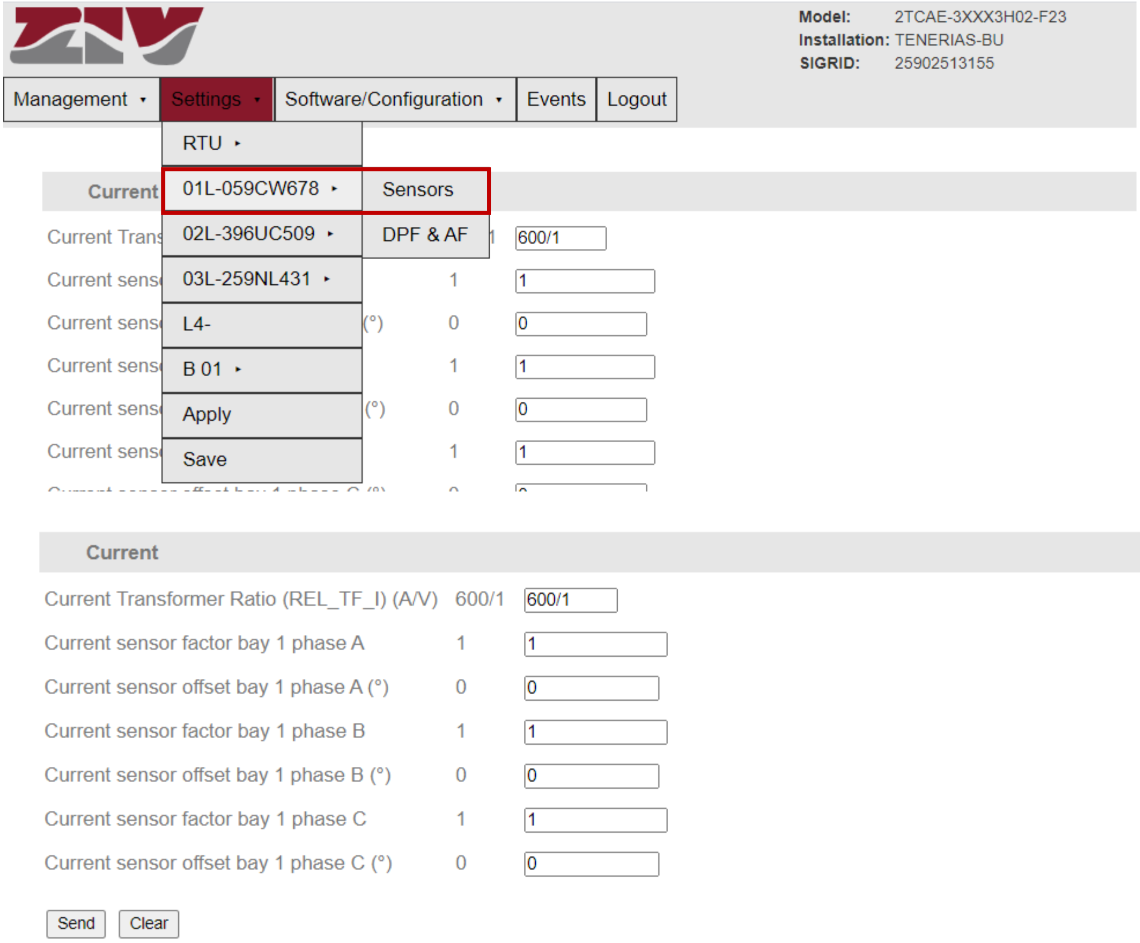


Figure 4.6.1 Current Sensor Settings.

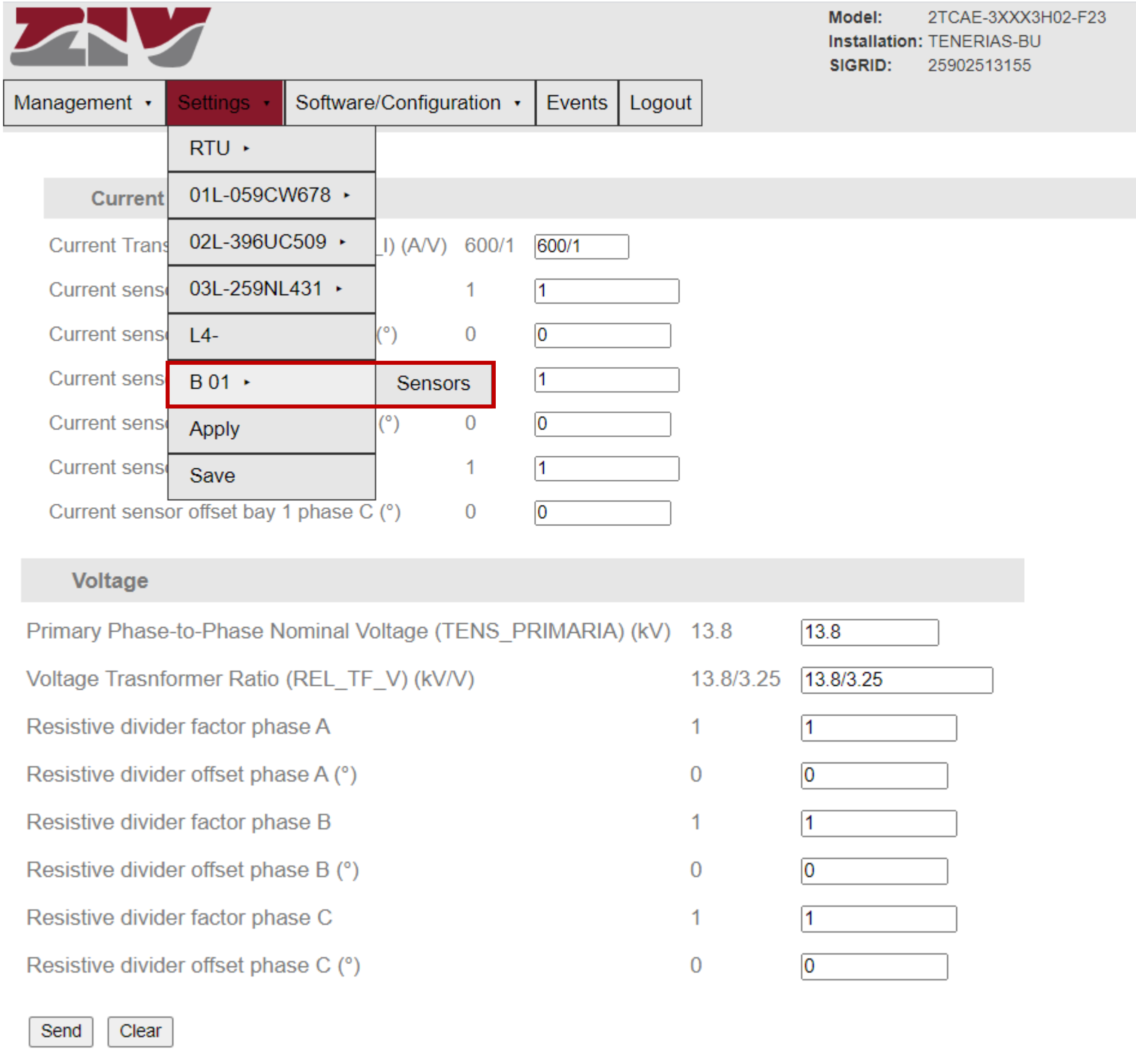


Figure 4.6.2 Voltage Sensor Settings.

4.7 Event Record

4.7.1 Description

The equipment's event logging capacity is 1670 annotations in non-volatile memory, for standard models, and in turn, for expanded memory models the event logging capacity is 4000 annotations. The signals that generate the events are selectable by the user and their annotation is made with a resolution of 2ms along with the 8 analog magnitudes of the equipment. The magnitudes annotated correspond to the bay that generates the event.

Each of the functions used by the system (protection units, system events, digital inputs/outputs and logic) will record an event in the History Log when any of the situations listed in Table 4.7-1 and Table 4.7-2 occur.

The events are organized in two groups:

- **Common system events**, which do not refer to a particular bay, but refer to the set of equipment that may be interconnected in an installation.
- **Events of bays**, which are linked to a given bay.

Table 4.7-1: Recording of Common System Events

System
Local / Remote Operation Mode
Communication with Control Center
Watchdog
Pickup Log
RTU Pickup
RTU Restart
Configuration File Transfer
Configuration Pattern Load
SW Update
Change of Configuration
Change of Configuration by WS
Static / Dynamic IP
Clock
Clock Synchronization
Change to winter / summer time
User Access
Remote access administrator user LOGIN
Remote access visualization user LOGIN
Local access administrator user LOGIN
Local access visualization user LOGIN
Web Login Failed
CLI Login Failed

Table 4.7-1: Recording of Common System Events
Digital Inputs and Outputs
Digital Input 01.
Digital Input 02.
Digital Input 03.
Digital Input 04.
Digital Input 05.
Digital Input 06.
Digital Input 07.
…
Digital Input 45.
Digital Input 46.
Digital Input 47.
Digital Input 48.
Global Unblocking Command of Digital Inputs.
Error in the digital input board 1.
Error in the digital input board 2
Error in the digital input board 3.
Auxiliary Output 01.
Auxiliary Output 02.
Auxiliary Output 03.
Auxiliary Output 04.
Auxiliary Output 05.
Auxiliary Output 06.
Auxiliary Output 07.
Auxiliary Output 08.
Analog Inputs
Voltage in Busses Measurement Validity
Possible Voltage in Busses
Incongruence current presence LE open
Logic
Simple logic state 01
Simple logic state 02
Simple logic state 03
Simple logic state 04
Simple logic state 05
Simple logic state 06
Simple logic state 07
Simple logic state 08
Simple logic state 09
Simple logic state 10
Simple logic state 11
Simple logic state 12
Simple logic state 13
Simple logic state 14
Simple logic state 15
Simple logic state 16
Simple logic state 17
Simple logic state 18
Simple logic state 19

Table 4.7-1: Recording of Common System Events
Logic
Simple logic state 20
Simple logic state 21
Simple logic state 22
Simple logic state 23
Simple logic state 24
Simple logic state 25
Simple logic state 26
…
Simple logic state 60
Simple logic state 61
Simple logic state 62
Simple logic state 63
Simple logic state 64
Double logic state 1
Double logic state 2
Double logic state 3
Double logic state 4
Double logic state 5
…
Double logic state 15
Double logic state 16
Double logic state 20
Double logic state 21
Double logic state 22
Double logic state 23

Note 1: Given the manufacturer's configuration for logic, it is possible to define types of special signals and own events.

Table 4.7-2: Recording of Bay Events
Direction of Phase Rotation
Phase Sequence ABC/ACB
Phase Instantaneous Overcurrent
50U Enable
50U Blocking
50U Time Disable
50U Torque Control Disable
50U Enabled
50A Pickup Conditions
50A Pickup
50A Trip
50B Pickup Conditions
50B Pickup
50B Trip
50C Pickup Conditions
50C Pickup
50C Trip
Ground Instantaneous Overcurrent
50N Enable
50N Blocking
50N Time Disable
50N Torque Control Disable
50N Enabled
50N Pickup Conditions
50N Pickup
50N Trip
Phase Time Overcurrent
51U Enable
51U Blocking
51U Time Disable
51U Torque Control Disable
51U Enabled
51A Pickup Conditions
51A Pickup
51A Trip
51B Pickup Conditions
51B Pickup
51B Trip
51C Pickup Conditions
51C Pickup
51C Trip

Table 4.7-2: Recording of Bay Events
Ground Time Overcurrent
51N Enable
51N Blocking
51N Time Disable
51N Torque Control Disable
51N Enabled
51N Pickup Conditions
51N Pickup
51N Trip
Sensitive Ground Time Overcurrent
51NS Enable
51NS Blocking
51NS Time Disable
51NS Torque Control Disable
51NS Enabled
51NS Pickup Conditions
51NS Pickup
51NS Trip
Phase Directional
67 Inhibition
67 Polarization Inversion
67A Instantaneous Direction
67A Time Direction
67A Instantaneous Reverse Direction
67A Time Reverse Direction
67B Instantaneous Direction
67B Time Direction
67B Instantaneous Reverse Direction
67B Time Reverse Direction
67C Instantaneous Direction
67C Time Direction
67C Instantaneous Reverse Direction
67C Time Reverse Direction
Ground Directional
67N Inhibition
67N Polarization Inversion
67N Instantaneous Direction
67N Time Direction
67N Instantaneous Reverse Direction
67N Time Reverse Direction
Sensitive Ground Directional
67NS Inhibition
67NS Polarization Inversion
67NS Time Direction
67NS Time Reverse Direction

Table 4.7-2: Recording of Bay Events
Absence of Voltage on Line
27 Enable
27 Blocking
27 Enabled
27A Pickup
27B Pickup
27C Pickup
27A Trip
27B Trip
27C Trip
27 Trip
Presence of Voltage on Line
59 Enable
59 Blocking
59 Enable
59A Pickup
59B Pickup
59C Pickup
59A Trip
59B Trip
59C Trip
59 Trip
Fault Passage Detector
Fault Passage Detector Enable
Fault Passage Detector Enabled
Fault Passage Detector Local Indication
Fault Passage Detector Remote Indication
Fault Passage Detector by 51Ns Indication
Not Detected Fault. Voltage / Current Presence.
Fault Isolation Automatism
Local Command of Switch to Manual Mode to Fault Isolation Automatism
Local Command of Switch to Automatic Mode to Fault Isolation Automatism
Remote Command of Switch to Manual Mode to Fault Isolation Automatism
Remote Command of Switch to Automatic Mode to Fault Isolation Automatism
Fault Isolation Automatism Enabled
Fault Isolation Automatism in Automatic Mode
Fault Isolation Automatism Pickup
Fault Isolation Automatism Actuation
Breaker Open Command by Fault Isolation
Fault Isolation Automatism Check Error

Table 4.7-2: Recording of Bay Events
Breaker 1
Breaker Blocking Input
Breaker in Open Position Input
Breaker in Closed Position Input
Local Command to Open Breaker Input
Local Command to Close Breaker Input
Remote Command to Open Breaker Input
Remote Command to Close Breaker Input
Breaker Blocked
Breaker Position
Command to Open Breaker Output
Command to Close Breaker Output
Open Breaker Failure Command
Close Breaker Failure Command
Motor Protection Switch Trip
Breaker 2
Breaker Blocking Input
Breaker in Open Position Input
Breaker in Closed Position Input
Local Command to Open Breaker Input
Local Command to Close Breaker Input
Remote Command to Open Breaker Input
Remote Command to Close Breaker Input
Breaker Blocked
Breaker Position
Command to Open Breaker Output
Command to Close Breaker Output
Open Breaker Failure Command
Close Breaker Failure Command
Motor Protection Switch Trip

4.7.2 Organization of the Event Record

The event record capacity is 400 (standard model) or 4000 (model with expanded memory) last generated 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 8 magnitudes selected at the time the event is generated.
- Event date and time.

In addition, the relative position generated by the event is noted.

The register is subdivided into two sub queues of events: one of high occurrence with a depth of 10% of the total depth (167 or 400 events) and the rest for the sub queue of events of low occurrence. All events are categorized according to this criterion. This feature allows you to prevent frequent events in the center such as remote user connections or other overloads the capacity of the logger and miss more relevant events.

4.7.3 Events Mask

There is the possibility of masking those events that are not necessary, or not useful, when studying the behavior of the equipment.

Important: Events that can be generated in excess should be masked since they could fill the memory (1670 or 4000 events) and erase more important previous events.

4.7.4 Defining User Event Texts

The texts corresponding to the events generated by the user signals (programmable logic signals) can be generated automatically or defined by means of text settings between 1 and 48 characters long. In addition, for this type of signal (User type) both the name of the signal and the action logic and its position must be configured. On the other hand, for other types of signals, for example, the switch type signal, all the configuration, the logic and the data are previously defined in order to satisfy the demand and the global needs of the industry.

On the other hand, in the event of double logic signals, there are 4 "Text-Event" that can be defined, corresponding to the 4 possible states (On, Off, Unknown and Erroneous). As in the case of simple logic signals, all data, configurations and logics are predefined if a type of double logic signal different from that of the User is chosen, for example, Switch signal type. However, if you want to choose the type of User signal , the user must configure the signal.

The named predefined texts are configured previously to agilize and satisfy the demand and the global needs of the industry. In addition, the user can overwrite them in case of needing a modification and/or ask factory for details to complete the information.

4.7.5 Assigning Events to Bays

To facilitate the identification and interpretation of events, the different groups of digital signals of the equipment can be assigned to each of the installation bays. These assignments will result in the addition to each recorded event of the bay identification text that will have been previously assigned by means of setting.

- The first assignable group (**Protection Bay**) corresponds to all the signals coming from the Protection and Measurement Units.
- The second assignable group is that of the signals from **Breaker 1**.
- The third is the signals from **Breaker 2**.
- Finally, the user logic signals, **Single Logic Signals** and **Double Logic Signals**, can be assigned individually to each of the 8 positions defined within the installation.

4.7.6 Querying the Event Log

The event log can be consulted through the Historical menu of the equipment WEB page and alternatively it can be downloaded in the form of XML file and/or CSV file.

The structure of an event is as follows:

- **Date**. This is the system date at the time the event is generated, in dd/mm/yyyyy format.
- **V/I**.
- **Time**. It is the system time at the moment the event is generated, with precision of 1 ms and format hh:mm:ss.ssss. If the equipment is not synchronized with a SNTP server when the event is generated, the "S" character is added to indicate "Suspicious time".
- **GRUPEVE** and **TIPEVE**
- **Bay** (**B3_NAME**). It is the identification text assigned to the bay to which the event is associated.
- **Description of the bay** (**B3_TEXT**). It is a descriptive text of the previous item. For reasons of space it is not shown on the WEB page, it is only available in the XML listing.
- **Description** (**TEXT**). It is the text that describes the event annotated. The descriptions of the user signals can be changed by means of settings.
- **Magnitudes**. They collect the value of the main magnitudes of the system: Va, Vb, Vc, Vn, Ia, Ib, Ic, and In at the time of the event annotation. They are indicated in primary values.

A maximum of 50 events are displayed simultaneously on the WEB page. The **>** (**>>**) and **<** (**<<**) buttons are used to scroll through the list of events, indicating in a window between them the range of registers being displayed at any given time and the total number of registers available.

The WEB page that displays events is static so as not to consume communications resources, so there is a "Refresh" push-button to update the display of events.

The event log can be deleted at any time using the ***Delete*** push-button. This generates a warning message prior to deletion, the concrete appearance of which depends on the web browser used.

The event log can be downloaded as an XML file and/or as a CSV file for later analysis. The "***XML Download***" push-button and the "***CSV Download***" push-button are available for this purpose. In the case of XML, the name of the downloaded file is **hist(nnn).xml**, being **nnn** a correlative number that increases according to other previous files that may exist in the same directory to avoid deleting an existing file. In the case of CSV the same thing happens, but with the extension csv, instead of xml.

The specific operation to follow for downloading the file and selecting the download directory depends on the browser used.

Note: All the magnitudes shown next to the events are in primary values and are therefore affected by the Transformation Ratios.

4.8 Programmable Logic

4.8.1 Description

Within the set of functions of the **2TCA-E** family, there is a configurable function that is the **Programmable Logic**.

This logic is included in the configuration template that is generated in the Engineering Department. However, it can be defined by the user through settings in the **Advanced Settings** section.

From the signals or readings generated by any of the functions of the equipment (Protection units, Digital inputs and Command functions), the user can define an operating logic using pre-configured logic blocks built from AND, OR and NOT logic gates and timers.

The programming function allows definition of the trip logic, control logic, interlocks, automatisms, local and remote states… required for complete protection and operation of a bay.

The processing of the input signals produces logical outputs that can be assigned to existing connections between the IED and the exterior: digital inputs of the protection units, auxiliary output contacts, LEDs, communications, etc.

4.8.2 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 processing and generation of alarms involves the possibility of obtaining logical alarms generated from the combination of the status of various input signals through logic gates, as well as "timers" of presence / absence of a given signal, either physical or logical.

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) 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**.

4.8.3 Basic Logic Blocks

There are four types of logic basic blocks, which share a common conception, although with some differences that will be detailed below:

- **User Signals**

The equipment has **64 Single Logic Signals** and **16 Double Logic Signals**. The first ones are based on a logic block with 12 inputs distributed in two doors, an AND and an OR, which in turn can be combined with an AND door or an OR depending on the value of a selection setting. The result of this last combination can be connected to the output of the logic block directly or through one of three types of timing, Ta, Tb or Pulse, also selectable by setting.

Next, the basic schema of the logic block mentioned in the previous point is represented graphically:

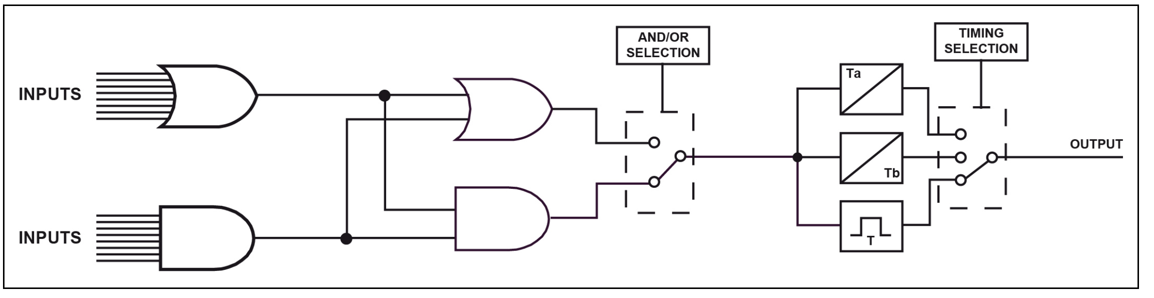


Figure 4.8.1 Logic Block Diagram.

The Double Logic Signals are made based on a simpler block than the previous one: only the two inputs that make up the signal state, the number of states that the signal can represent and the transition time during which intermediate states are not taken into account are defined.

- **Internal Signals**

Each of the modules or units of the equipment that have logic inputs that control their behavior has a configurable logic block for each one of its inputs. The architecture of these modules is identical to that of the User Simple Logic Signals.

- **Digital Outputs**

Each output of the equipment is governed by a configurable logic block. The architecture of these modules is identical to that of the User Simple Logic Signals.

- **LED Signal Devices**

The configurable LEDs of the equipment have a logic block with an architecture similar to that of the User Simple Logic Signals. The differences are that, instead of the final timing, the LED block has a selectable status memorization and a section is added to define the blinking of the indication with a fixed cadence of 1 second.

4.8.3.b User Signals

The User Signals definition screen is divided into two sections: **Single Logic Signals** and **Double Logic Signals**.

Each of the logic blocks is defined by a drop-down list in which the type of signal is selected and another text setting that defines the configuration of the logic block.

To simplify the editing of this configuration, the setting is not written directly, but is built from the information entered in the box that is displayed by clicking on the block we want to edit.

- **Type**

Adjust the signal name by selecting the desired signal from a drop-down list showing all available signals. This name will also determine the text that will be displayed in the events.

- **Bay**

The relative cell bay of the signal is adjusted. To do this, the signal bay is selected by means of a drop-down menu, in which the previously configured bays are displayed.

- **Input Selection**

Pressing in this zone displays a drop-down list that allows you to select any of the digital signals, both single and double, that are available in the equipment.

The selected signal will be connected to the input door, AND or OR at the top of the column.

- **Type**

When pressing in this zone, a drop-down list appears allowing you to select the type of logic state of the signal to be connected to the previously selected input.

The possible values are six:

- **On**: Indicates that the signal is active when the connected signal is in Active state. It is the most common option and therefore appears as default value
- **Off**: Active when the signal is in the Off state.
- **Trn**: Active when the signal presents a Transition State (00). This condition can only occur when the input signal is double.
- **Err**: Activates when the signal presents an Error State (11). This condition can only occur when the input signal is double.
- **Inv**: Activates when the connected signal has the Invalidity Bit active.
- **Blq**: Active when the connected signal is blocked by an excessive number of changes.

- **Neg**

Checking this box activates the logical inversion of the connected signal. It is equivalent to inserting a NOT gate between the signal and the block input.

- **Output Logic**

Allows to select if the combination of the two gates of 6 inputs is done through an AND gate or an OR gate.

- **Output Timer**

If the timing value is 0 seconds, the output of the logic block is applied directly without any timing.

Otherwise, a selectable time function is applied from the corresponding drop-down among the following values:

- **Pulse**. The output is active for the selected time regardless of the duration of the input.
- **Temp A**. The output is activated after the applied timer has elapsed after the input has been activated and is immediately reset when the input is deactivated (activation delay). If the input activation has a duration shorter than the setting, the output is not activated.
- **Temp B**. The output is activated immediately when the input is activated and is reset after the time delay has elapsed after the input has been deactivated (delay to deactivation).

- **Automatic Quality**

All **2TCA-E** digital signals are associated with quality information. The two elements that are taken into account are the validity of the signal and the state of blocking due to an excessive number of changes.

To generate the quality associated with the output signals of the programmable logics, it can be **automatically** calculated from the quality information of the inputs involved, or it can be defined **manually** by means of two other logic blocks identical to those that make up the value of the signal.

In the case of the manual definition, two new tabs would be accessible, **Invalidity** and **Blocking**, in which we would select the signals and logic that will determine the quality information.

- **Double Logic Signals**

As with the logic block of **Single Logic Signals**, pressing on any of the **Double Logic Signals** displays a help window for their configuration.

The fields **Type**, **Bay**, **Input Selection**, **Type**, **Neg** and **Automatic Quality** have the same functionality as the block explained above.

- **Number of States**

The two possible options are **4E** (four states) and **3E** (three states).

- **4E.** The combination "00" of the inputs is considered as "Transition" (Trn), while the combination "11" is considered as "Error" (Err).
- **3E**. Both input combinations "00" and "11" have the "Transition" (Trn) treatment.

- **Transition Time**

This setting determines the time during which the inputs can be transitorily set to "00" or "11" and therefore the signal status is not updated until a stable **On** or **Off** situation is reached.

If one of the above combinations is still present after this time, the signal is updated to the **Trn** or **Err** state, depending on the combination of inputs and the value in the **Number of States** field.

4.8.3.c Internal Signals

For each of the input signals of the units and internal modules of the equipment, there is a logic block that is configured in exactly the same way as the blocks of User Signals, with the only difference that the name of the signal cannot be chosen, but is assigned permanently.

4.8.3.d Digital Outputs

The logic block that defines the connection of the **Digital Outputs** is identical to that of the **Internal Signals**.

4.8.3.e LEDs

The logic block that governs the configurable **LED** indicators is the same as the **Digital Outputs** with two exceptions.

An additional **Blinking** tab is available to define a flashing LED status. This equation takes precedence over the fixed-light equation, so that when the output corresponding to this tab is active, the corresponding LED blinks at a rate of 1 second, regardless of the status of the **On** tab.

The second difference is the lack of timing functions. Instead we have a **Memorized** box that when it is marked makes the LED lighting memorized and remains illuminated, even if the output signal is reset. To reset the LEDs, there is an internal signal for this purpose, called **Memorized Signals Reset**.

4.8.4 Smart RTU Configuration with ZIV e-NET Tool®

4.8.4.a Introduction

The **2TCA-E** model which includes the feature to communicate with MODBUS slaves (IED for Smart RTU application) will be configured with ***ZIV e-NET Tool***® program.

ZIV e-NET Tool® will be used to configure:

- The control logic of the device so that it will comply with the IEC 61131-3 standard.
- Modbus master protocol to communicate with up to 3 IEDs (15 IEDs in future versions, check the model selection options) so that the RTU will have that information of the slaves available to be sent by IEC 104 to the control center.

The configuration tool will generate one file that will be loaded to the IED by the webserver.

On the other hand, the webserver of the IED will be used for:

- Visualization: SLD diagram, measurements, status, alarms, events.
- IED settings (protection, synchronization, etc.) and communication settings (ports, IEC 104, etc.).
- Users configuration.
- Configuration/assignation of signals to activate digital outputs and LEDs.
- FW, template and configuration file load/download.
- Remote commands, reboot and default parameters.

4.8.4.b Control Logic

The objective of the control logic configuration is generating or giving value to new user signals so that they will be available in the system to activate the digital outputs or LEDs of the RTU, which are configured (assigned) in the webserver, or to be sent by IEC 104 to the SCADA.

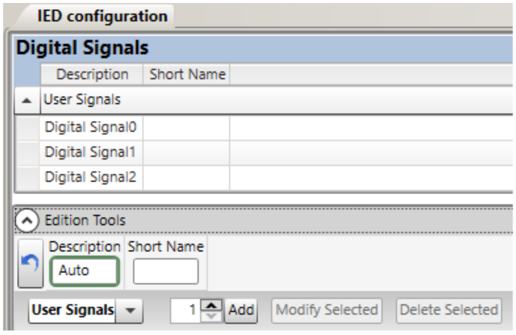
These new signals will be calculated in the control logic as a combination of the existing signals in the RTU (internal signals of the RTU or signals of the MODBUS devices) being able to use also constants values.

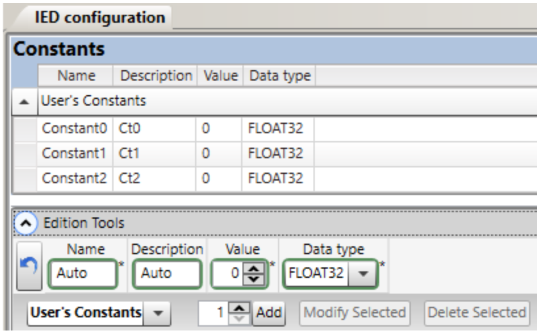
These are the available OPCODES:

- Booleans: AND, NOT, OR, XOR
- Comparisons: <, <=, <>, =, >, >=, LVCOMP, LVCOMPmem
- Counters: COUNT_I, COUNT_R, COUNTmem_I, COUNTmem_R
- Timers: TMA, TMAmem,TMB, TMBmem
- Triggers: FFD, FFRS, PLSTRAIN, PULSE, R_TRIG (and the corresponding memorized ones)
- Move instructions: MUX

- **Example of Control Logic Configuration**

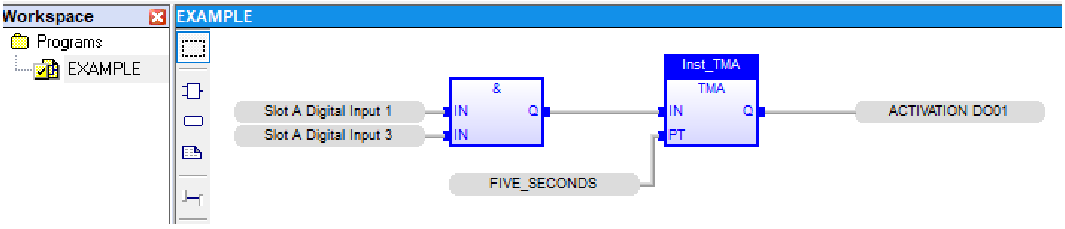
1. Generate the necessary user resources that will be needed in the control logic, these are: user signals and constants. There will be also available all the signals of the RTU and the signals and measurements of the Modbus devices that have been added. The Bay Number is used by the RTU to identify the resource and display it, if necessary, in the corresponding bay of the SLD diagram.



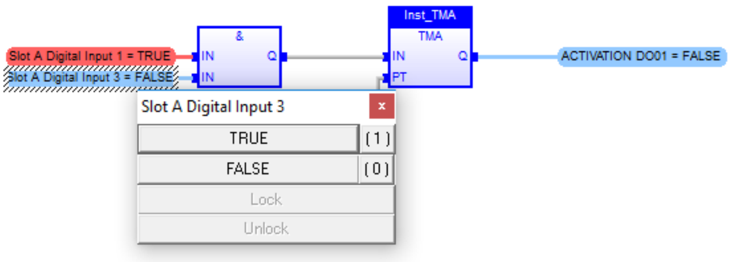


2. Open the control logic editor by clicking over Programmable Logic inside the Navigation View area.
3. Insert a new program. Righ click with the mouse in the Workspace area.
4. Click two times over the generated program in order to open and edit it.
5. Add the necessary opcodes (select and drag from the OPCODE area to the programming area). If you want to use the simulation mode, in those cases in which the OPCODE can be instantiated (counters, timers and triggers) select and drag from the OPCODE area to the variables area (top area over the OPCODE area) so that the OPCODE will be instantiated inside the program and then select and drag from there to the programming area.
6. You can also use the tools of the menu located on the left side of the programming area.

7. When adding an OPCODE or a variable to the programming area, click two times over the OPCODE to modify it or over the variable (input/output variables of the OPCODE) to select the signals that will be used.



8. You can define in which cycle of logic the programs will be executed: 2ms/10ms/20ms. By default, all are generated to be executed in the 10ms cycle. Go to Project/Tasks to change it:
   - Digital Inputs, Digital Outputs and protection: 2ms.
   - Control: 10ms.
   - Front Panel: 20ms.
9. Go to Project/Simulate if you want to simulate the logics.



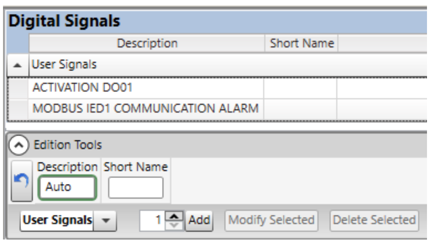
4.8.4.c Predefined MODBUS Slaves

The RTU can communicate with up to 3 IEDs (15 IEDs in future versions, check the model selection options) by any of the 2 serial ports. When adding a new MODBUS IED, the IED can be defined as predefined (Self-powered relay or ADEL Power Supply) or generic. If any of the predefined options is selected, then automatically the configuration tool will add the signals and measurements inside the corresponding functions and the related user signals and measurements will be generated inside the Resources area (even though they will not be visible). The user does not have to configure anything else. Everything will be fixed, and the tool will just allow modifying the texts of the signals or measurements which have been added.

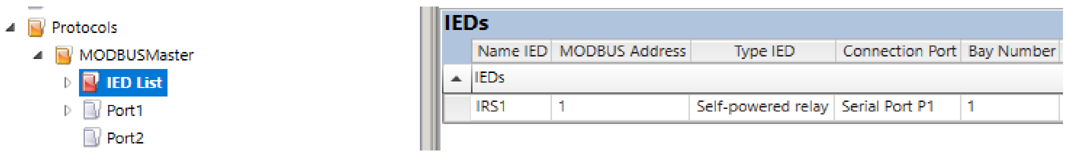
The communication parameters of the serial ports will be configured through the webserver.

- **Example of Configuration to Add one Predefined MODBUS Slave**

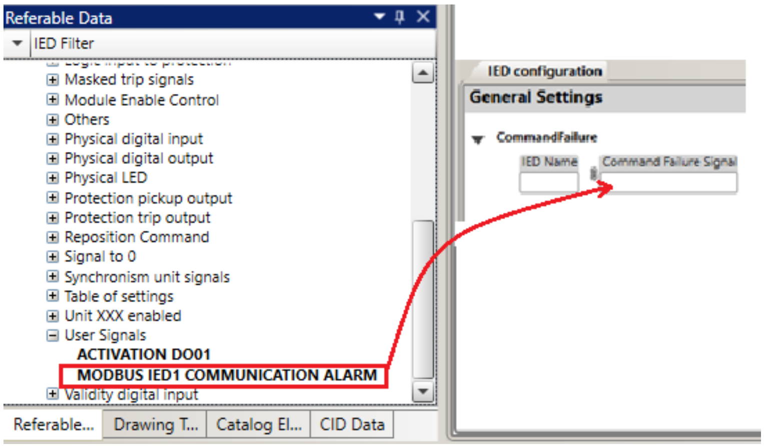
1. Go to ***Resources/Digital Signals/*** inside the Navigation View area and add a new signal that will contain the communication failure alarm with the IED.



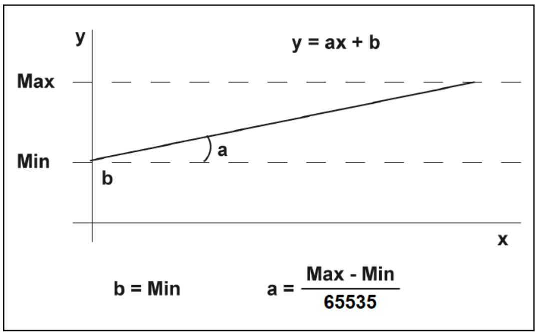
2. Go to ***Protocols/MODBUSMaster/IED List***, inside the Navigation View area.
3. Add a new IED:
   - Name of the IED: configurable name.
   - Address: MODBUS address and internal identifier.
   - Type of IED: Self-powered relay or ADEL Power Supply.
   - Connection port: serial Port P1 or serial Port P2.
   - Bay number: identification of the bay. This number will be used to identify the resources of that IED in the control logic editor and in **2TCA-E**.



4. Automatically the IED will be added below inside the selected port (Serial Port1 / Serial Port2).
5. The predefined mapping will be shown inside the corresponding type of data (digital signal or measurement). The signals and measurements cannot be modified in terms of modbus address or position, just the description of the signal can be modified.
6. Go to ***General Settings*** and link the user signal generated that will receive the communications error with that IED. Select ***Referable Data*** and go to ***Resources/Digital signals/User Signals***. Select and drag the signal generated in step 1 to the Command Failure Signal box.



7. If required, modify inside ***General Settings*** the ***Transmission delay*** setting. This setting will define the minimum time required by the IED to receive/process two consecutive messages/petitions.
8. If required, check/review the configuration parameters to represent the measurements in engineering values inside each measurement resource added in the MODBUS IED mapping. If the RTU receives the measurement in engineering values, then leave the default values (65535 and 0).



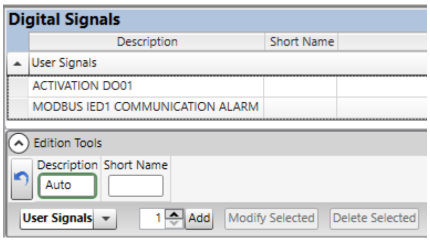
4.8.4.d Generic MODBUS Slaves

The RTU can communicate with up to 3 IEDs (15 IEDs in future versions, check the model selection options) by any of the 2 serial ports. When adding a new MODBUS IED, the IED can be defined as predefined (Self-powered relay or Power Supply) or generic. If the generic MODBUS IED is selected, then the configuration tool will add the structure of the MODBUS IED empty so that the user can configure the list of signals and measurements required.

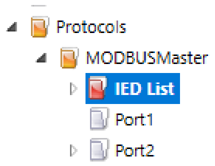
The communication parameters of the serial ports will be configured through the webserver.

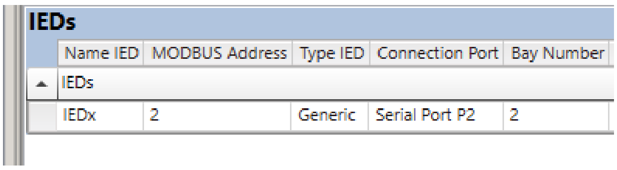
- **Example of Configuration to Add one Predefined MODBUS Slave**

1. Go to Resources/Digital Signals/User Signals inside the Navigation View area and add a new signal that will contain the communication failure alarm with the IED.



2. Go to ***Protocols/Modbus Master/IED List***, inside the Navigation View area.
3. Add a new IED:
   - Name of the IED: configurable name.
   - Address: MODBUS address and internal identifier.
   - Type of IED: Generic.
   - Connection port: serial Port P1 or serial Port P2.
   - Bay number: identification of the bay. This number will be used to identify the resources of that IED in the control logic editor and in **2TCA-E**.



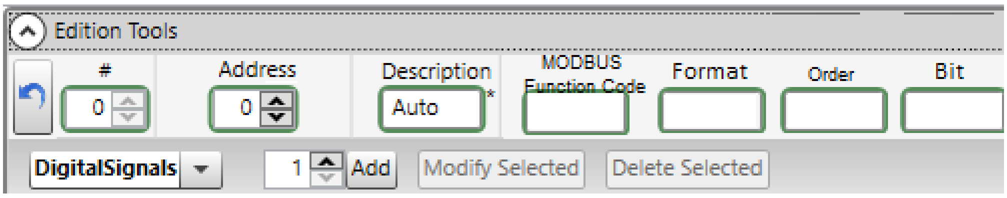


4. Automatically the IED will be added below inside the indicated port (Serial Port1 / Serial Port2).
5. Go to ***Protocols/Modbus Master/Serial PortX/YYY/Addressing*** (where YYY will be the name of the IED that has been added) and add the resources inside the corresponding MODBUS function code.
   a. Digital Signal. They support function code 01, 02, 03 and 04. When adding a new digital signal, the tool will automatically generate one digital signal (not visible) in resources.
      i. Address: initial MODBUS address of the register.
      ii. Description: description of the resource.
      iii. MODBUS Function Code: 01, 02, 03 or 04.
      iv. Format: 16 bit or 32 bit. Just in case of selecting function code 03 or 04. This way the RTU will ask for 1 or 2 registers. By default, 32 bits. It is no applying for function codes 01 and 02.
      v. Order: just if the format is 32 bit. It will indicate if the registers that arrives in first position is the most significant one (MSR) or the less significant one (LSR). Options. MSR first, LSR First. By default, MSR first or blank when format is 16 bits.

vi. Bit: just apply for function 03 or 04. It will indicate the number of bit (0 to 31) inside the register that the RTU will take. When adding few bits from the same register (same address), the RTU will ask just once for the whole register and it will extract from there the bits. Default 1. Just used for function codes 03 and 04.

vii. Example of configuration of a digital signal which is included in a 16 bits register
Address: 40500.
MODBUS Function Code: 03.
Format: 16 bits.
Bit: 0.

viii. Example of configuration of a digital signal which is included in a 32 bits register (Trip signal of the Self-powered relay).
Address: 40500.
MODBUS Function Code: 03.
Format: 32 bits.
Order: MSR first.
Bit: 0.



b. Measurement. They support function code 03 and 04. When adding a new measurement, the tool will automatically generate one measurement in resources.

i. Address: initial MODBUS address of the register.

ii. Description: description of the resource.

iii. MODBUS Function Code: 03 or 04.

iv. Format: 16 bit or 32 bit. This way the RTU will ask for 1 or 2 registers. By default, 32 bit.

v. Order: just if the format is 32 bit. It will indicate if the registers that arrives in first position is the most significant one (MSR) or the less significant one (LSR). Options. MSR first, LSR First. By default, MSR first or blank when format is 16 bit.

vi. Register Type: type of data received. It can be: INT16, UINT16, FLOAT32, INT32 or UINT32.

vii. Data Type: type of internal measurement in the RTU (FLOAT or INTEGER).

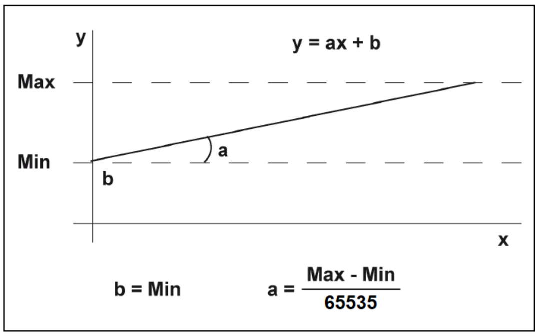
viii. Limits/Maximum: value used to convert from counts to engineering values. Default: 1.

ix. Limits/Minimum: value used to convert from counts to engineering values. Default: 0.

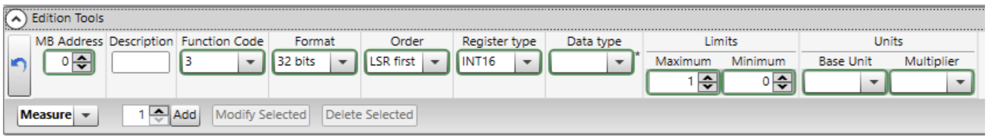
x. The **2TCA-E** needs the gradient and the offset of the conversion line. Therefore, the tool will use the maximum and minimum values to calculate them (a/gradient, and b/offset parameters).

xi. Units: base unit and multiplier.

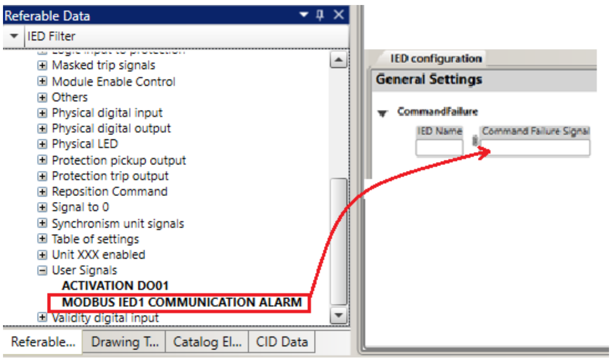
xi. Example of configuration of a measurement sent in a 16 bits register.
Address: 40300.
MODBUS Function: 03.
Format: 16 bits.
Register Type: UINT16.Data Type: FLOAT. Max=65535, Min=0.



xii. Example of configuration of a measurement sent in a 32 bits register.
(IA measurement of the Self-powered relay).
Address: 40300.
MODBUS Function: 03.
Format: 32 bits.
Order MSR first.
Register Type: FLOAT32. Data Type: FLOAT. Max=65535, Min=0.



6. Go to ***General Settings*** and link the user signal generated that will receive the communications error with that IED. Select ***Referable Data*** and go to ***Resources/Digital signals/User Signals***. Select and drag the signal generated in step 1 to the Command Failure Signal box.



7. If required modify inside ***General Settings*** the ***Transmission delay*** setting. This setting will define the minimum time required by the IED to receive/process two consecutive messages/petitions.

4.9 Instantaneous/Permanent Fault Indicator Automatism

4.9.1 Introduction

One of the main functions of the **2TCA-E** equipment is the Fault Passage Detection (FPD). The device will have two FDPs, the one described in chapter 4.1 and a second one called Instantaneous/Permanent Fault Indication. By default, the FPD will be disabled.

The **2TCA-E** has as many detection units as analogue input modules. The detection mechanism is based on the sequence of changes in the magnitudes of current and voltage that occurs when there is a fault in the system and it is cleared by the overcurrent protection of the header substation. This sequence consists of the appearance of an overcurrent in all or some of the phases followed by a drop in the voltage and current once the fault clearing time has elapsed and the circuit breaker has tripped.

4.9.2 General Block

Inputs		Block		Outputs
Voltage Outage Detection	→	**INST./PERM. FAULT INDICATOR**	→	Instantaneous FI
Phase, Neutral and SN Overcurrent Pickups	→		→	Permanent FI
Voltage Detection Pickup	→			
Phase/Neutral/SN Enable	→			
Instantaneous FI time	→			
Permanent FI time	→			

4.9.3 Operation Principle

When the RTU detects a fault current, phase, neutral or sensitive neutral, higher than the corresponding pickup current and there is a voltage outage (activation of the **Voltage Outage** signal of the open phase unit), the IED will start the Instantaneous FI indication calculation. Once the power flow on the RTU becomes normal again (detection of current greater than 4A in all phases and activation of the **Voltage Detection Pickup** signal of the open phase unit), the IED will start a timer. When the time defined in the ***Instantaneous FI time*** setting expires, the **Instantaneous FI** indication will be activated. The **Instantaneous FI** activation will be reset when the IED receives the reset command through communications (IEC 104) or when activating the reset signal by digital input or control logic. When the ***Permanent FI*** is set, the ***Instantaneous FI time*** will be reset, therefore, the **Instantaneous FI** will never active if the **Permanent FI** has been activated after a fault condition.

When the RTU detects a fault current, phase, neutral or sensitive neutral, higher than the corresponding pickup current and there is a voltage outage (0 voltage of the three phases simultaneously), it will start a timer. When the time defined in the ***Permanent FI time*** expires, the **Permanent FI** indication will be activated. The **Permanent FI** activation will be reset automatically when the RTU detects a normal power flow.

The IED will take into account the pickup signals coming from the phase, neutral and sensitive neutral overcurrent units to start the automatism. It will use the signals which do not depend on the torque condition.

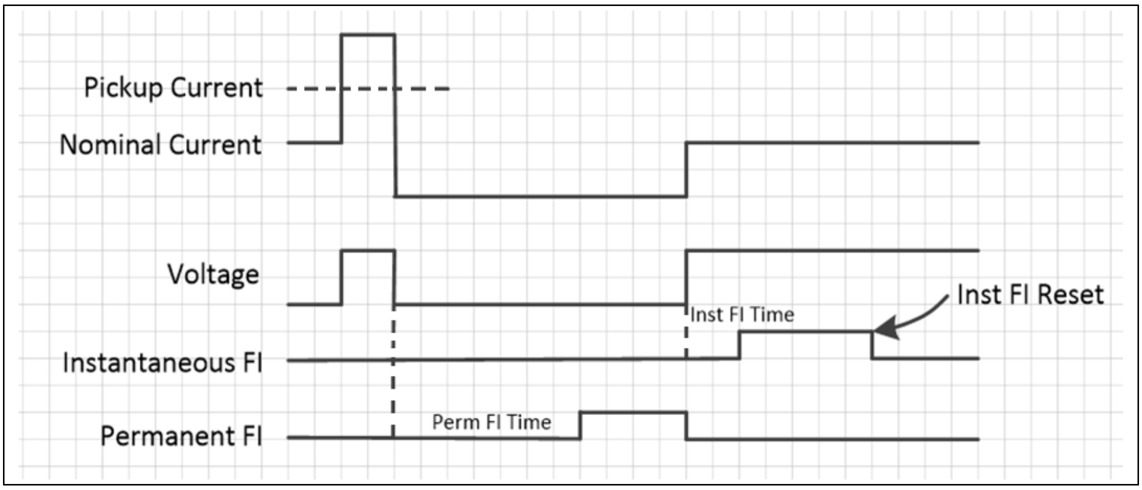


Figure 4.9.1 Generation of Instantaneous and Permanent FI Indications.

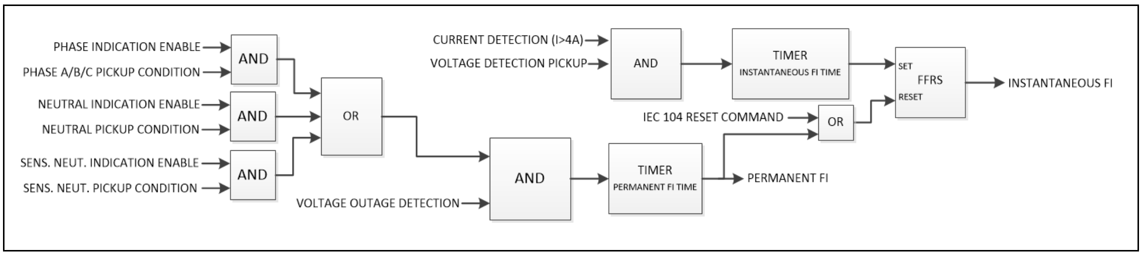


Figure 4.9.2 Logic Diagram of the Element.

4.9.4 Application

This unit is used to send the information about the fault detection to the control centre.

4.9.5 Setting Ranges

Parameters/ Lx/ Instantaneous-Permanent Fault Isolation Automatism			
Setting	**Range**	**Step**	**Default**
Phase Indication Enable	YES / NO	-	YES
Neutral Indication Enable	YES / NO	-	YES
Sensitive Neutral Indication Enable	YES / NO	-	YES
Instantaneous FI time	1-180s	1s	2s
Permanent FI time	1-180s	1s	20s

4.9.6 Digital Inputs of the Automatism

Table 4.9-1: Digital Inputs of the Inst./Perm. Fault Indicator Automatism[1]

Name	Group	IEC 61850	Webserver name	Vis.	Function
ENBL_FIPH	Enabling Commands	-	Phase Fault indicator Enable Input		Activation of this input puts the element into service. It can be assigned to status contact inputs by. The default value of this logic input signal is a "1" (unit enabled).
ENBL_FIN	Enabling Commands	-	Neutral Fault indicator Enable Input		
ENBL_FISN	Enabling Commands	-	S.N. Fault indicator Enable Input		
INSTFI_RESET	Automations	-	Instantaneous FI Reset command		Activation of this input will reset the Instantaneous FI Indication. It can be activated by IEC 104, by DI or control logic.

4.9.7 Auxiliary Outputs and Events of the Automatism

Table 4.9-2: Digital Outputs and Events of the Inst./Perm. Fault Indicator Automatism [1]

Name	Group	IEC 61850	Webserver name	Vis.	Description
INSTFI_ACT		-	Instantaneous FI	S D E I	Activation of the instantaneous FI.
PERMFI_ACT		-	Permanent FI	S D E I	Activation of the permanent FI.

Note: Vis column, will indicate where the signal is going to appear: SLD Diagram (S), Details (D), Event (E), IEC 104 (I). All the signals will be available in the system so that they can be used to configure the DOs and LEDs.

[1] For the second analog board the signals are identified in the same way, but with the prefix "U1_".

4.9.8 Protection Element Test

Elements must be tested one at a time, disabling those not being tested at that time.

Inst.-Permanent Fault Indicator	**Ranges**	**Test Settings**
Phase Indication Enable	YES / NO	YES
Neutral Indication Enable	YES / NO	YES
Sensitive Neutral Indication Enable	YES / NO	NO
Instantaneous FI time	1-180s	2s
Permanent FI time	1-180s	20s
Phase Instantaneous Overcurrent	**Ranges**	**Test Settings**
Phase IOC Enable	YES / NO	YES
Phase IOC Pickup	10-3000A	400A
Phase IOC Delay	0-300s	0s
Neutral Inst. Overcurrent	**Ranges**	**Test Settings**
Gnd IOC Enable	YES / NO	YES
Gnd IOC Pickup	15-2000A	200A
Gnd IOC Delay	0-5s	0s

- **Instantaneous Fault Indication**

Inject nominal voltage and 100A by the three phases. Increment the three phase currents up to 600A for 50ms and stop the injection. Wait for four seconds and inject again the normal conditions (nominal voltage and 100A). Check that the **Instantaneous FI** event is generated 2 seconds after the normal conditions. Keep on injecting and check that the *Instantaneous FI* is still active, even when stopping the injection. Reset the event using the IEC 104 reset command or generating the **Permanent FI** event.

Repeat the test but injecting a neutral current fault instead of a three-phase fault after the normal condition (IA=300A, IB=0A, IC= 0A).

- **Permanent Fault Indication**

Inject nominal voltage and 100A by the three phases. Increment the three phase currents up to 600A for 50ms and stop the injection. Wait for 30 seconds and inject again the normal conditions (nominal voltage and 100A). Check that the **Permanent FI** event has been generated 20 seconds after stopping the injection and it has reset when injecting again the normal condition, this is, the **Permanent FI** even has been active for 10 seconds.

Repeat the test but injecting a neutral current fault instead of a three-phase fault after the normal condition (IA=300A, IB=0A, IC= 0A).

Chapter 5.

Configurations

5.1 General

5.1.1 Configurability

Fault isolation automatisms are applied not only in small compact switchgears or aerial breakers but also in modular switchgears with a large number of positions.

The modular design of the device allows attending with flexibility the different automatization levels required by any electrical company. The internal microcontroller implements the overcurrent protection functions as well as the absence/presence of voltage over the different lines or the available analogue acquisition modules, being the maximum admitted per device five line positions (with common busbar voltage measurement). The directional fault passage detector and the fault isolation automatisms work using this protection functions.

Due to the fact that the device covers automations from one to five line bays and from one to five transformer protection bays, it is necessary its configuration depending on the system or switchgear where it is installed.

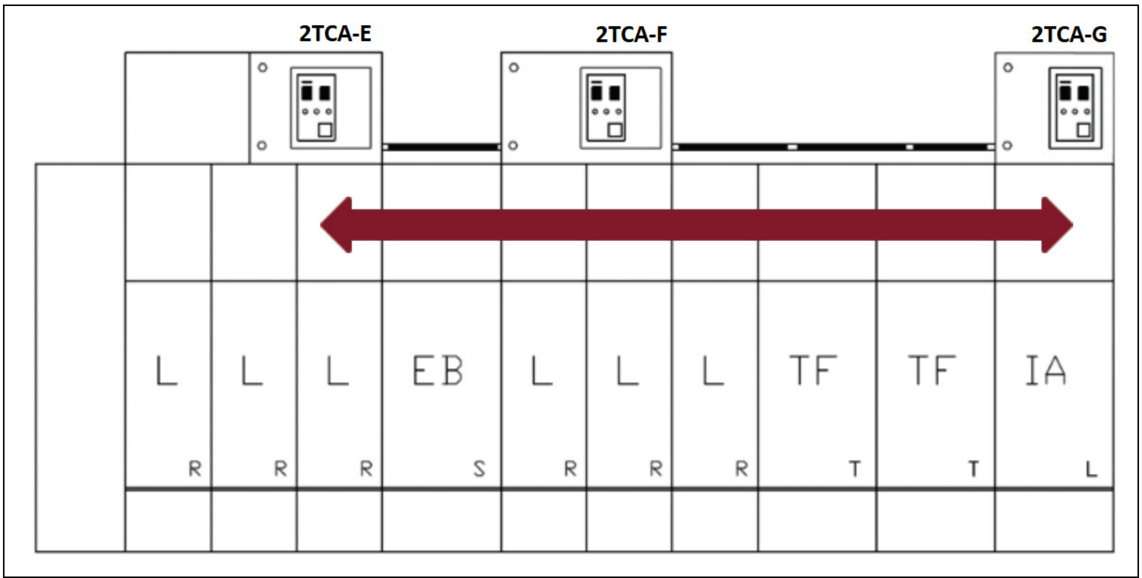


Figure 5.1.1 Example of Devices Installed in a MV Switchgear.

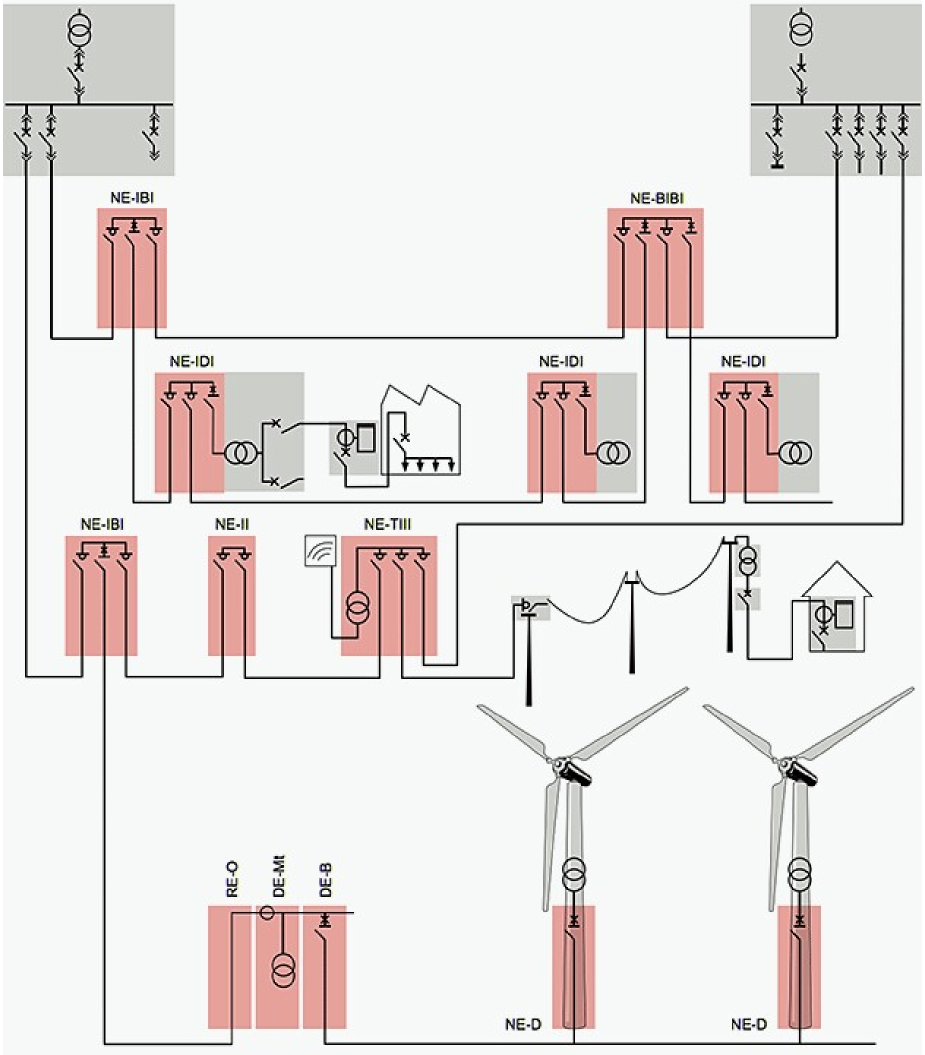


Figure 5.1.2 Examples of Different Applications where the Device can be Installed.

5.1.2 Device Configuration

The configuration of the device can be done in different ways. You can find a detailed description about it in the physical description chapter:

- Web server/page: XML file load.
- Web services (depending on the model):
  - Partial configuration load (S03, R03).
  - Total configuration load (S08, R08).

The IED will always check that the configuration sent matches the device model and once the device accepts it and it reconfigures itself with the new configuration, it will show in the web server/page the SLD diagram defined.

5.1.3 Configuration Types

Depending on the model and from the hardware point of view, the current possibilities are the following ones:

- 3L5P: 3 line bays with load break switch, 5 transformer protection bays with load break switch and fuses.
  48 inputs, 16 outputs, 3 voltage channels and 12 current channels.

- 5L5P: 5 line bays with load break switch, 5 transformer protection bays with load break switch and fuses.
  64 inputs, 16 outputs, 3 voltage channels and 20 current channels.

- 4LE5P: 4 line bays with load break switch, 1 couper bay with ruptor, 5 transformer protection bays with load break switch and fuses.
  64 inputs, 16 outputs, 6 voltage channels and 16 current channels.

- Smart RTU 2L1T: 2 line bay with load break switch, 1 transformer protection bay with breaker.
  32 inputs, 16 outputs, 3 voltage channels and 8 current channels.

- Smart RTU 2L2T: 2 line bay with load break switch, 2 transformer protection bays with breaker.
  48 inputs, 16 outputs, 3 voltage channels and 12 current channels.

- Smart RTU 3L1T: 3 line bay with load break switch, 1 transformer protection bay with breaker.
  48 inputs, 16 outputs, 3 voltage channels and 12 current channels.

5.2 A Type Configuration: 3LxP

5.2.1 Application

Compact or modular MV switchgear with tree line functions and one protection function which includes the features of the line cubicles and the protection cubicles with fuses accommodated in the same vessel.

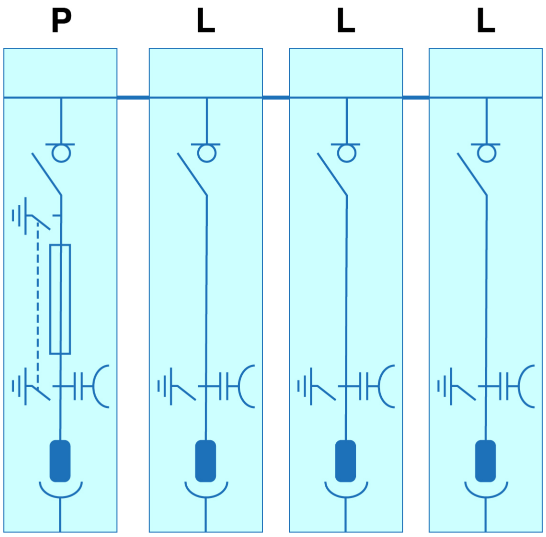


Figure 5.2.1 3LxP Type Configuration.

This switchgear configuration is mostly used in transformation centres where there is a derivation of the main line.

5.2.2 Device Connections

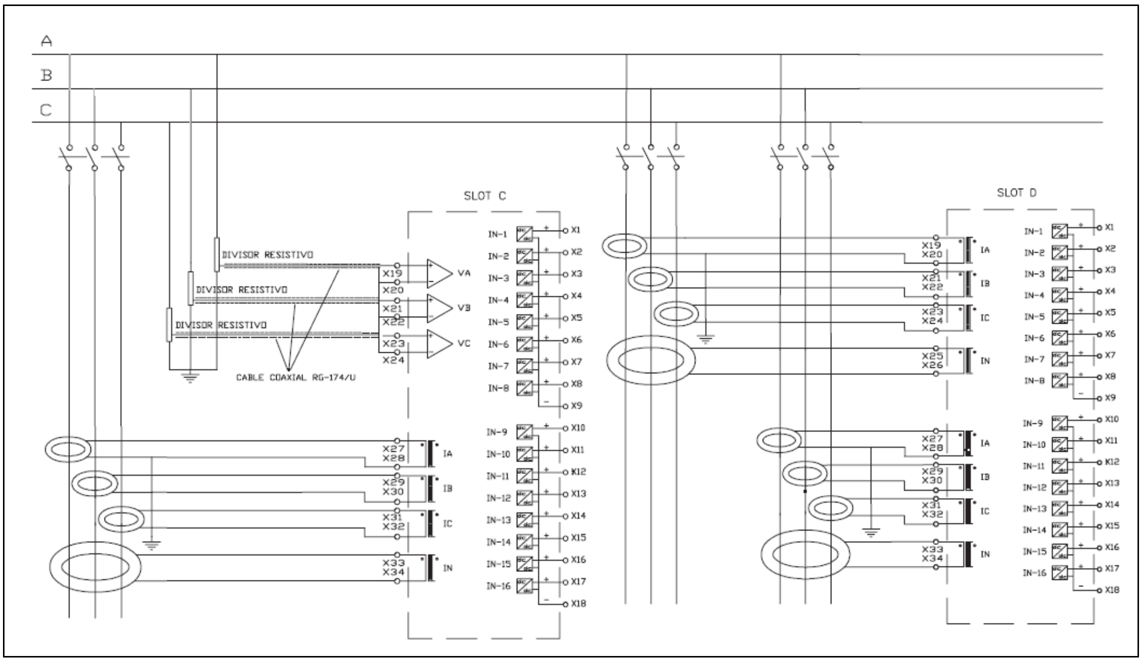


Figure 5.2.2 External Connections.

5.2.3 SLD Diagram

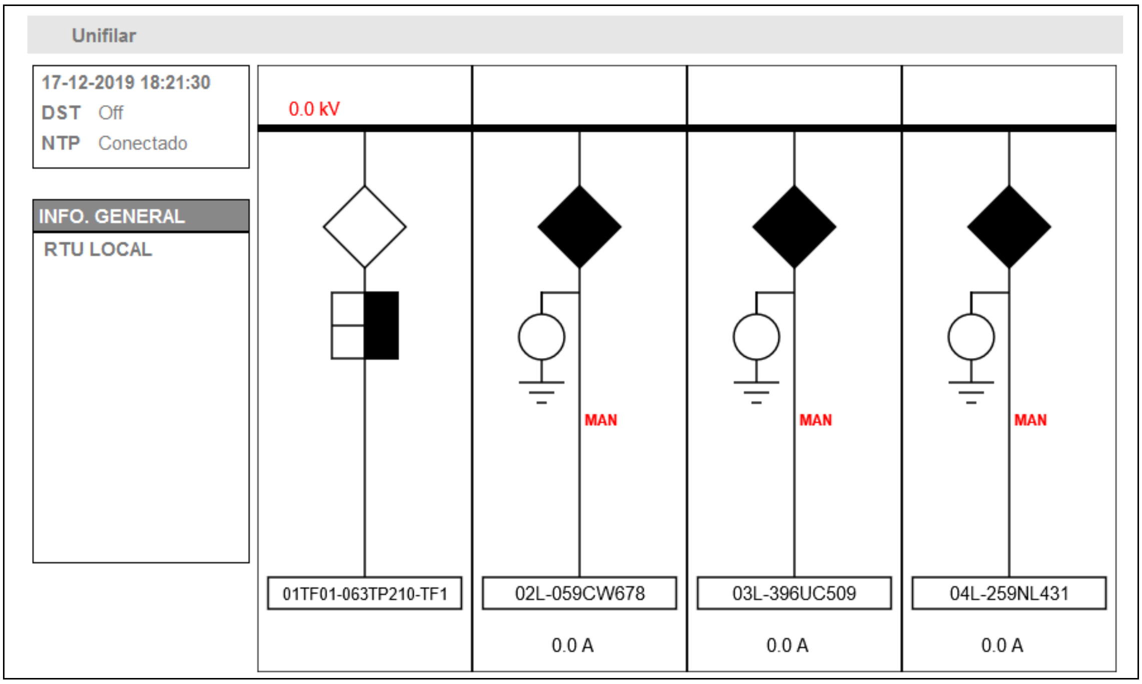


Figure 5.2.3 SLD Diagram.

5.3 B Type Configuration: 5LxP

5.3.1 Application

Set of modular switchgears with five line functions and one protection function which includes the features of the line cubicles and the protection cubicles with fuses accommodated in independent vessels.

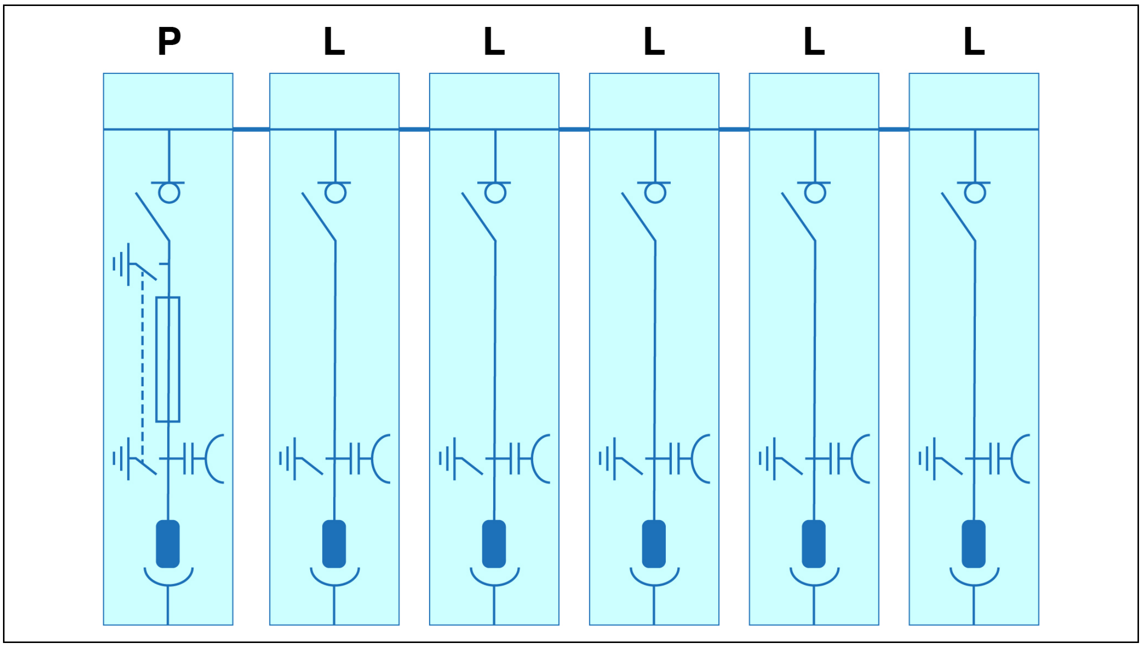


Figure 5.3.1 5LxP Type Configuration.

This configuration is mainly used in MV Switching and Distribution Substations as a complete set or as a second busbar.

5.3.2 Connection of the Device

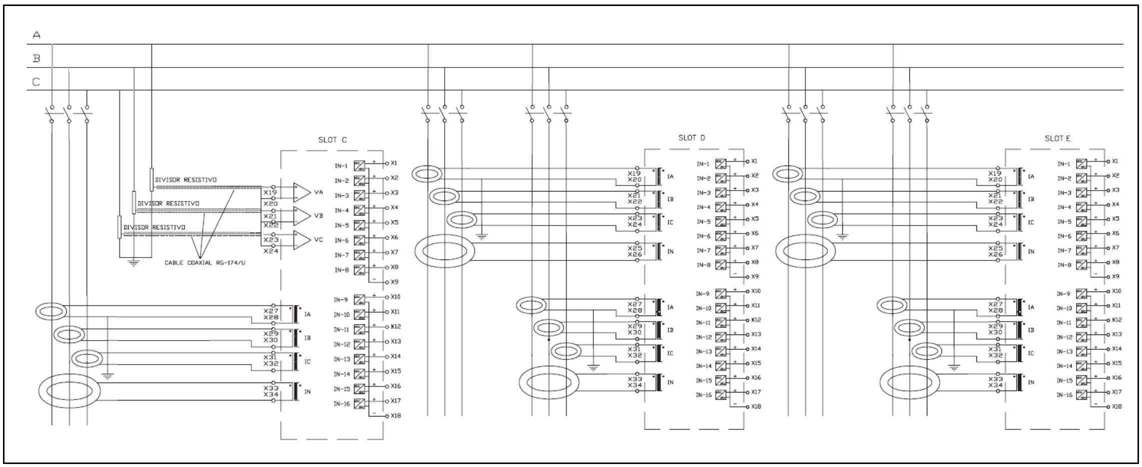


Figure 5.3.2 External Connections.

5.3.3 SLD Diagram

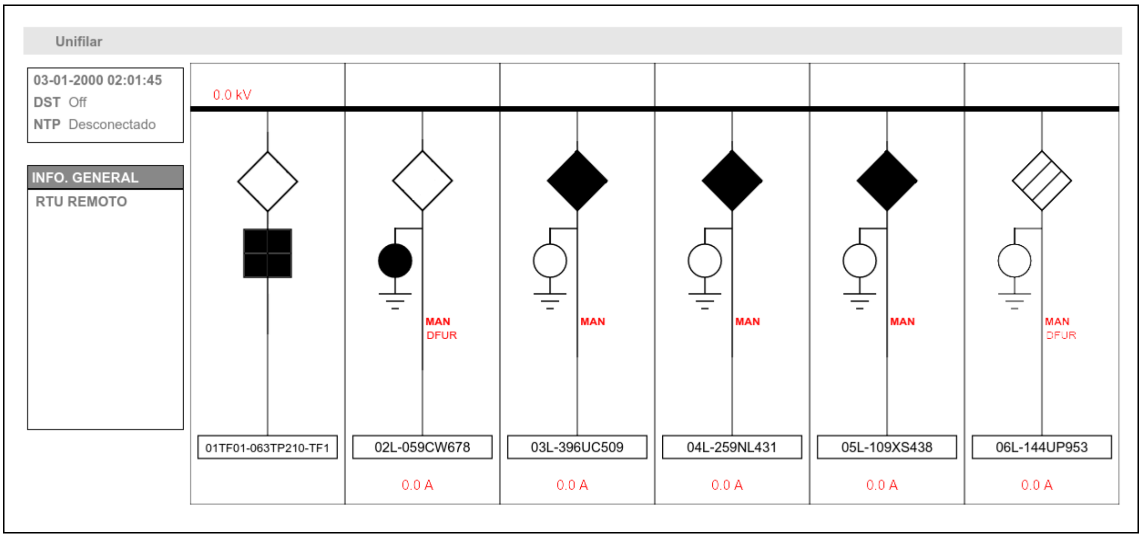


Figure 5.3.3 SLD Diagram.

5.4 C Type Configuration: 4LExP

5.4.1 Application

Set of modular switchgears with four line functions, one protection function and one coupler accommodated in independent vessels.

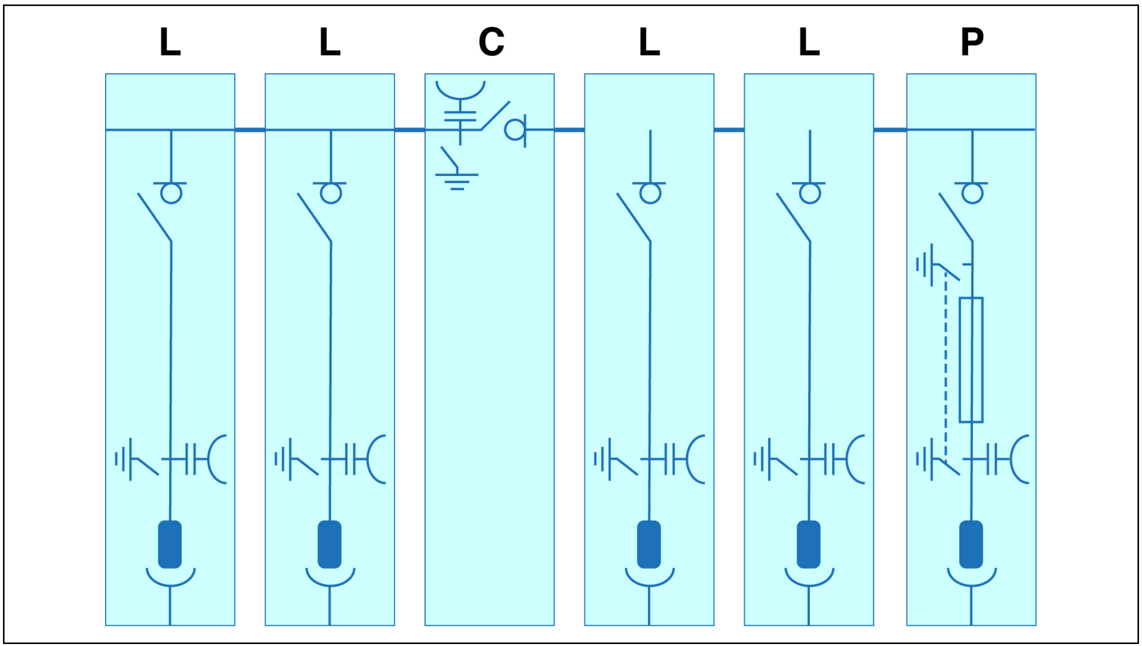


Figure 5.4.1 4LE Type Configuration.

This configuration is mainly used in MV Switching and Distribution Substations as a complete set of two busbars and two positions per busbar or as a main busbar to which a second busbar is coupled.

5.4.2 Device Connections

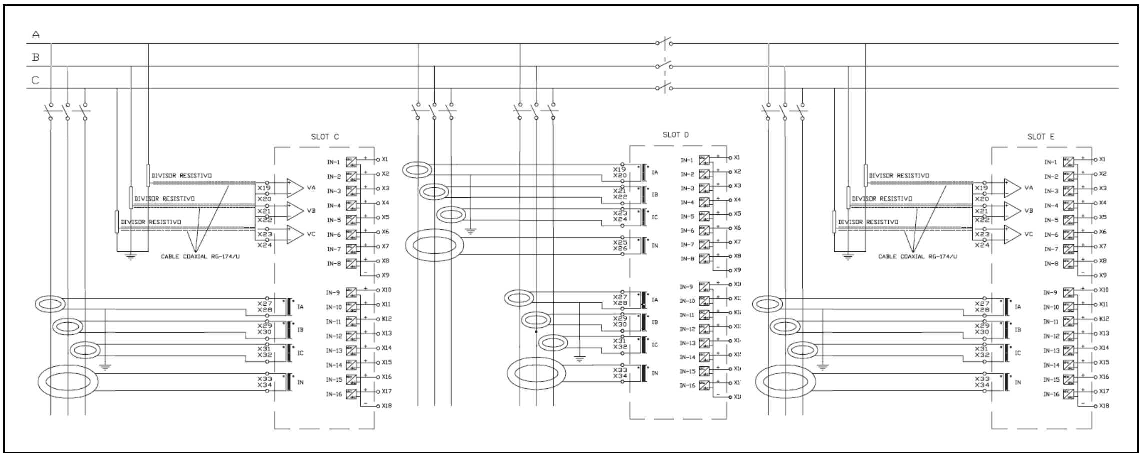


Figure 5.4.2 External Connections.

5.4.3 SLD Diagram

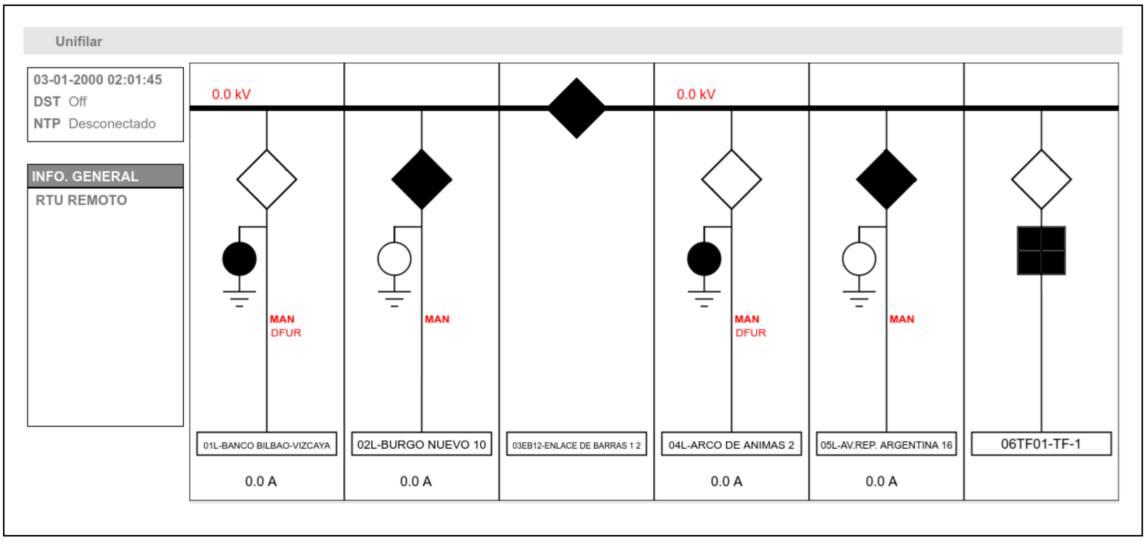


Figure 5.4.3 SLD Diagram.

5.5 G Type Configuration: Smart RTU 2L1T

5.5.1 Application

Compact or modular MV switchgear with tree line functions and one protection function which includes the features of the line cubicles and the protection cubicles accommodated in the same vessel.

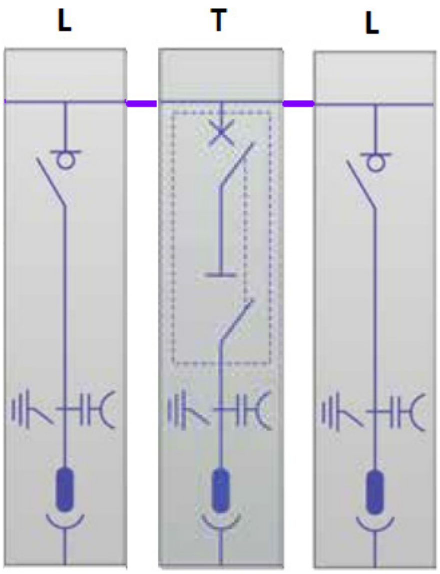


Figure 5.5.1 2L1T Type Configuration.

This switchgear configuration is mostly used in transformation centres where there is a derivation of the main line.

5.5.2 Device Connections

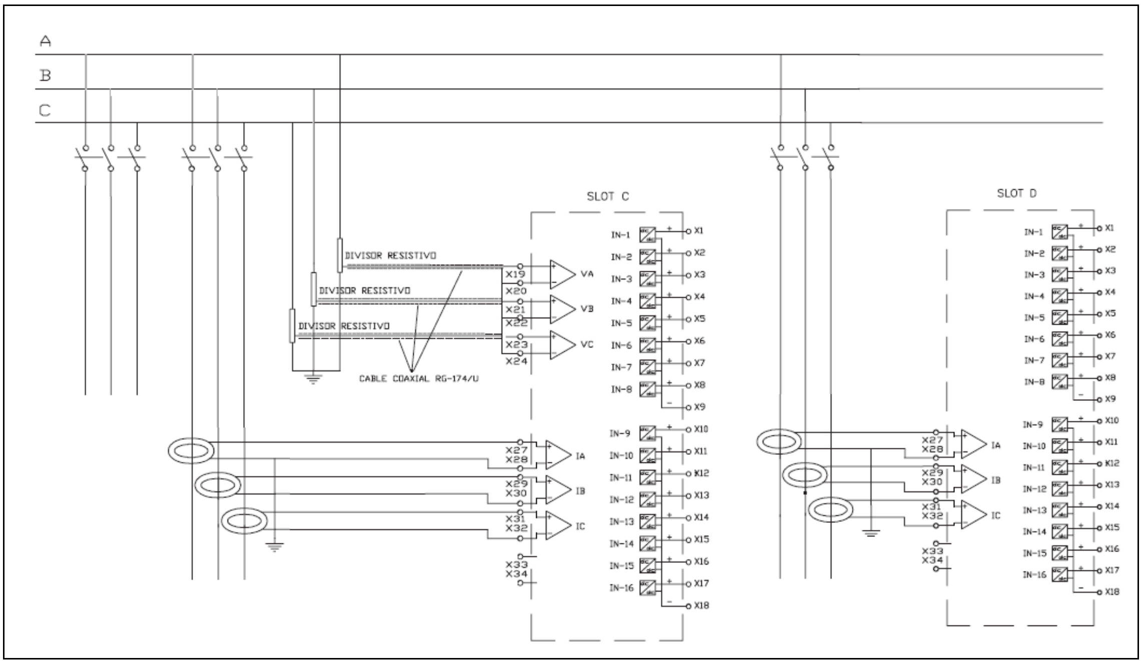


Figure 5.5.2 External Connections.

5.5.3 SLD Diagram

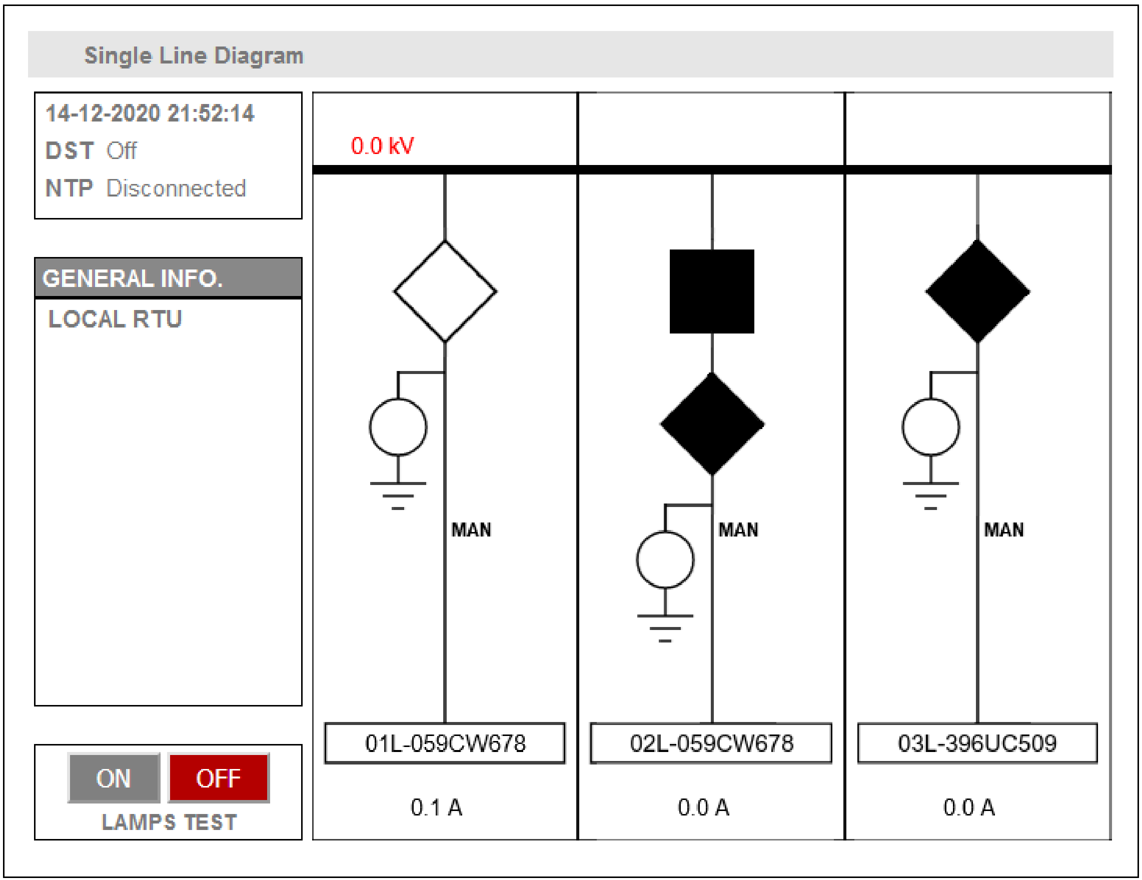


Figure 5.5.3 SLD Diagram.

5.6 H Type Configuration: Smart RTU 2L2T

5.6.1 Application

Compact or modular MV switchgear with tree line functions and one protection function which includes the features of the line cubicles and the protection cubicles accommodated in the same vessel.

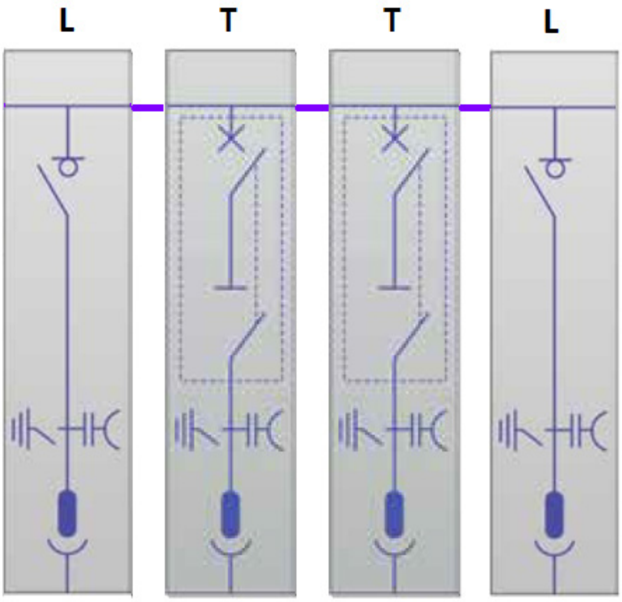


Figure 5.6.1 2L2T Type Configuration.

This switchgear configuration is mostly used in transformation centres where there is more than one derivation of the main line.

5.6.2 Device Connections

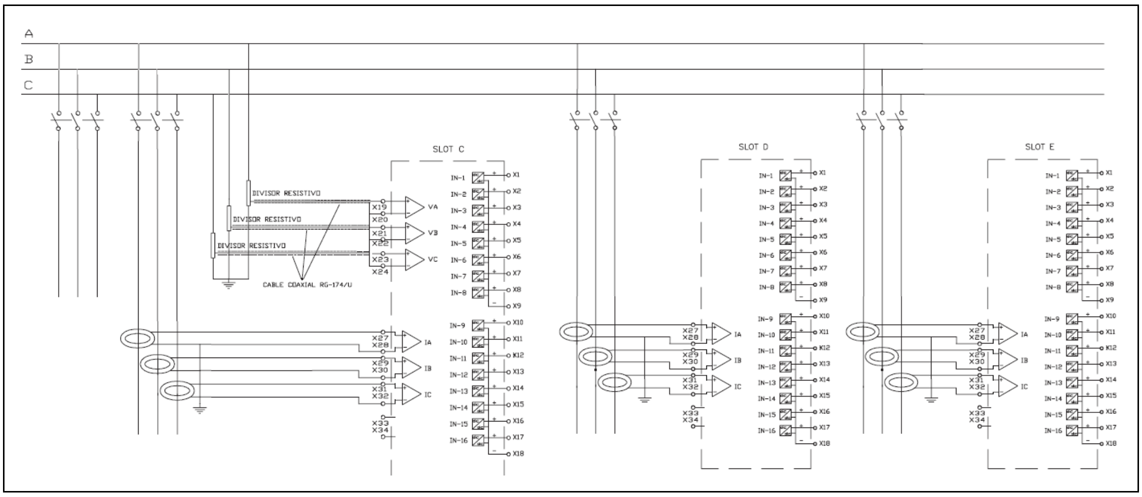


Figure 5.6.2 External Connections.

5.6.3 SLD Diagram

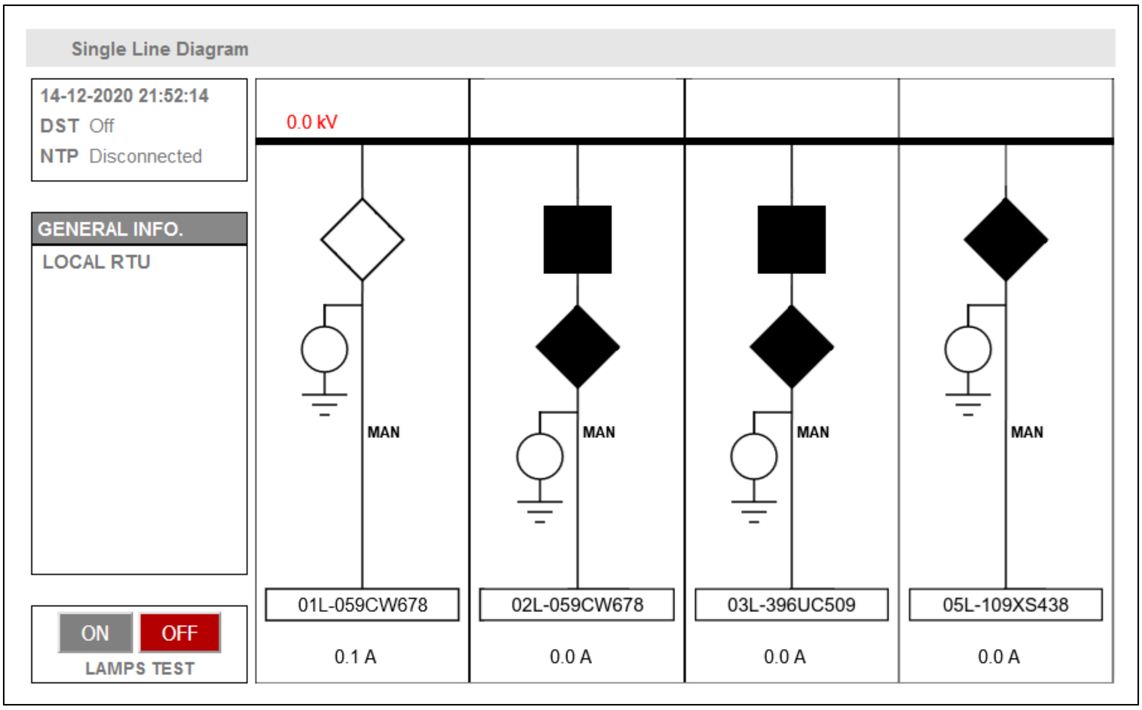


Figure 5.6.3 SLD Diagram.

5.7 H Type Configuration: Smart RTU 3L1T

5.7.1 Application

Compact or modular MV switchgear with tree line functions and one protection function which includes the features of the line cubicles and the protection cubicles accommodated in the same vessel.

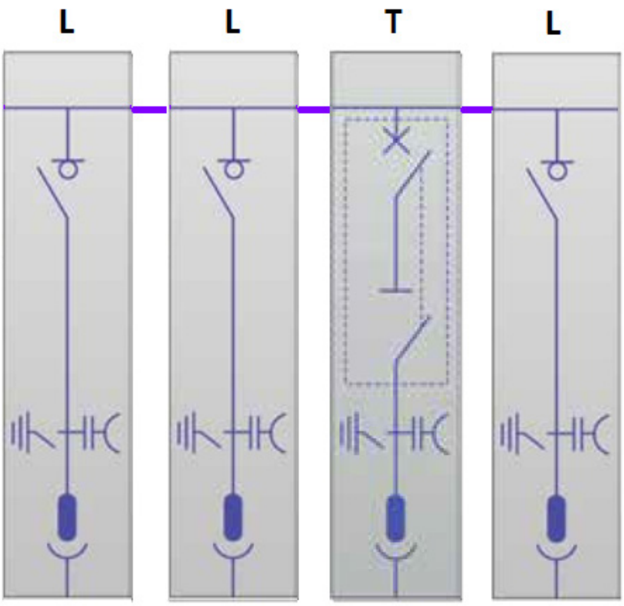


Figure 5.7.1 3L1T Type Configuration.

This switchgear configuration is mostly used in transformation centres where there is more than one derivation of the main line.

5.7.2 Device Connections

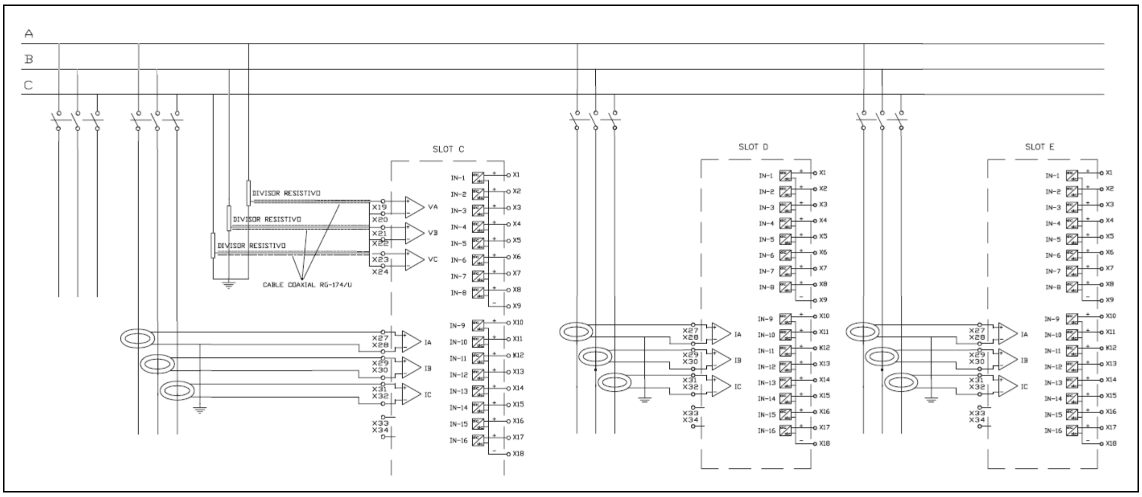


Figure 5.7.2 External Connections.

5.7.3 SLD Diagram

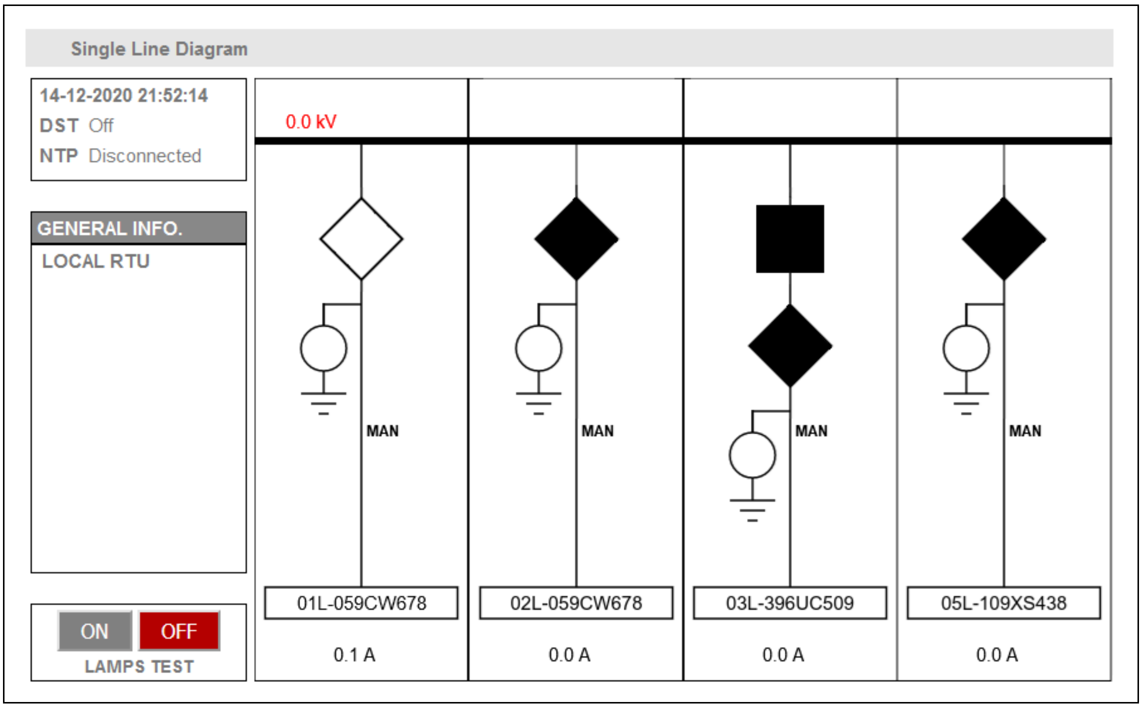


Figure 5.7.3 SLD Diagram.

A. List of Illustrations and Tables

A.1 List of Figures

A.2 List of Tables

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