

AQ-E215

Energy management IED

Instruction manual



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Disclaimer

Please read these instructions carefully before using the equipment or taking any other actions with respect to the equipment. Only trained and qualified persons are allowed to perform installation, operation, service or maintenance of the equipment. Such qualified persons have the responsibility to take all appropriate measures, including e.g. use of authentication, encryption, anti-virus programs, safe switching programs etc. necessary to ensure a safe and secure environment and usability of the equipment. The warranty granted to the equipment remains in force only provided that the instructions contained in this document have been strictly complied with.

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1 Document information

1.1 Version 2 revision notes

Table. 1.1 - 1. Version 2 revision notes

| | |
|----------|--|
| Revision | 2.00 |
| Date | 6.6.2019 |
| Changes | <ul style="list-style-type: none"> - New more consistent look. - Improved descriptions generally in many chapters. - Improved readability of a lot of drawings and images. - Updated protection functions included in every IED manual. - Every protection IED type now has connection drawing, application example drawing with function block diagram and application example with wiring. - Added General-menu description. |
| Revision | 2.01 |
| Date | 6.11.2019 |
| Changes | <ul style="list-style-type: none"> - Added description for LED test and button test. - Complete rewrite of every chapter. - Improvements to many drawings and formula images. - Order codes revised. - Added double ST 100 Mbps Ethernet communication module and Double RJ45 10/100 Mbps Ethernet communication module descriptions |
| Revision | 2.02 |
| Date | 7.7.2020 |
| Changes | - A number of image descriptions improved. |
| Revision | 2.03 |
| Date | 27.8.2020 |

| | |
|----------|---|
| Changes | <ul style="list-style-type: none"> - Terminology consistency improved (e.g. binary inputs are now always called digital inputs). - Tech data modified to be more informative about what type of measurement inputs are used (phase currents/voltages, residual currents/voltages), what component of that measurement is available (RMS, TRMS, peak-to-peak) and possible calculated measurement values (powers, impedances, angles etc.). - Improvements to many drawings and formula images. - Improved and updated IED user interface display images. - AQ-E215 Functions included list Added: Voltage memory, objects, indicator objects, programmable switches, mA outputs and measurement recorder. - Changed disturbance recorder maximum digital channel amount from 32 to 95. - Added residual current coarse and fine measurement data to disturbance recorder description. - Updated I01 and I02 rated current range. - Added inches to Dimensions and installation chapter. - Added raising frames, wall mounting bracket, combiflex frame to order code. - Added logical input and logical output function descriptions. - Additions to Abbreviations chapter. - Added button test description to Local panel structure chapter. - Added Fault register view to Basic configuration chapter. - Added parameter descriptions to General menu IED user interface chapter. - Added new parameter descriptions to Monitoring menu IED user interface chapter. - Added note to Configuring user levels and passwords chapter that user level with a password automatically locks itself after 30 minutes of inactivity. - Added more "Tripped stage" indications and fault types to Measurement value recorder function. - Updated: Digital input activation and release threshold setting ranges and added drop-off delay setting. - Added sample rate to voltage and current measurement tech data. |
| Revision | 2.04 |
| Date | 8.6.2021 |
| Changes | <ul style="list-style-type: none"> - increased the consistency in terminology - various image upgrades - visual update to the order codes |

1.2 Version 1 revision notes

Table. 1.2 - 2. Version 1 revision notes

| | |
|----------|--|
| Revision | 1.00 |
| Date | 19.1.2015 |
| Changes | - The first revision for AQ-E215 IED. |
| Revision | 1.01 |
| Date | 12.1.2016 |
| Changes | - Added digital input operation description. |
| Revision | 1.02 |
| Date | 30.5.2016 |

| | |
|----------|--|
| Changes | - Added PCB and Terminal options to order code. |
| Revision | 1.03 |
| Date | 30.8.2016 |
| Changes | - Added password set up guide (previously only in AQtivate user guide) |
| Revision | 1.04 |
| Date | 13.1.2017 |
| Changes | - Added Programmable Control Switch and Indicator Object descriptions - Order code updated |
| Revision | 1.05 |
| Date | 12.12.2017 |
| Changes | - Measurement value recorder description - ZCT connection added to current measurement description - RTD&mA card description improvements - Ring-lug CT card option description added - Order code revised |
| Revision | 1.06 |
| Date | 14.8.2018 |
| Changes | - Added mA output option card description and ordercode |
| Revision | 1.07 |
| Date | 18.1.2019 |
| Changes | - HMI display technical data added |

2 Abbreviations

| | | |
|------|---|-------------------------------------|
| AI | – | Analog input |
| AR | – | Auto-recloser |
| ASDU | – | Application service data unit |
| AVR | – | Automatic voltage regulator |
| BCD | – | Binary-coded decimal |
| CB | – | Circuit breaker |
| CBFP | – | Circuit breaker failure protection |
| CLPU | – | Cold load pick-up |
| CPU | – | Central processing unit |
| CT | – | Current transformer |
| CTM | – | Current transformer module |
| CTS | – | Current transformer supervision |
| DG | – | Distributed generation |
| DHCP | – | Dynamic Host Configuration Protocol |
| DI | – | Digital input |
| DO | – | Digital output |
| DOL | – | Direct-on-line |
| DR | – | Disturbance recorder |
| DT | – | Definite time |
| FF | – | Fundamental frequency |
| FFT | – | Fast Fourier transform |
| FTP | – | File Transfer Protocol |
| GI | – | General interrogation |
| HMI | – | Human-machine interface |
| HR | – | Holding register |
| HV | – | High voltage |
| HW | – | Hardware |
| IDMT | – | Inverse definite minimum time |
| IED | – | Intelligent electronic device |

IGBT – Insulated-gate bipolar transistor

I/O – Input and output

IRIG-B – Inter-range instruction group, timecode B

LCD – Liquid-crystal display

LED – Light emitting diode

LV – Low voltage

NC – Normally closed

NO – Normally open

NTP – Network Time Protocol

RMS – Root mean square

RSTP – Rapid Spanning Tree Protocol

RTD – Resistance temperature detector

RTU – Remote terminal unit

SCADA – Supervisory control and data acquisition

SG – Setting group

SOTF – Switch-on-to-fault

SW – Software

THD – Total harmonic distortion

TRMS – True root mean square

VT – Voltage transformer

VTM – Voltage transformer module

VTS – Voltage transformer supervision

3 General

The AQ-E215 energy management IED is a member of the AQ-200 product line. The hardware and software are modular: the hardware modules are assembled and configured according to the application's I/O requirements and the software determines the available functions. This manual describes the specific application of the AQ-E215 energy management IED. For other AQ-200 series products please consult their respective device manuals.

AQ-E215 integrates into a single equipment a fault location functionality and a kWh measurement as accurate as that used by energy companies for billing. This combination of highly accurate measurement technology and fault detecting algorithms allows AQ-E215 to be applied for volt/var optimization as well as for tracking power losses and reducing power outages through accurate fault location.

4 IED user interface

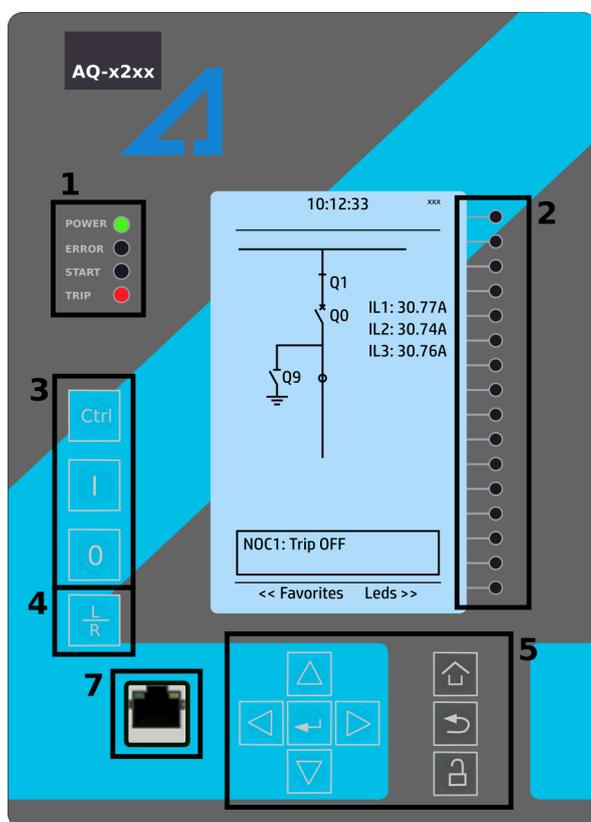
4.1 Panel structure

The user interface section of an AQ-200 series device is divided into two user interface sections: one for the hardware and the other for the software. You can access the software interface either through the front panel or through the AQtivate freeware software suite.

4.1.1 Local panel structure

The front panel of AQ-200 series devices have multiple LEDs, control buttons and a local RJ-45 Ethernet port for configuration. Each unit is also equipped with an RS-485 serial interface and an RJ-45 Ethernet interface on the back of the device. See the image and list below.

Figure. 4.1.1 - 1. Local panel structure.



1. Four (4) default LEDs: "Power", "Error", "Start" (configurable) and "Trip" (configurable).
2. Sixteen (16) freely configurable LEDs with programmable legend texts.
3. Three (3) object control buttons: Choose the controllable object with the **Ctrl** button and control the breaker or other object with the **I** and **O** buttons.
4. The **L/R** button switches between the local and the remote control modes.
5. Eight (8) buttons for IED local programming: the four navigation arrows and the **Enter** button in the middle, as well as the **Home**, the **Back** and the password activation buttons.
6. One (1) RJ-45 Ethernet port for IED configuration.

When the unit is powered on, the green "Power" LED is lit. When the red "Error" LED is lit, the relay has an internal (hardware or software) error that affects the operation of the unit. The activation of the yellow "Start" LED and the red "Trip" LED are based on the setting the user has put in place in the software.

The sixteen freely configurable LEDs are located on the right side of the display. Their activation and color (green or yellow) are based on the settings the user has put in place in the software.

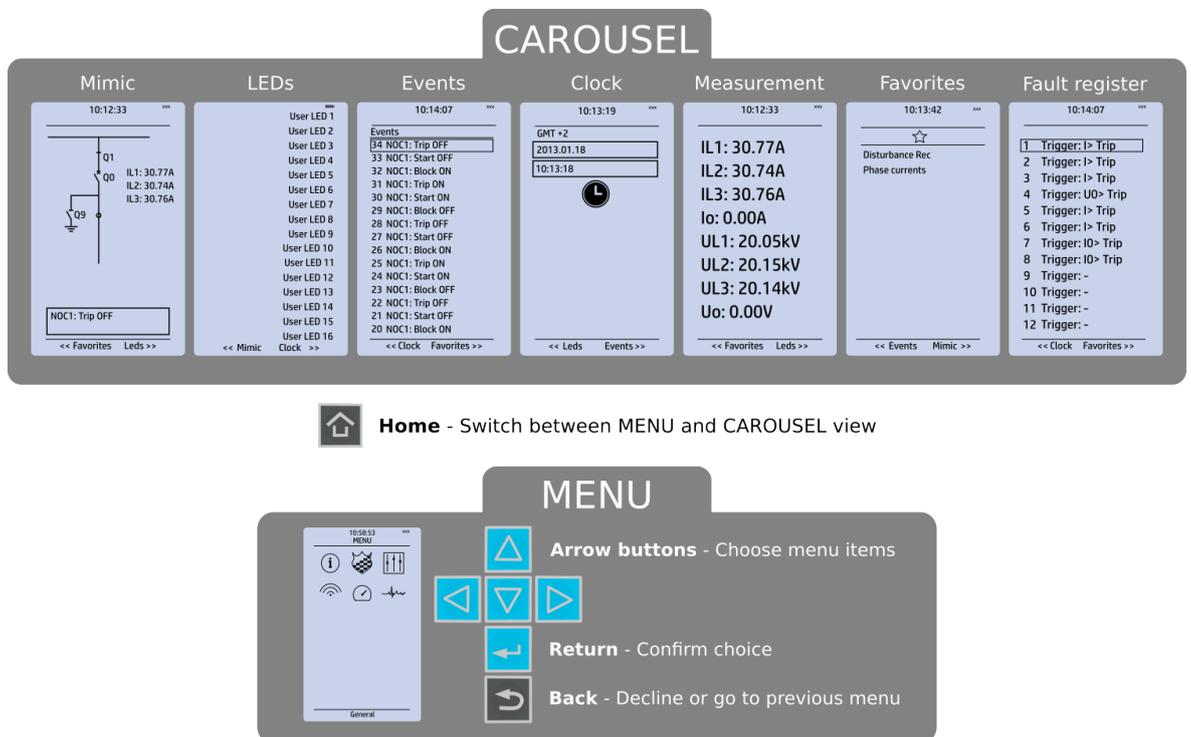
Holding the I (object control) button down for five seconds brings up the button test menu. It displays all the physical buttons on the front panel. Pressing any of the listed buttons marks them as tested. When all buttons are marked as having been tested, device will return back to default view.

4.2 Mimic and main menu

4.2.1 Basic configuration

The user interface is divided into seven (7) quick displays: "Mimic", "LEDs", "Events", "Clock", "Measurement", "Favorites" and "Fault register". The default quick display (as presented in the image below) is the mimic view; you can move through these menus by pressing the left and right arrow buttons. Please note that the available quick display carousel view might be different if you have changed the view with AQtivate's Carousel Designer tool.

Figure. 4.2.1 - 2. Basic navigation (general).



The **Home** button switches between the quick display carousel and the main display with the six (6) main configuration menus (*General, Protection, Control, Communication, Measurements and Monitoring*). Note that the available menus vary depending on the device type. You can select one of the menus by using the four navigation arrows and pressing **Enter** in the middle. The **Back** button takes you back one step. If you hold it down for three seconds, it takes you back to the main menu. You can also use it to reset the alarm LEDs you have set. The password activation button (with the padlock icon) takes you to the password menu where you can enter the passwords for the various user levels (User, Operator, Configurator, and Super-user).

4.2.2 Navigation in the main configuration menus

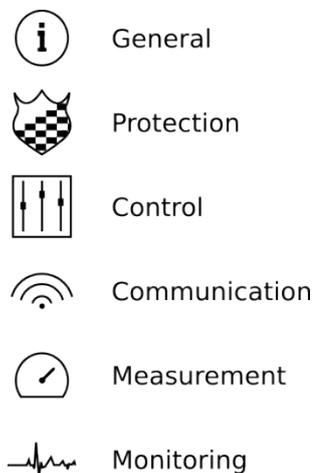
All the settings in this device have been divided into the following six (6) main configuration menus:

- General
- Protection

- Control
- Communication
- Measurement
- Monitoring.

They are presented in the image below. The available menus vary according to the device type.

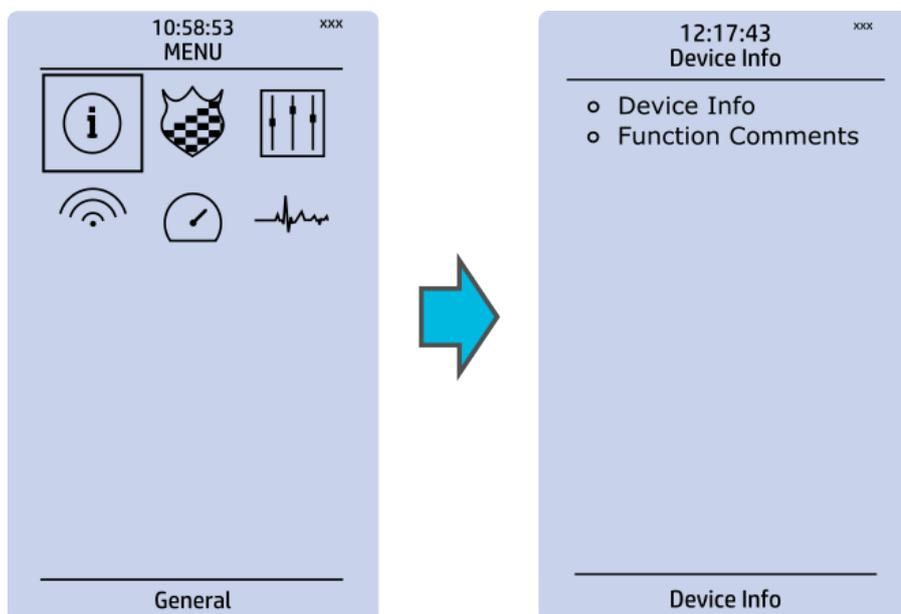
Figure. 4.2.2 - 3. Main configuration menus.



4.3 General menu

The *General* main menu is divided into two submenus: the *Device info* tab presents the information of the device, while the *Function comments* tab allows you to view all comments you have added to the functions.

Figure. 4.3 - 4. General menu structure



Device info

Figure. 4.3 - 5. Device info.

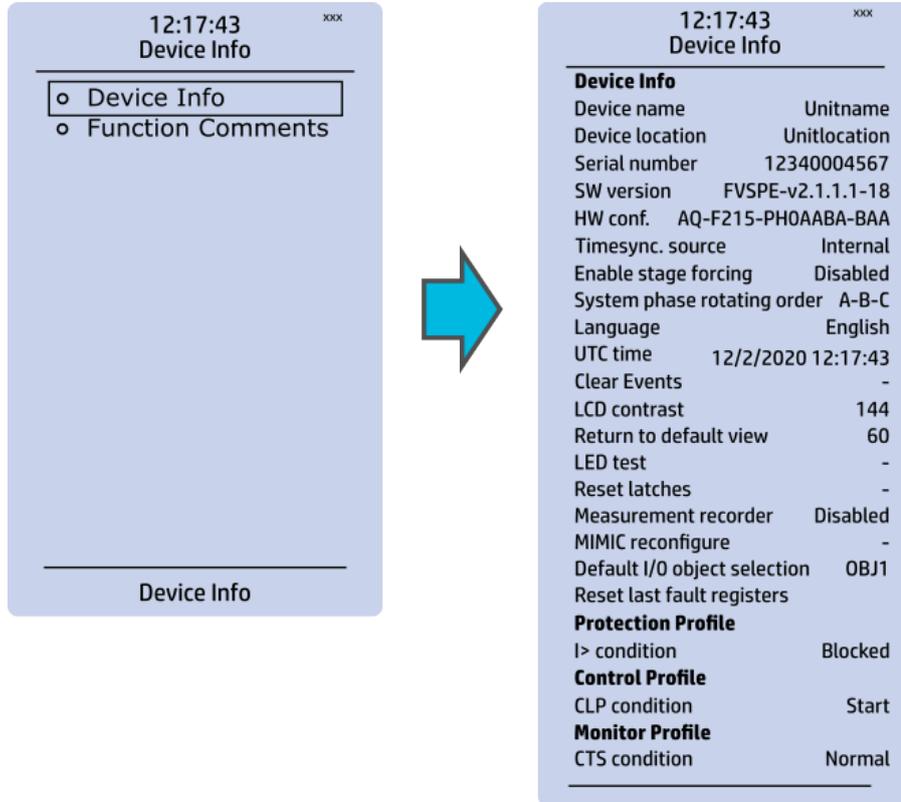


Table. 4.3 - 3. Parameters and indications in the *General* menu.

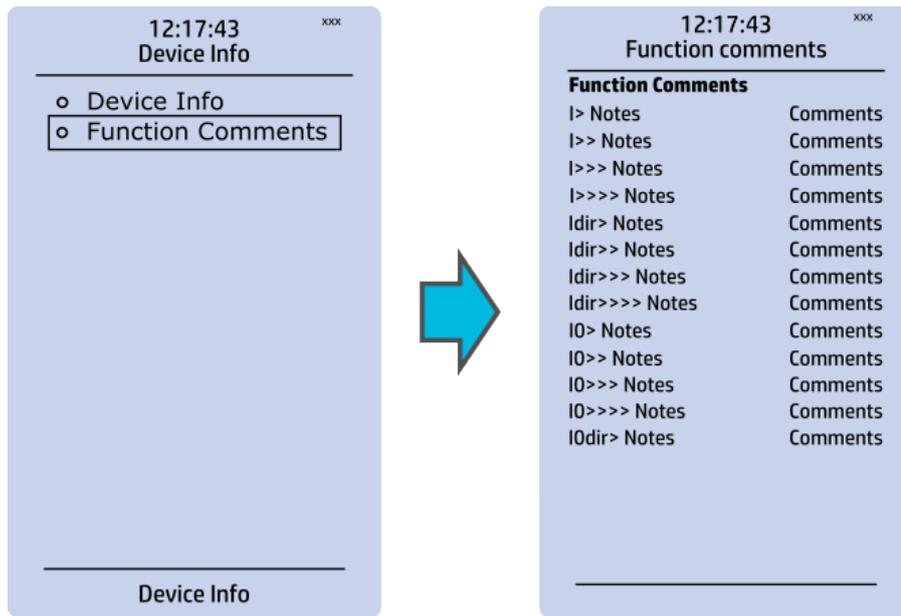
| Name | Range | Step | Default | Description |
|-----------------------------|---|------|--------------|--|
| Device name | - | - | Unitname | The file name uses these fields when loading the .aqc configuration file from the AQ-200 unit. |
| Device location | - | - | Unitlocation | |
| Serial number | - | - | - | Displays the unit's unique serial number. The serial number is also printed on the sticker located on the side of the unit. |
| Firmware version | - | - | - | Displays the software version (firmware) used by the unit. Upgradable by the user if a newer version is available. |
| Hardware configuration | - | - | - | Displays the hardware configuration of the unit. The hardware configuration is also printed on the sticker located on the side of the unit. |
| Time synchronization source | 0: Internal 1: External NTP 2: External Serial 3: IRIG-B | - | 0: Internal | If an external clock time synchronization source is available, the type is defined with this parameter. In the internal mode there is no external Timesync source. IRIG-B requires a serial fiber communication option card. |
| Enable stage forcing | 0: Disabled 1: Enabled | - | 0: Disabled | When this parameter is enabled it is possible for the user to force the protection, control and monitoring functions to different statuses like START and TRIP. This is done in the function's <i>Info</i> page with the <i>Force status to</i> parameter. |
| System phase rotating order | 0: A-B-C 1: A-C-B | - | 0: A-B-C | Allows the user to switch the expected order in which the phase measurements are wired to the unit. |

| Name | Range | Step | Default | Description |
|------------------------------------|---|------|-------------|--|
| Language | 0: User defined 1: English 2: Finnish 3: Swedish 4: Spanish 5: French 6: German 7: Russian 8: Ukraine | - | 1: English | Changes the language of the parameter descriptions in the HMI. If the language has been set to "Other" in the settings of the AQtivate setting tool, AQtivate follows the value set into this parameter. |
| UTC time | - | - | - | Displays the UTC time used by the unit without time zone corrections. |
| Clear events | 0: - 1: Clear | - | 0: - | Clears the event history recorded in the AQ-200 device. |
| LCD Contrast | 0...255 | 1 | 120 | Changes the contrast of the LCD display. |
| Return to default view | 0...3600 s | 10 s | 0 s | If the user navigates to a menu and gives no input after a period of time defined with this parameter, the unit automatically returns to the default view. If set to 0 s, this feature is not in use. |
| LED test | 0: - 1: Activated | - | 0: - | When activated, all LEDs are lit up. LEDs with multiple possible colors blink each color. |
| Reset latches | 0: - 1: Reset | - | 0: - | Resets the latched signals in the logic and the matrix. When a reset command is given, the parameter automatically returns back to "-". |
| Measurement recorder | 0: Disabled 1: Enabled | - | 0: Disabled | Enables the measurement recorder tool, further configured in <i>Tools</i> → <i>Misc</i> → <i>Measurement recorder</i> . |
| Reconfigure mimic | 0: - 1: Reconfigure | - | 0: - | Reloads the mimic to the unit. |
| Reset last fault registers | - | - | - | Activation of input selected here resets the values in "Fault registers" view in carousel. |
| Protection/Control/Monitor profile | - | - | - | Displays the status of all enabled functions. |

Function comments

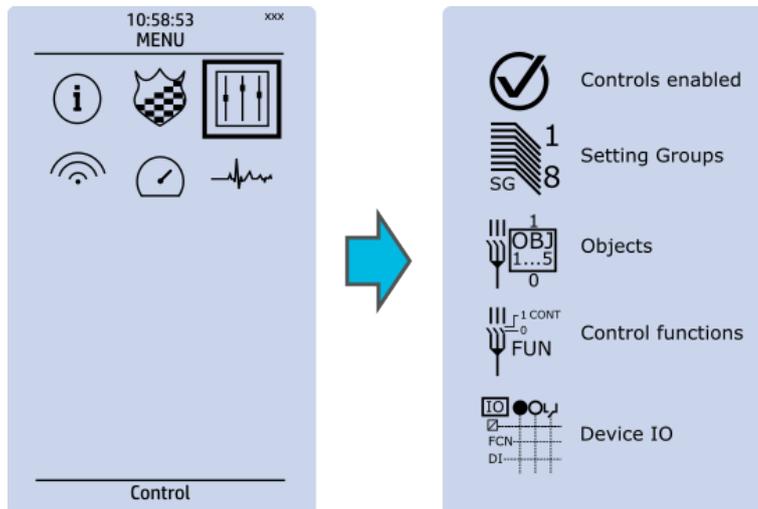
Function comments displays notes of each function that has been activated in the Protection, Control and Monitoring menu. Function notes can be edited by the user.

Figure. 4.3 - 6. Function comments.



4.4 Control menu

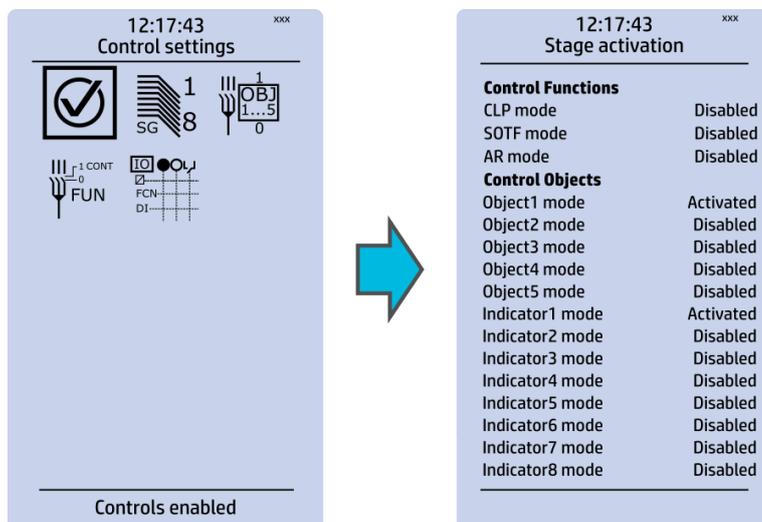
Main menu



The *Control* main menu includes submenus (see the image above) for enabling the various control functions and objects (*Controls enabled*), for enabling and controlling the setting groups (*Setting groups*), for configuring the objects (*Objects*), for setting the various control functions (*Control functions*), and for configuring the inputs and outputs (*Device I/O*). The available control functions depend on the model of the device in use.

Controls enabled

Figure. 4.4 - 7. Controls enabled submenu.

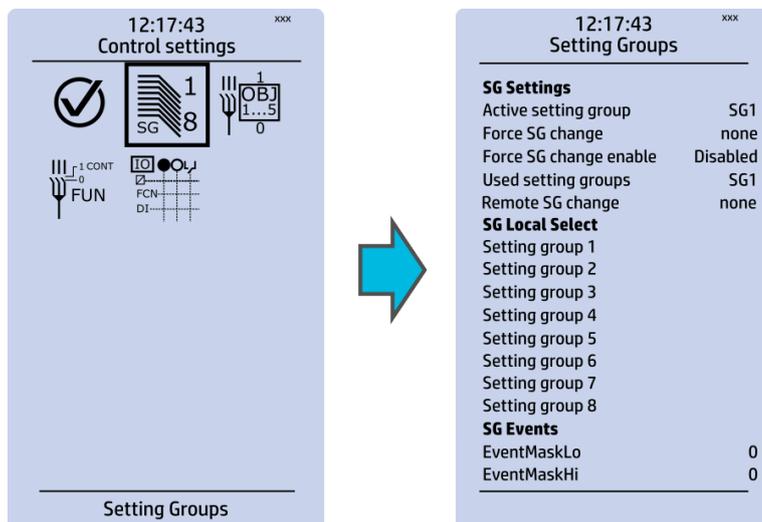


You can activate the selected control functions in the *Controls enabled* submenu. By default all the control functions are disabled. All activated functions can be viewed in the *Control functions* submenu (see the section "Control functions" below for more information).

In this submenu you can also activate and disable controllable objects. As with control functions, all objects are disabled by default. All activated objects can be viewed in the *Objects* submenu (see the section "Objects" below for more information).

Setting groups

Figure. 4.4 - 8. Setting groups submenu.



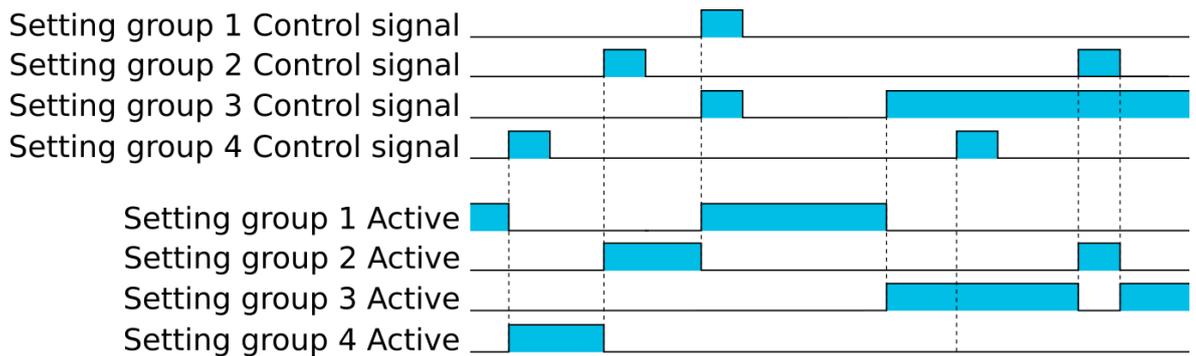
The *Setting groups* submenu displays all the information related to setting group changing, such as the following:

- **Active setting group:** displays the current active setting group (SG1...SG8).
- **Force setting group change:** this setting allows the activation of a setting group at will (please note that Force SG change enable must be "Enabled").
- **Used setting groups:** this setting allows the activation of setting groups SG1...SG8 (only one group is active by default).

- **SG local select:** selects the local control for the different setting groups (can use digital inputs, logical inputs or outputs, RTDs, object status information as well as stage starts, trips or blocks).
- **Remote setting group change:** When enabled it is possible to change the setting group manually through SCADA.
- **SG events:** event masking for setting groups (masks are OFF by default; please note that only masked events are recorded into the event history).

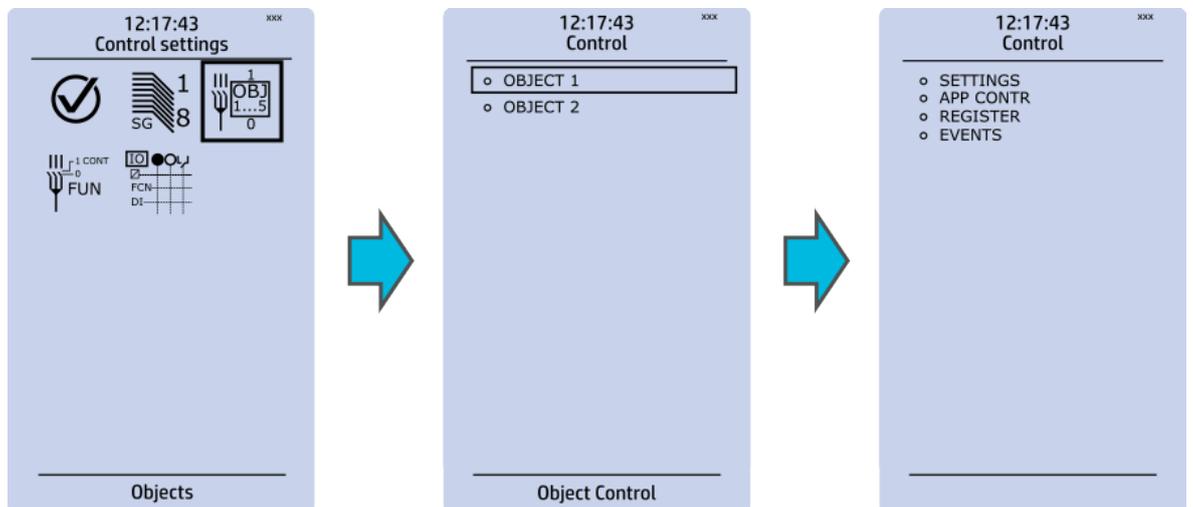
Setting group 1 (SG1) has the highest priority, while Setting group 8 (SG8) has the lowest priority. Setting groups can be controlled with pulses or with both pulses and static signals (see the image below).

Figure. 4.4 - 9. Example of setting group (SG) changing.



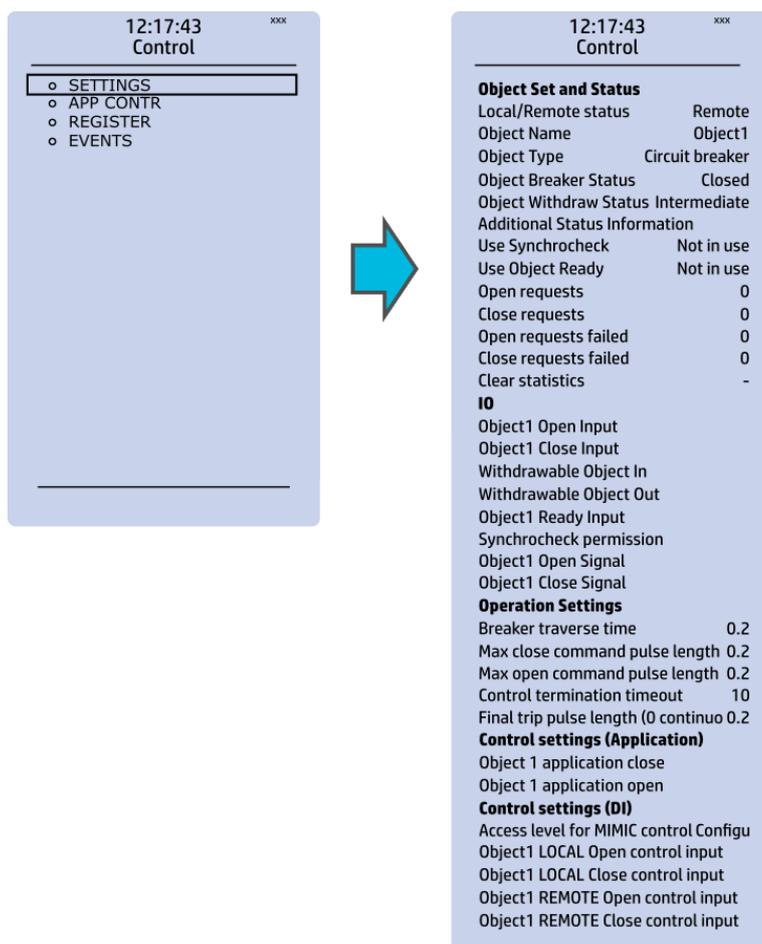
Objects

Figure. 4.4 - 10. Objects submenu.



Each activated object is visible in the *Objects* submenu. By default all objects are disabled unless specifically activated in the *Controls* → *Controls enabled* submenu. Each active object has four sections in their submenus: "Settings", "Application control" ("App contr"), "Registers" and "Events". These are described in further detail below.

Figure. 4.4 - 11. Settings section.



OBJECT SET AND STATUS

- **Local/Remote status:** control access may be set to Local or Remote (Local by default; please note that when local control is enabled, the object cannot be controlled through the bus and vice versa).
- **Object name:** the name of the object (objects are named "ObjectX" by default).
- **Object type:** selects the type of the object from Grounding disconnector, Motor-controlled disconnector, Circuit breaker and Withdrawable circuit breaker (Circuit breaker by default).
- **Object x status:** the status can be Bad, Closed, Open and Intermittent. The status "Intermittent" is the phase between "Open" and "Closed" where both status inputs are 0. The status "Bad" occurs when both status inputs of the object/cart are 1.
- **Additional status information:** gives feedback from the object on whether the opening and closing are allowed or blocked, whether the object is ready, and whether the synchronization status is ok.
- **Use synchrocheck and Use Object ready:** closing the object is forbidden when the sides are not synchronized or when the object is not ready to be closed.
- **Open requests and Close requests:** displays the statistics, i.e. the number of Open and Close requests.
- **Open requests failed and Close requests failed:** displays the statistics of Open and Close request failures. A request is considered to have failed when the object does not change its status as a result of that request.
- **Clear statistics:** statistics can be cleared by choosing "Clear statistics" and then "Clear".

I/O

- An object has both **Open input** and **Close input** signals which are used for indicating the status of the breaker on the HMI and in SCADA. Status can be indicated by any of the following: digital inputs, logical inputs or outputs.
- A withdrawable object has both **In** and **Out** inputs. The status can be indicated by any of the following: digital inputs, logical inputs or outputs.
- Both **Object ready** and **Synchrocheck permission** have status inputs. If either one is used, the input(s) must be active for the relay to be able to give the "Object Close" command.
- **Object open** and **Object close** signals define which digital output is controlled.

OPERATION SETTINGS

- **Breaker traverse time:** determines how long a gap there can be between a status change from "Open" to "Closed" before an intermittent status is reported by the function.
- **Max close/open command pulse length:** defines the maximum length of "Open" and "Close" commands. If the status has changed before the maximum pulse length has elapsed, the pulse is cut short.
- **Control termination timeout:** If the status of the object does not change during the set time, an "Open/Close request failed" event is recorded.
- After the set delay, if the controlled object does not respond accordingly, the procedure is terminated and a fail message is issued.

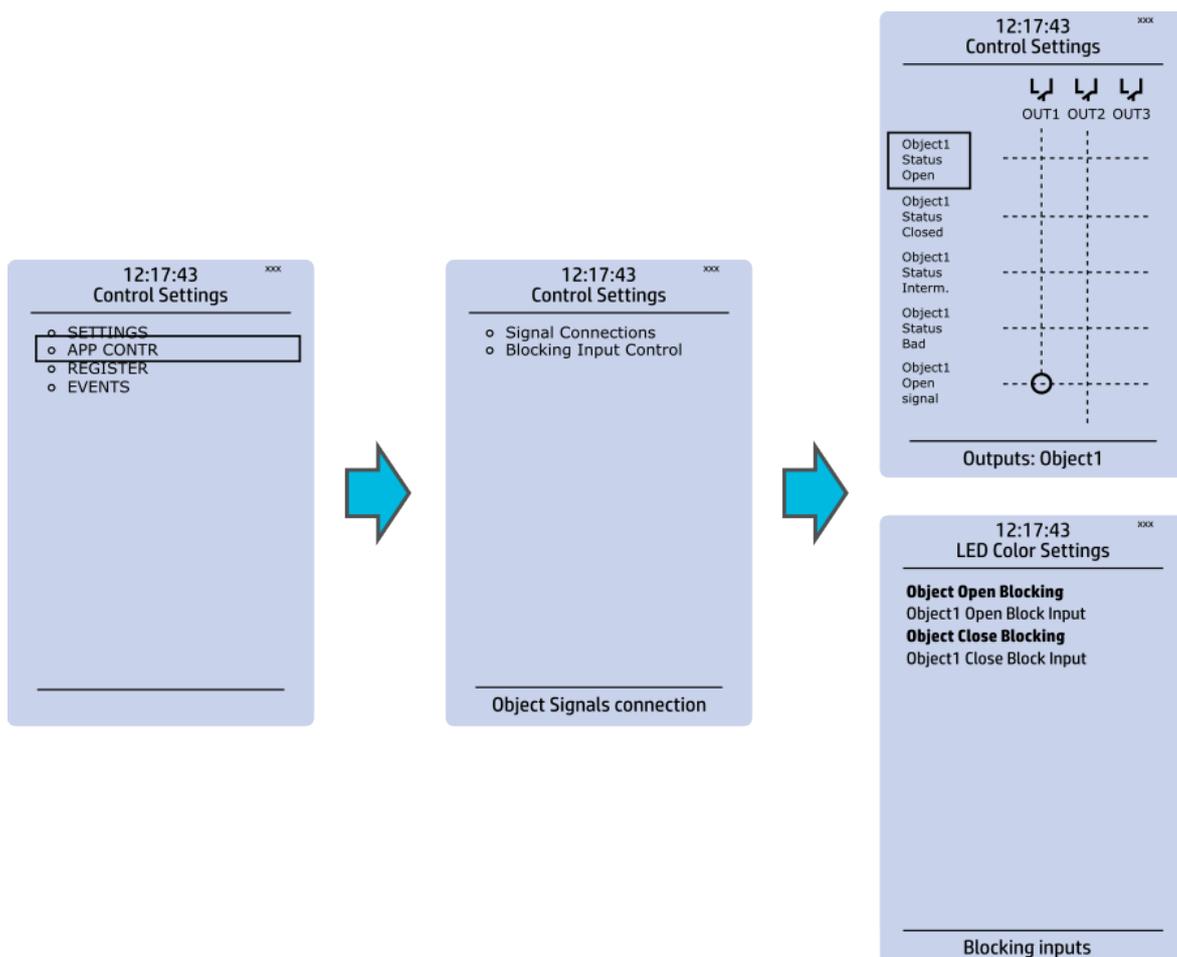
CONTROL SETTINGS (APPLICATION)

- **Object application close** and **Object application open:** a signal set to these points can be used to open and close the object. Controlling the object through this point does not follow the local/remote status of the relay.

CONTROL SETTINGS (DI)

- **Access level for MIMIC control:** determines the access level required to control the MIMIC (each level has its own password). By default, the access level is set to "Configurator".
- You can use digital inputs to control the object locally or remotely. Remote controlling via the bus is configured on the protocol level.

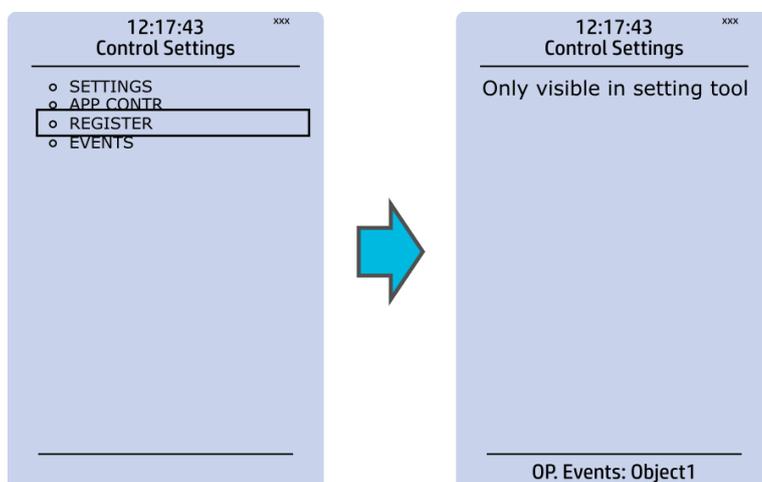
Figure. 4.4 - 12. Application control section.



You can connect object statuses directly to specific physical outputs in the "Signal connections" subsection (*Control* → *Application control*). A status can be connected to output relays, as well as to user-configurable LEDs. A connection to an output can be either latched ("|x|") or non-latched ("x").

Object blocking is done in the "Blocking input control" subsection. It can be done by any of the following: digital inputs, logical inputs or outputs, object status information as well as stage starts, trips or blocks.

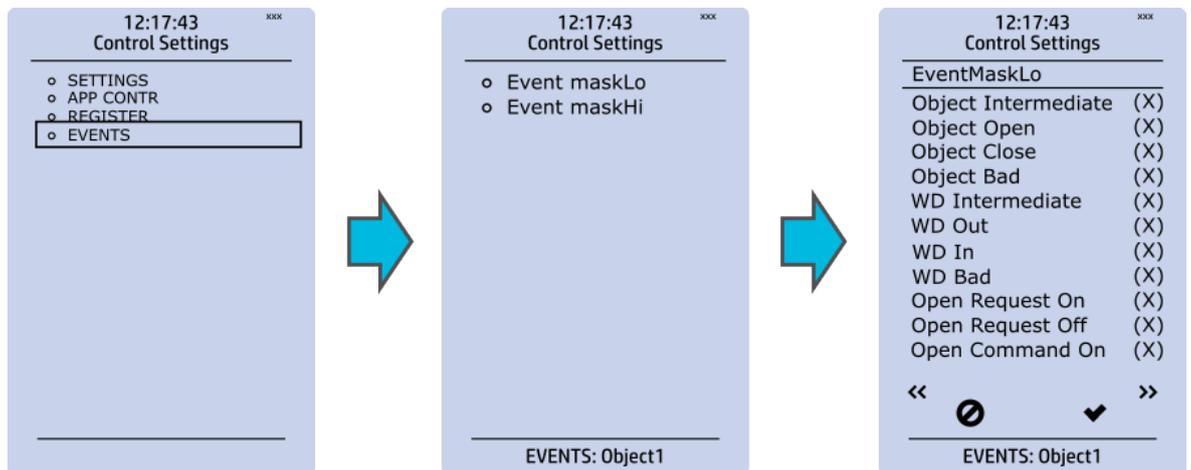
Figure. 4.4 - 13. Registers section.



The "Registers" section stores the function's specific fault data. There are twelve (12) registers, and each of them includes data such as opening and closing times, command types and request failures. The data included in the register depend on the protection function. You can clear the the operation register by choosing "Clear registers" → "Clear".

Please note that the content of the *Registers* section is not available in the HMI. It can only be accessed via the AQtivate setting tool.

Figure. 4.4 - 14. Events section.

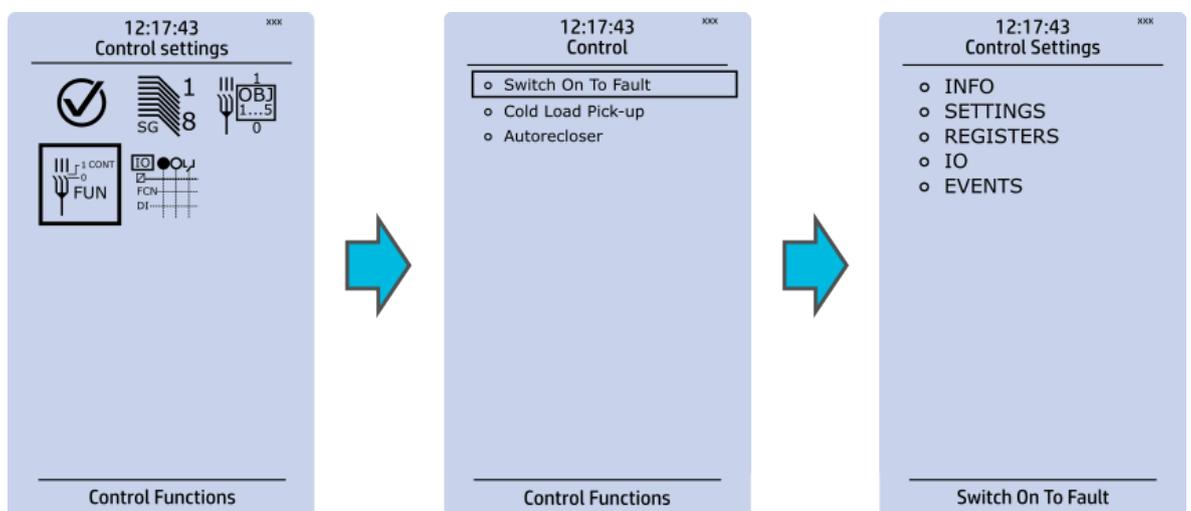


You can mask on and mask off events related to an object's stage in "Event mask". By default all events are masked off. You can activate the desired events by masking them ("x"). Please remember to save your maskings by confirming the changes with the check mark icon. If you want to cancel the changes, select the strike-through circle to do so. Only masked events are recorded to the event history (which can be accessed in the "Events" view in the user view section).

Control functions

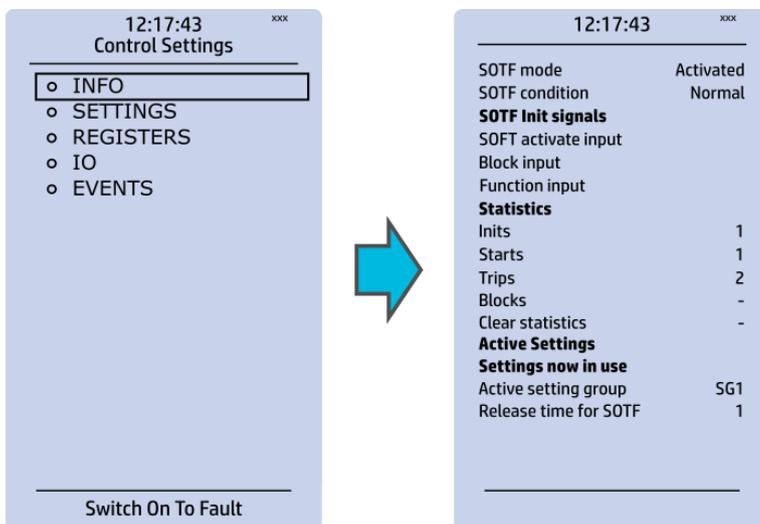
Once a control function has been activated in the *Controls* → *Controls enabled* submenu, its own submenu can be opened. In the image series below, the user has activated three control functions. The user accesses the list of activated control stages through the "Control functions" module, and selects the control function for further inspection.

Figure. 4.4 - 15. Control functions submenu.



Each control function that has been activated is listed in the *Control functions* submenu (see the middle image above). This submenu includes the following sections: "Info", "Settings", "Registers", "I/O" and "Events". The text below describes these in further detail.

Figure. 4.4 - 16. Info section.

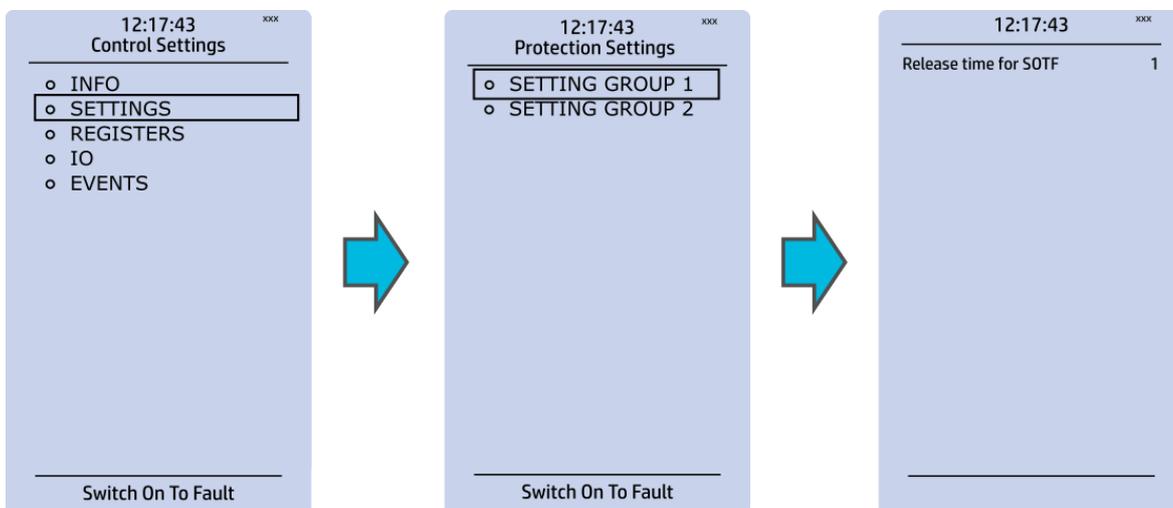


The "Info" section offers many details concerning the function and its status:

- **Function condition:** indicates the stage's condition which can be Normal, Start, Trip, or Blocked.
- **Measured magnitude:** In some functions it is possible to choose the monitored magnitude between Peak-to-peak, TRMS, or RMS (the default is RMS; the available magnitudes depend on the function).
- **Statistics:** indicates the number of function starts, trips and blocks (can be cleared through "Clear statistics" → "Clear").
- **Measurements:** displays the measurements carried out by the function.
- **Active settings:** displays the setting group that is currently in use and its settings (other setting groups can be set in the "Settings" section).

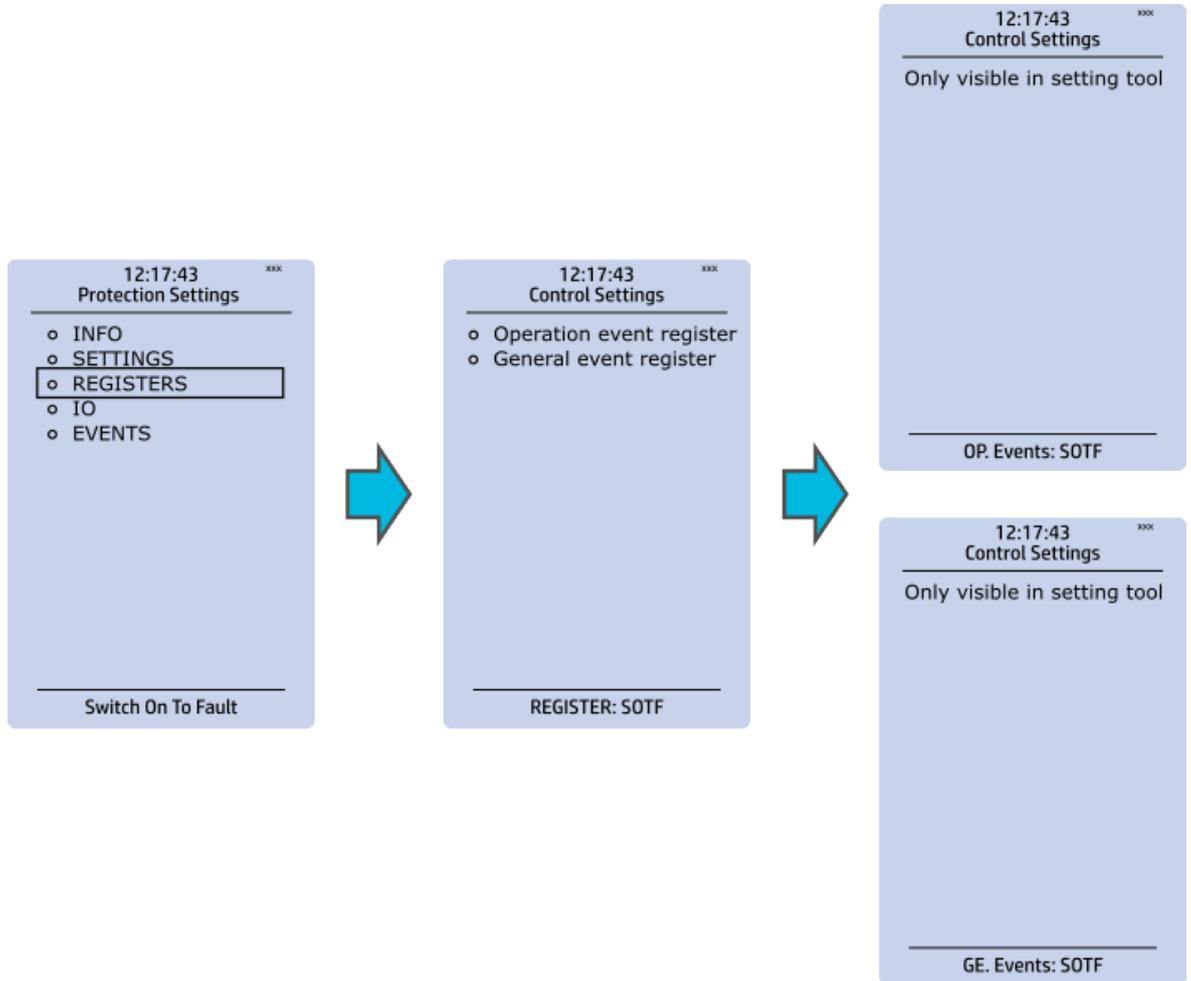
While the function is activated and disabled in the *Control* → *Controls enabled* submenu, you can disable the function through the "Info" section (the [function name] mode at the top of the section).

Figure. 4.4 - 17. Settings section.



The stage settings vary depending on which control function they are a part of. By default only one setting group of the eight available setting groups is activated. You can enable more groups in the *Control* → *Setting groups* menu, although they are set here in the "Settings" section.

Figure. 4.4 - 18. Registers section.

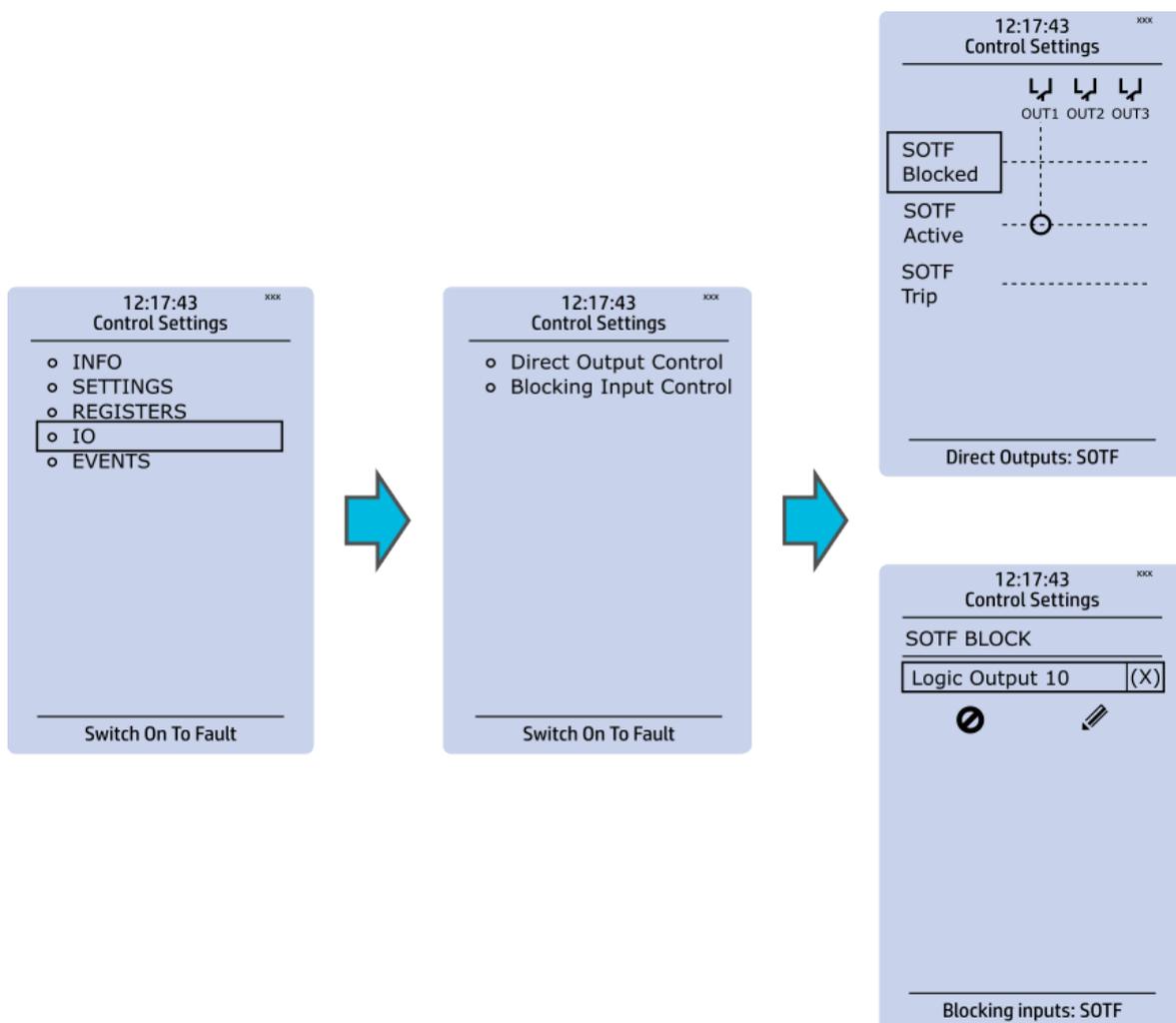


Please note that the content of the "Registers" section is not available in the HMI. It can only be accessed via the AQtivate setting tool. Stored in the "Registers" section you can find both "Operation event register" and "General event register".

"Operation event register" stores the function's specific operation data. There are twelve (12) registers, and each of them includes data like the pre-fault value, the fault value, the time stamp and the active group during the trigger. Data included in the register depend on the control function. You can clear the the operation register by choosing "Clear registers" → "Clear".

"General event register" stores the event generated by the stage. These general event registers cannot be cleared.

Figure. 4.4 - 19. I/O section.



The "I/O" section is divided into two subsections: "Direct output control" and "Blocking input control".

In "Direct output control" you can connect the stage's signals to physical outputs, either to an output relay or an LED (START or TRIP LEDs or one of the 16 user configurable LEDs). If the stage is blocked internally (by a digital input or another signal), you can configure an output to indicate the stage that is blocked. A connection to an output can be either latched ("|x|") or non-latched ("x").

"Blocking input control" allows you to block stages. The blocking can be done by using any of the following:

- digital inputs.
- logical inputs or outputs.
- the START, TRIP or BLOCKED information of another protection stage.
- object status information.

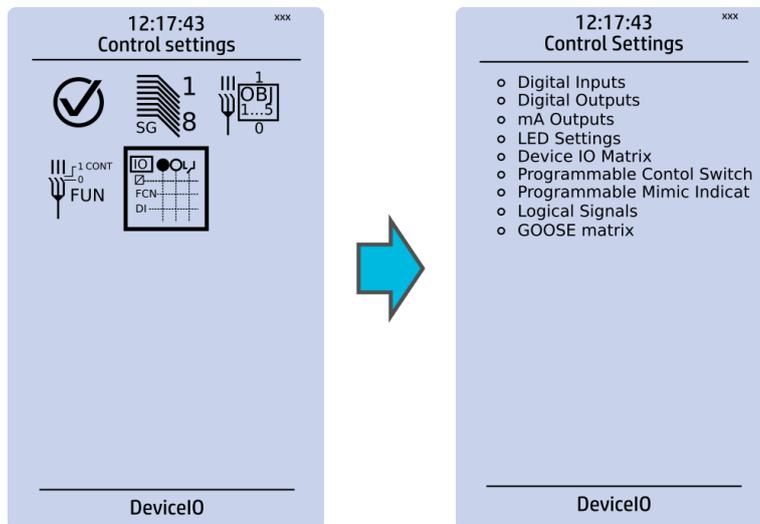
Figure. 4.4 - 20. Events section.



You can mask on and mask off events related to an object's stage in "Event mask". By default all events are masked off. You can activate the desired events by masking them ("x"). Please remember to save your maskings by confirming the changes with the check mark icon. If you want to cancel the changes, select the strike-through circle to do so. Only masked events are recorded to the event history (which can be accessed in the "Events" view in the user view section).

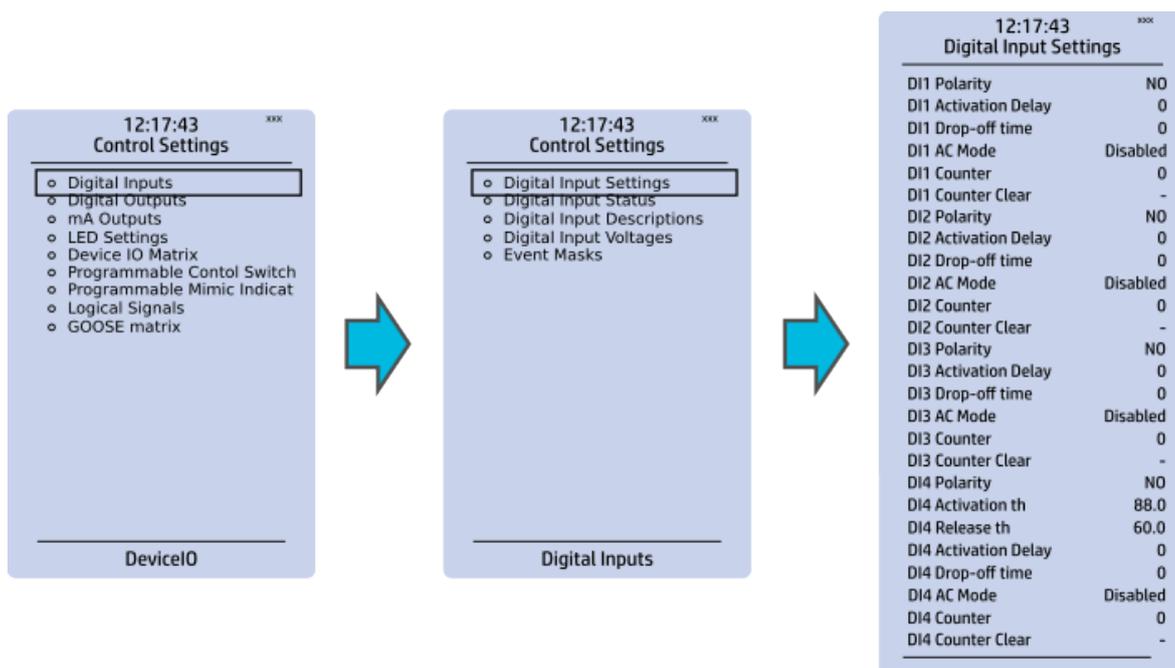
Device I/O

Figure. 4.4 - 21. Device I/O submenu.



The *Device I/O* submenu is divided into the following nine sections: "Digital inputs", "Digital outputs", "mA Outputs", "LED settings", "Device I/O matrix", "Programmable control switch", "Programmable Mimic Indicator", "Logic signals" and "GOOSE matrix". Please note that digital inputs, logic outputs, protection stage status signals (START, TRIP, BLOCKED, etc.) as well as object status signals can be connected to an output relay or to LEDs in the "Device I/O matrix" section.

Figure. 4.4 - 22. Digital input section.

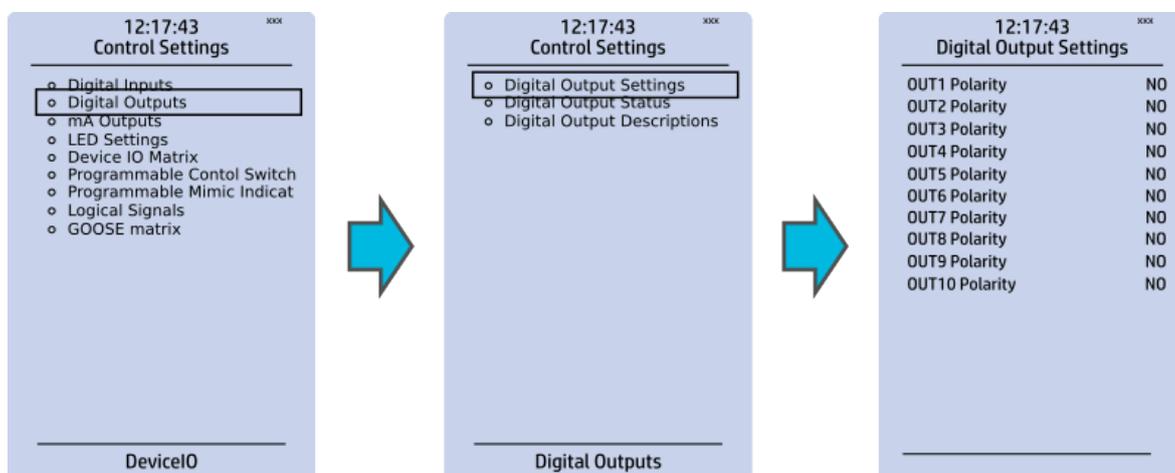


All settings related to digital inputs can be found in the "Digital inputs" section.

The "Digital inputs settings" subsection includes various settings for the inputs: the polarity selection determines whether the input is Normal Open (NO) or Normal Closed (NC) as well as the activation threshold voltage (16...200 V AC/DC, step 0.1 V) and release threshold voltage (10...200 V AC/DC, step 0.1 V) for each available input. There is also a setting to determine the wanted activation and release delay (0...1800 s, step 1 ms). Digital input activation and release threshold follow the measured peak value. The activation time of an input is 5...10 ms. The release time with DC is 5...10 ms, while with AC it is less than 25 ms. The first three digital inputs don't have activation and release threshold voltage settings as these have already been defined when the unit was ordered.

Digital input statuses can be checked from the corresponding subsection ("Digital input status"). The "Digital input descriptions" subsection displays the texts the user has written for each digital input. In the "Event masks" subsection you can determine which events are masked –and therefore recorded into the event history– and which are not.

Figure. 4.4 - 23. Digital outputs section.



All settings related to digital outputs can be found in the "Digital outputs" section.

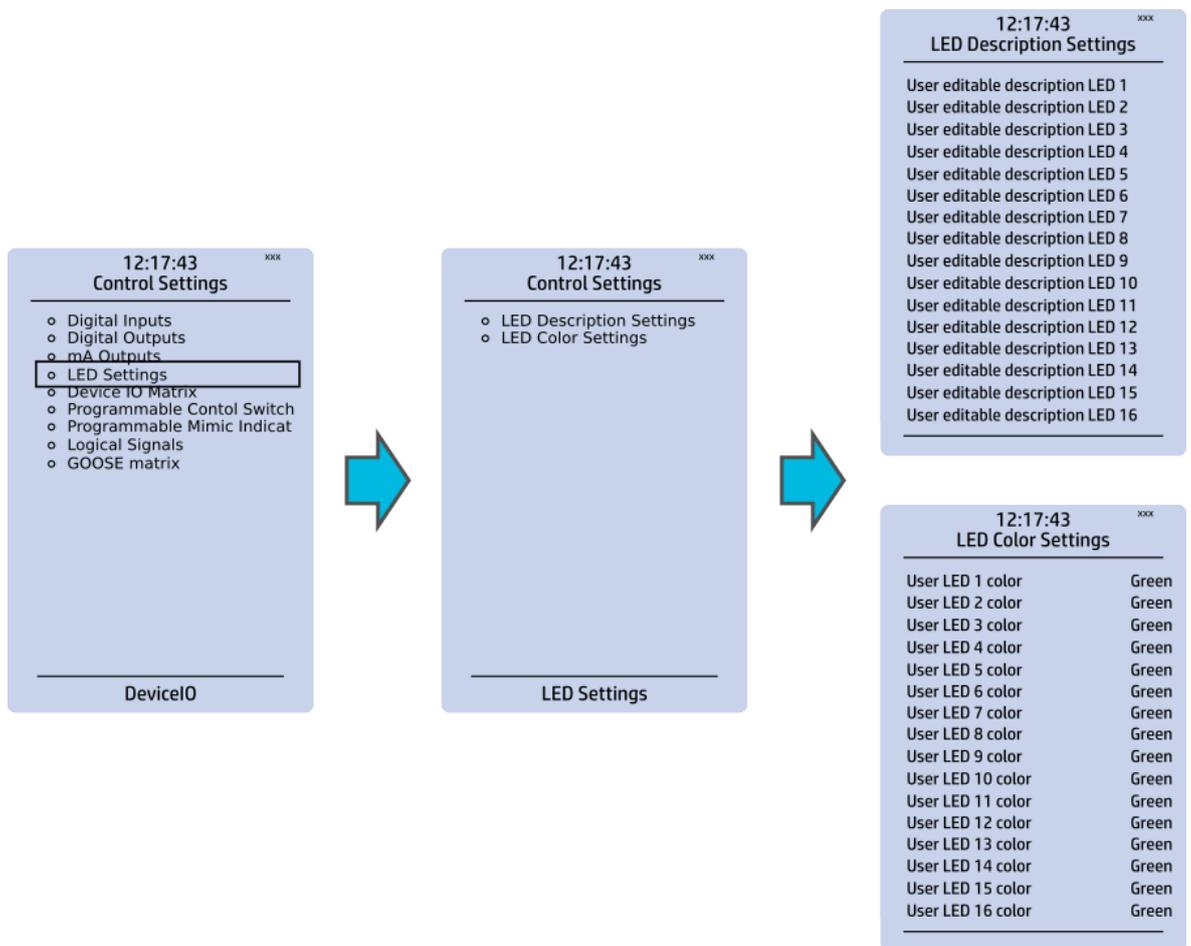
The "Digital outputs settings" subsection lets you select the polarity for each output; they can be either Normal Open (NO) or Normal Closed (NC). The default polarity is Normal Open. The operational delay of an output contact is approximately 5 ms. You can view the digital output statuses in the corresponding subsection ("Digital output status"). The "Digital output descriptions" subsection allows you to configure the description text for each output. All name changes affect the matrices as well as input–output selection lists.

NOTE!



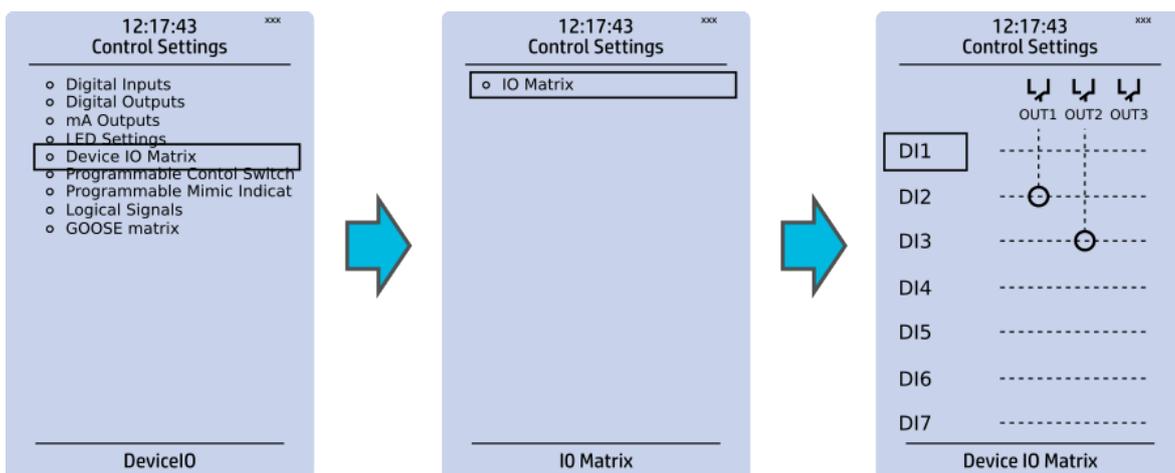
An NC signal goes to the default position (NO) if the relay loses the auxiliary voltage or if the system is fully reset. However, an NC signal does not open during voltage or during System full reset. An NC output signal does not open during a Communication or Protection reset.

Figure. 4.4 - 24. LED settings section.



The "LED settings" section allows you to modify the individual label text attached to an LED ("LED description settings"); that label is visible in the LED quick displays and the matrices. You can also modify the color of the LED ("LED color settings") between green and yellow; by default all LEDs are green.

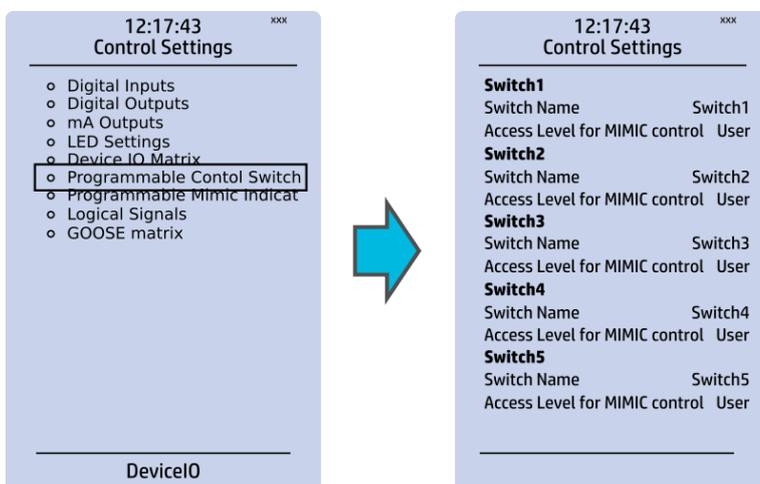
Figure. 4.4 - 25. Device I/O matrix section.



Through the "Device I/O matrix" section you can connect digital inputs, logical outputs, protection stage status signals (START, TRIP, BLOCKED, etc.), object status signals and many other binary signals to output relays, or to LEDs configured by the used. A connection can be latched ("|x|") or non-latched ("x"). Please note that a non-latched output is deactivated immediately when the triggering signal is disabled, while a latched signal stays active until the triggering signal deactivates and the latched function is manually cleared.

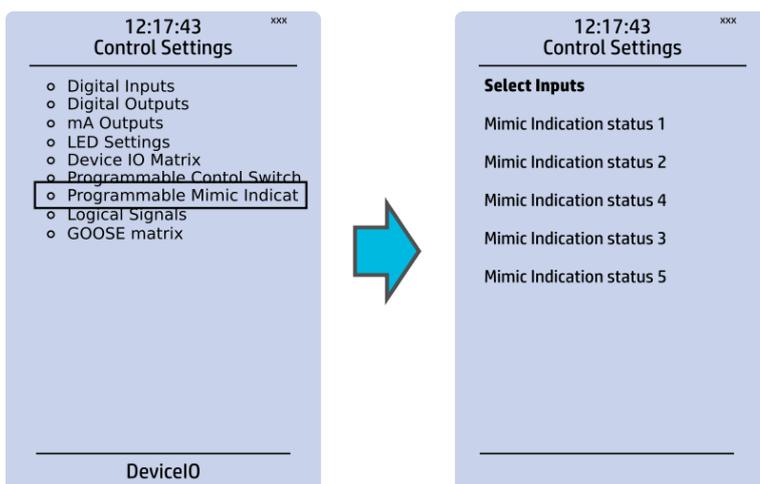
You can clear latched signals by entering the mimic display and the pressing the Back button on the panel.

Figure. 4.4 - 26. Programmable control switch section.



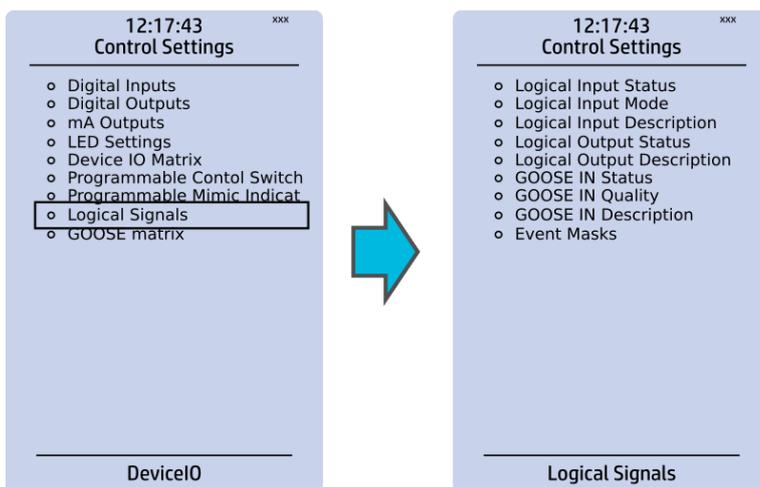
Programmable control switches (PCSs) are switches that can be used to control signals while in the mimic view. These signals can be used in a variety of situations, such as for controlling the logic program, for function blocking, etc. You can name each switch and set the access level to determine who can control the switch.

Figure. 4.4 - 27. Programmable mimic indicators section



Programmable mimic indicators can be placed into the mimic to display a text based on the status of a given binary signal (digital input, logical signal, status of function start/tripped/blocked signals etc.). When configuring the mimic with the AQtivate setting tool, it is possible to set a text to be shown when an input signal is ON and a separate text for when the signal is OFF.

Figure. 4.4 - 28. Logical signals section.



All AQ-200 series units have three different types of logical signals:

- 32 logical input signal status bits; the status of a bit is either 0 or 1.
- 32 logical output signal status bits; the status of a bit is either 0 or 1.
- 64 GOOSE input signal status bits; the status of a bit is either 0 or 1.
- 64 quality bits for GOOSE input signals; the status of a bit is either 0 or 1.

Logical input signals can be used when building a logic with the AQtivate setting tool. The status of a logical input signal can be changed either from the mimic or through SCADA. By default logical inputs use "Hold" mode in which the status changes from 0 to 1 and from 1 to 0 only through user input. The mode of each input can be changed to "Pulse" in which a logical input's status changes from 0 to 1 through user input and then immediately back to 0.

Logical output signals can be used as the end result of a logic that has been built in the AQtivate setting tool. The end result can then be connected to a digital output or a LED in the matrix, block functions and much more.

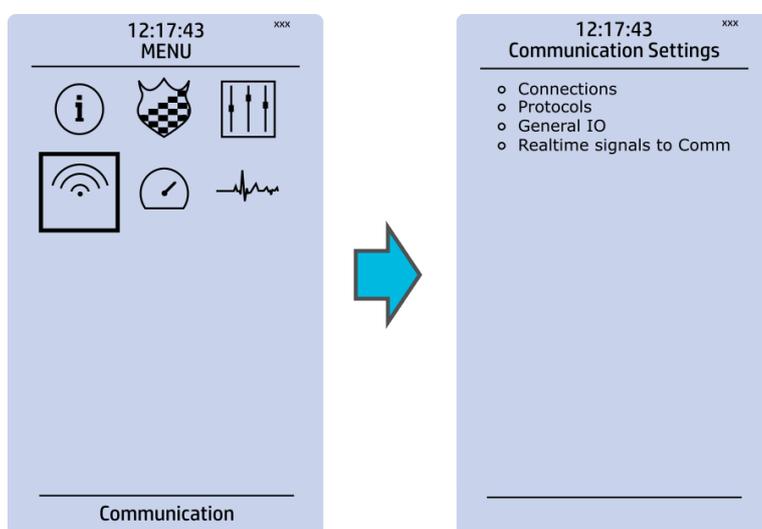
GOOSE inputs are mainly used for controlling purposes and in conjunction with the IEC 61850 communication protocol. There are 64 GOOSE inputs signal status bits, and their status can be either 0 or 1. "GOOSE IN quality" checks the quality of a GOOSE input message. There are 64 GOOSE input quality signals, and their status can be either 0 ("Good" or "Valid") or 1 ("Bad" or "Invalid"). Logical outputs can be used when building a programmable logic. Activating a logic gate does not create an event but when a logical output is connected to a logic gate it is possible to create an event from the gate's activation. All logical inputs and outputs have both ON and OFF events, and they can be masked on when necessary (they are masked off by default).

NOTE!



Please refer to the "System integration" chapter for a more detailed description of the use of logical signals.

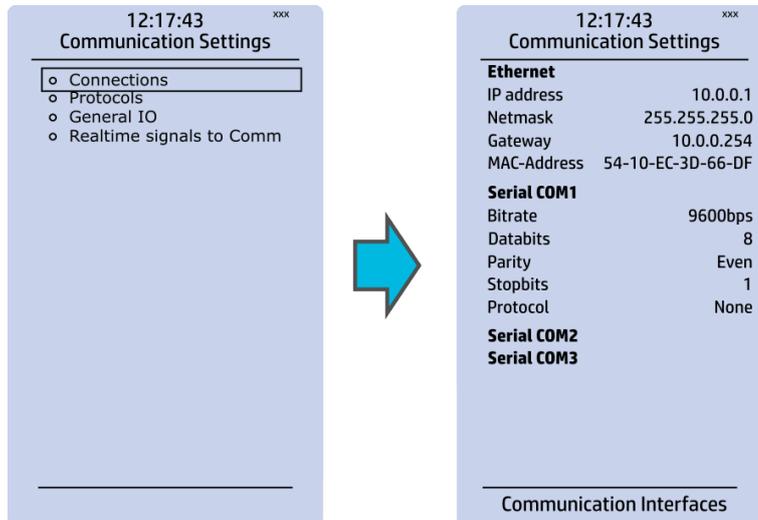
4.5 Communication menu



The *Communication* main menu includes four submenus: *Connections*, *Protocols*, *General IO* and *Realtime signals to Comm*. All devices can be configured through the Ethernet connection in the back panel with the AQtivate setting tool software. Connecting to the AQtivate software requires knowing the IP address of your device (can be found in the *Communication* → *Connections* submenu). As a standard, the devices support the following communication protocols: NTP, IEC 61850, Modbus/TCP, Modbus/RTU, IEC 103, IEC 101/104, SPA, DNP3 and Modbus/IO.

Connections

Figure. 4.5 - 29. View of the Connections submenu.



The *Connections* submenu offers the following bits of information and settings:

ETHERNET

This section defines the IP settings for the ethernet port in the back panel of the unit.

- IP address: the IP address of the device which can be set by the user (the default IP address depends on the device).
- Network: the network subnet mask is entered here.
- Gateway: the gateway is configured only when communicating with the devices in a separate subnet.
- MAC-Address: Unique MAC address of the device. Not configurable by user.

SERIAL COM

This section defines the basic settings of RS-485 port in the back panel of the unit.

- Bitrate: displays the bitrate of the RS-485 serial communication interface (9600 bps as standard, although can be changed to 19 200 bps or 38 400 bps if an external device supports the faster speed).
- Databits, Parity and Stopbits: these can be set according the connected external devices.
- Protocol: by default the device does not have any serial protocol activated, although IEC 103, Modbus I/O and Modbus/RTU can be used for communication.

NOTE!



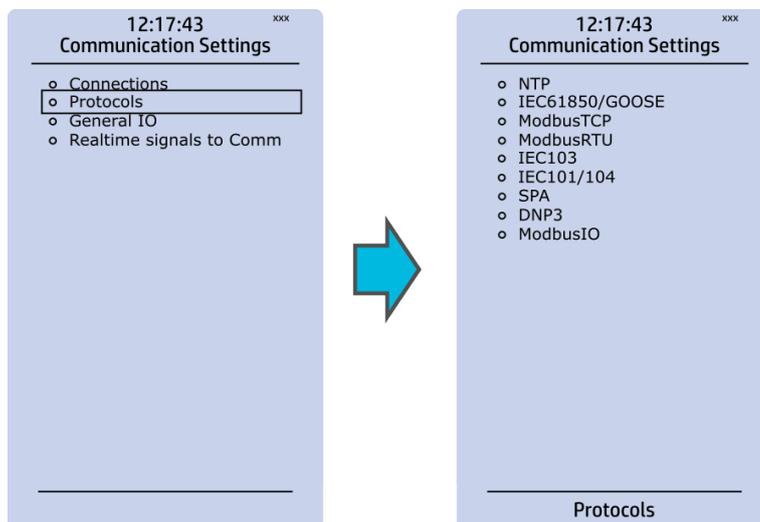
When communicating with a device through a front Ethernet port connection, the IP address is always 192.168.66.9.

SERIAL COM1 & COM2

SERIAL COM1 and SERIAL COM2 are reserved for serial communication option cards. They have the same settings as RS-485 port.

Protocols

Figure. 4.5 - 30. View of the Protocols submenu.



The *Protocols* submenu offers access to the various communication protocol configuration menus. Some of the communication protocols use serial communication and some use Ethernet communication. Serial communication protocols can be used either with the RS-485 port that is always equipped in AQ-200 series units or with serial communication option card. Ethernet communication protocols can be used either with the RJ-45 port in the back of the unit or with an ethernet communication option card.

The communication protocols are:

- NTP: this protocol is used for time synchronization over Ethernet, and can be used simultaneously with the ethernet based communication protocols.
- IEC 61850: Ethernet based communication protocol.
- Modbus/TCP: Ethernet communication protocol.
- Modbus/RTU: Serial communication protocol.
- IEC103: Serial communication protocol.
- IEC101/104: The standards IEC 60870-5-101 and IEC 60870-5-104 are closely related. On the physical layer the IEC 101 protocol uses serial communication whereas the IEC 104 protocol uses Ethernet communication.
- SPA: Serial communication protocol.
- DNP3: Supports serial and Ethernet communication.
- ModbusIO: Used for connecting external devices like ADAM RTD measurement units.

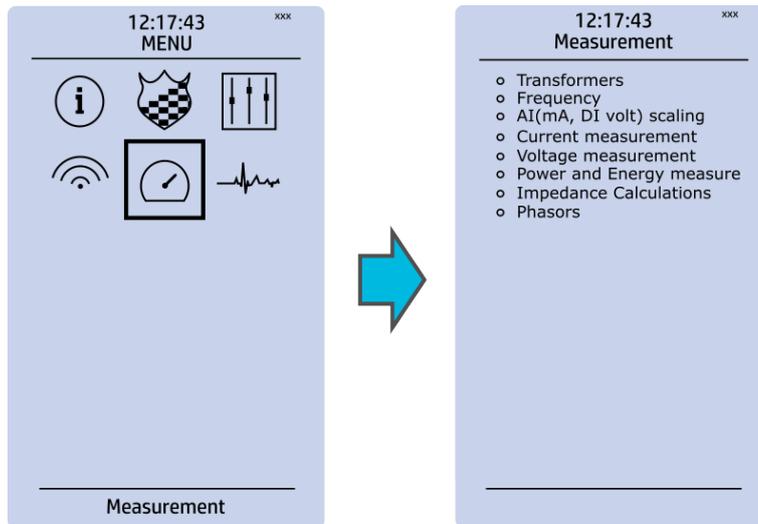
NOTE!



Please refer to the "System integration" chapter for a more detailed text on the various communication options.

4.6 Measurement menu

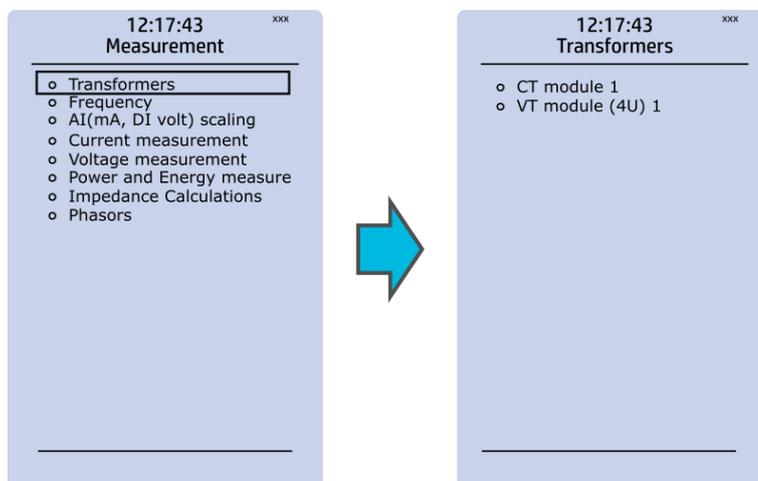
Figure. 4.6 - 31. Measurement section.



The *Measurement* menu includes the following submenus: *Transformers*, *Frequency*, *Current measurement*, *Voltage measurement*, *Power and energy measurement*, *Impedance calculations*, and *Phasors*. The available measurement submenus depends on the type of IED in use. The ratio used by the current and voltage transformers is defined in the *Transformers* submenu, while the system nominal frequency is specified in the *Frequency* submenu. Other submenus are mainly for monitoring purposes.

Transformers

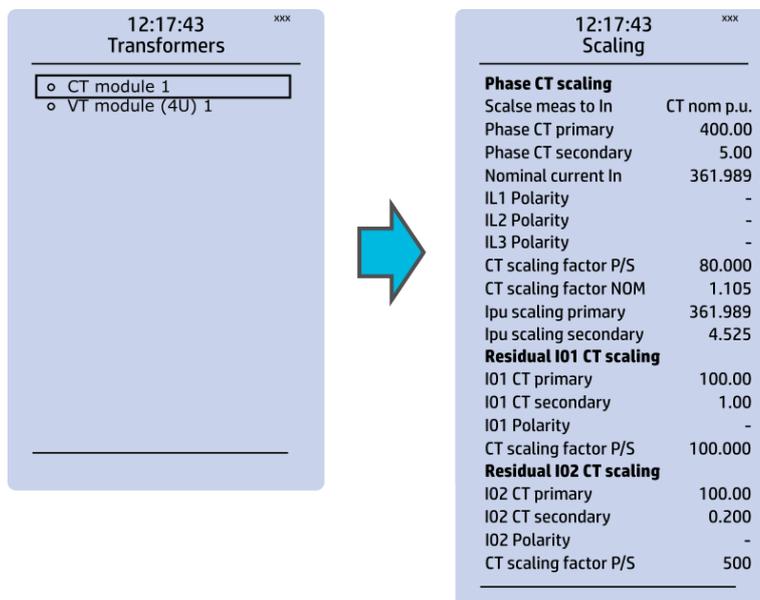
Figure. 4.6 - 32. Transformers section.



Transformers menu is used for setting up the measurement settings of available current transformer modules or voltage transformer modules. Some unit types have more than one CT or VT module. Some unit types like AQ-S214 do not have current or voltage transformers at all.

CT module

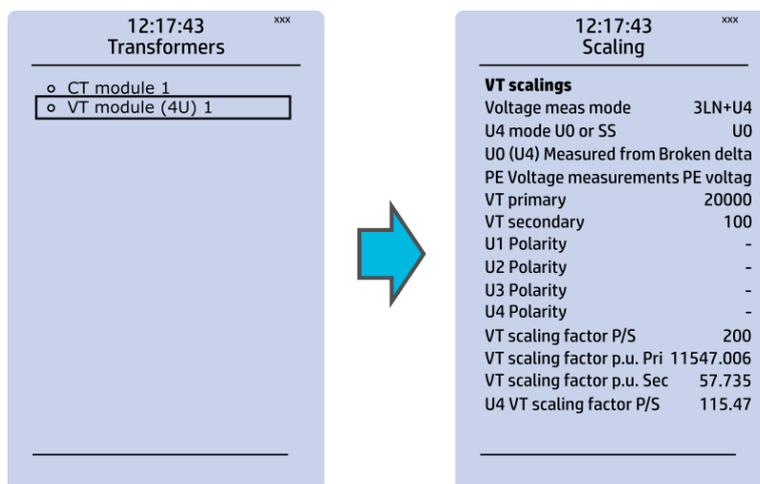
Figure. 4.6 - 33. CT module section.



The three main sections ("Phase CT scaling", "Residual I01 CT scaling" and "Residual I02 CT scaling") determine the ratio of the used transformers. Additionally, the nominal values are also determined in the *CT module* submenu. Sometimes a mistake in the wiring can cause the polarity to be changed; in such cases, you can invert the polarity of each phase current individually. The *CT module* submenu also displays additional information such as CT scaling factors and per-unit scaling factors.

VT module

Figure. 4.6 - 34. VT module section.

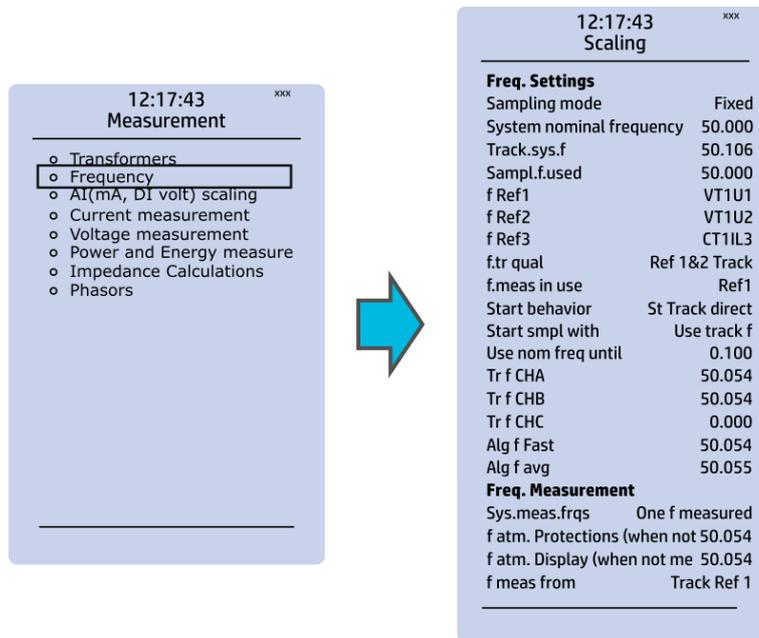


Voltage transformer settings include voltage measurement mode selection, voltage transformer nominal settings and voltage channel polarity switching. Voltage transformer setting defines what kind of voltages are connected to the VT module card. The voltages are: three line-to-line voltages, three line-to-neutral voltages, two line-to-line voltages leaving the third one free as additional voltage channel for neutral voltage or synchrochecking. U4 channel can be set to work as residual voltage mode or "SS" (system set) mode, which can be used for synchrochecking, synchronizing and other uses.

VT primary and secondary voltages must match with the connected voltage transformer in addition to the voltage measurement mode. These settings are then used for scaling the voltage channel input voltages to primary and per unit values as well as power and energy measurement values if current measurements are also available.

Frequency

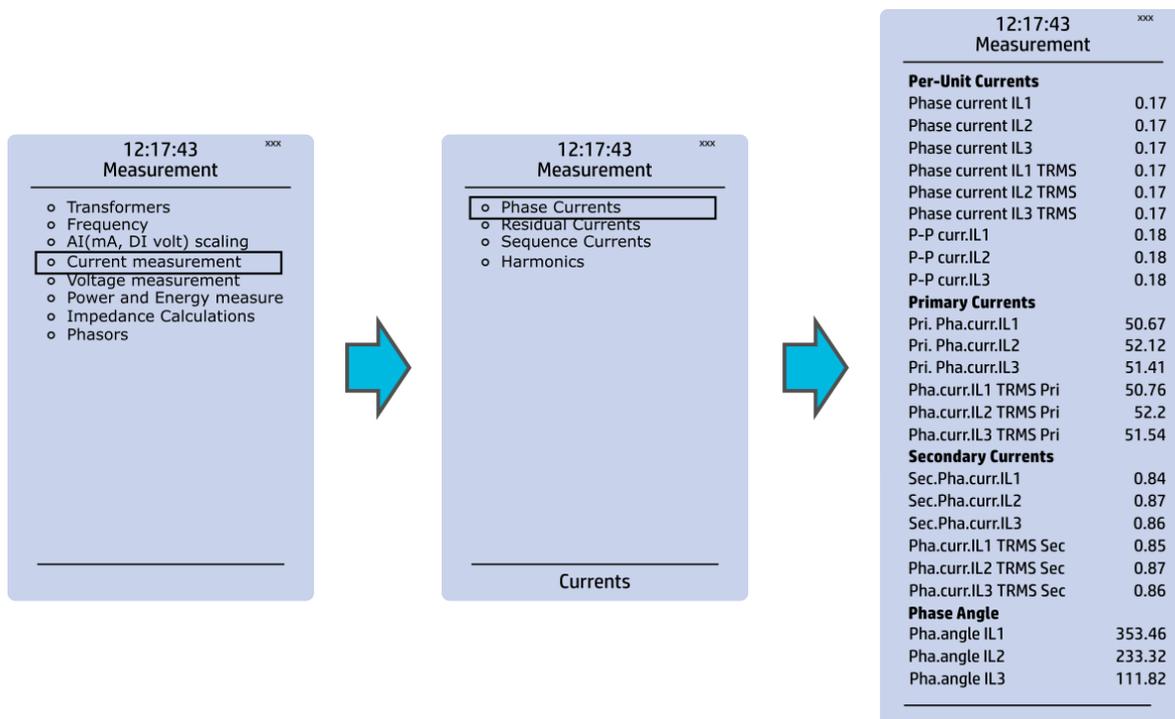
Figure. 4.6 - 35. Frequency submenu.



Frequency measurements use the fixed sampling mode as the default, and "System nominal frequency" should be set to the desired level. When "Sampling mode" is set to "Tracking", the device uses the measured frequency value as the system nominal frequency. There are three frequency reference channels: f Ref1, fRef2 and fRef3. With these parameters it is possible to set up three voltage or current channels to be used for frequency sampling. Parameter "f.meas in use" indicates which of the three channels are used for sampling if any.

Current measurement

Figure. 4.6 - 36. Current measurement submenu.



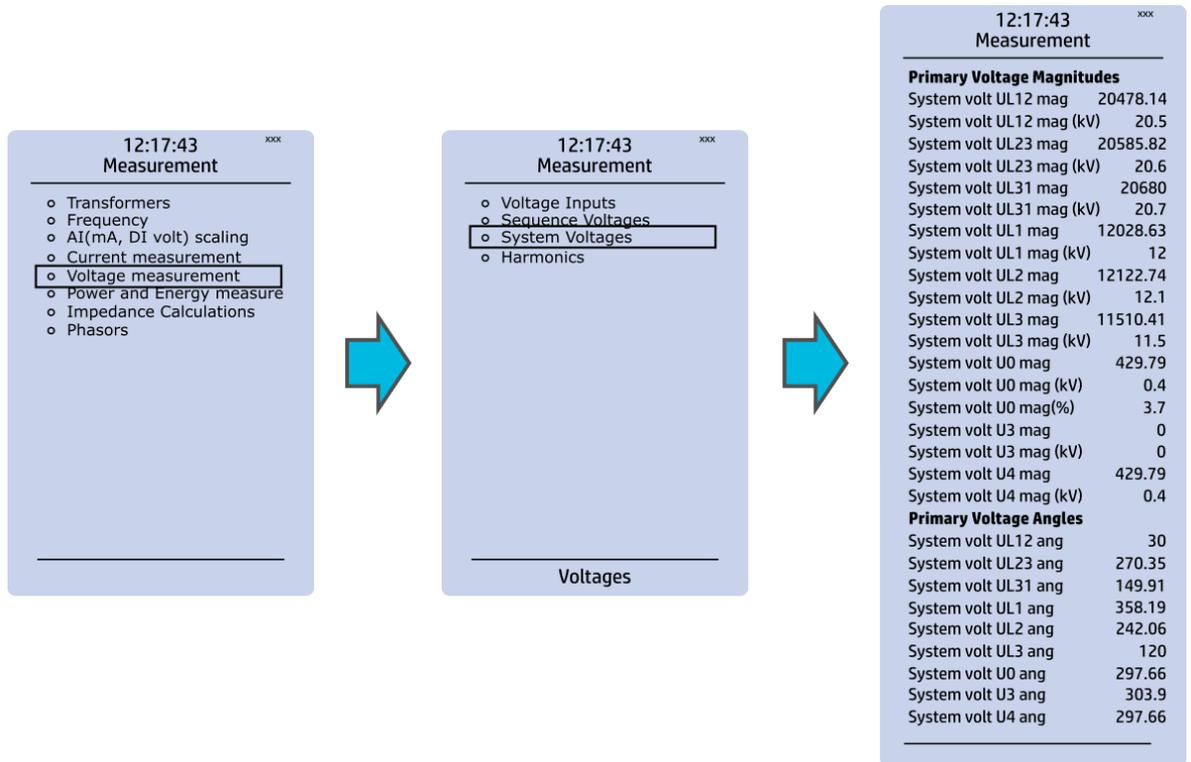
Current measurement submenu includes various individual measurements for each phase or phase-to-phase measurement.

The *Current measurement* submenu has been divided into four sections: "Phase currents", "Residual currents", "Sequence currents", and "Harmonics".

- "Phase currents" and "Residual currents" have been further divided into four subsections ("Per-unit currents", "Primary currents", "Secondary currents" and "Phase angle"), and they display the RMS, TRMS and peak-to-peak values, amplitude and power THD values as well as the angle of each measured component.
- "Sequence currents" has also been further divided into the four above-mentioned sections, and it calculates the positive, negative and neutral sequence currents.
- "Harmonics" displays current harmonics up to the 31st harmonic for the three phase current (IL1, IL2, IL3) as well as the two residual currents (I01, I02); each component can be displayed as absolute or percentage values, and as primary or secondary amperages or in per-unit values.

Voltage measurement

Figure. 4.6 - 37. Voltage measurement submenu and System Voltages menu.



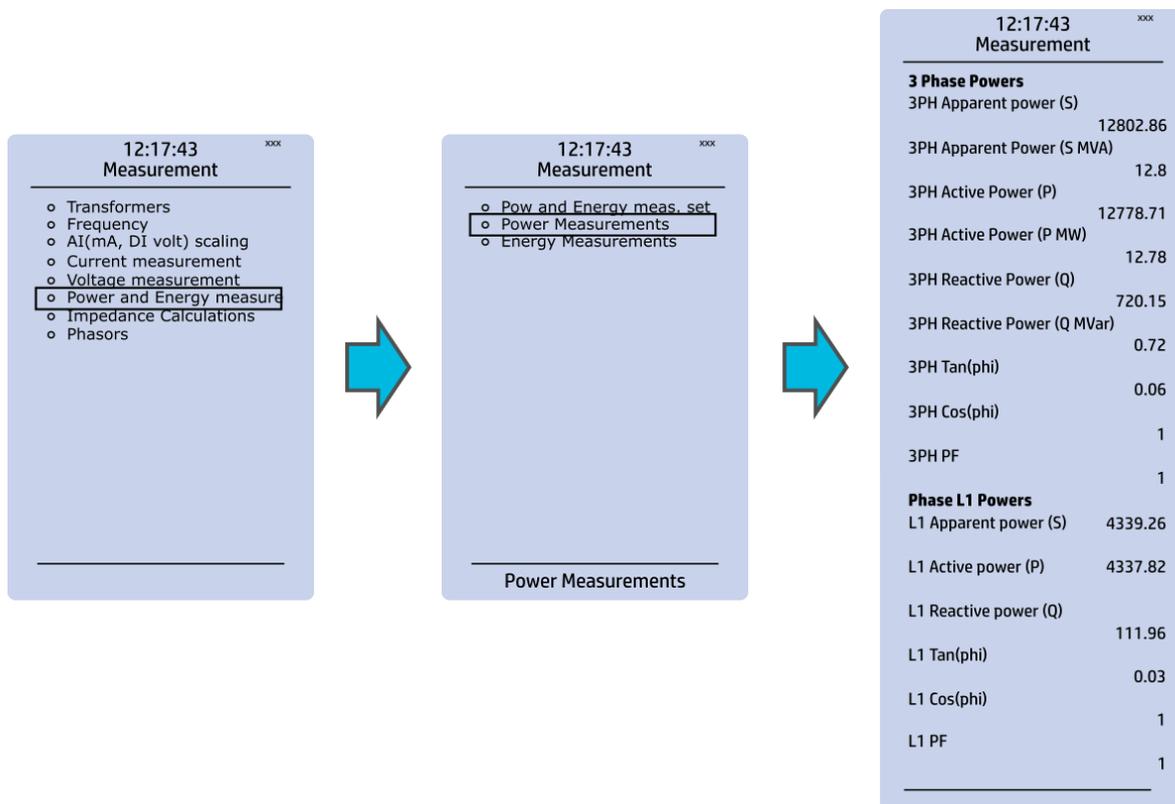
Voltage measurement submenu includes various individual measurements for each phase or phase-to-phase measurement.

The *Voltage measurement* submenu has been also divided into four sections: "Voltage inputs", "Sequence voltages", "System voltages", and "Harmonics".

- "Voltage inputs" displays the values of per-unit and secondary voltages as well as phase angles.
- "Sequence voltages" displays the per-unit, primary and secondary voltages as well as phase angles, and it calculates the positive, negative and neutral sequence voltages.
- "System voltages" displays primary voltage magnitudes and primary voltage angles.
- "Harmonics" displays harmonics up to the 31st harmonic for all four voltages (U1, U2, U3, U4); each component can be displayed as absolute or percentage values, and as primary or secondary voltages or in per-unit values.

Power and energy measurement

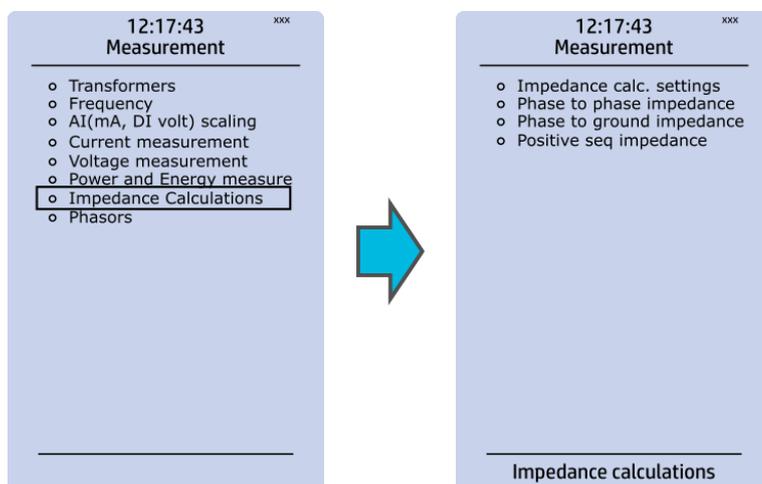
Figure. 4.6 - 38. Power and Energy measurement submenu.



The Power and energy measurement submenu includes three sections: "Power and energy measurement settings", "Power measurements" and "Energy measurements". As the name suggests, the first section determines the settings by which the power and energy calculations are made. In the settings you can also activate (and then set the parameters) for the Energy dose counter mode. "Power measurements" displays all three-phase powers as well as the powers of individual phases. "Energy measurements" displays the three-phase energy as well as the energies of the individual phases.

Impedance calculations

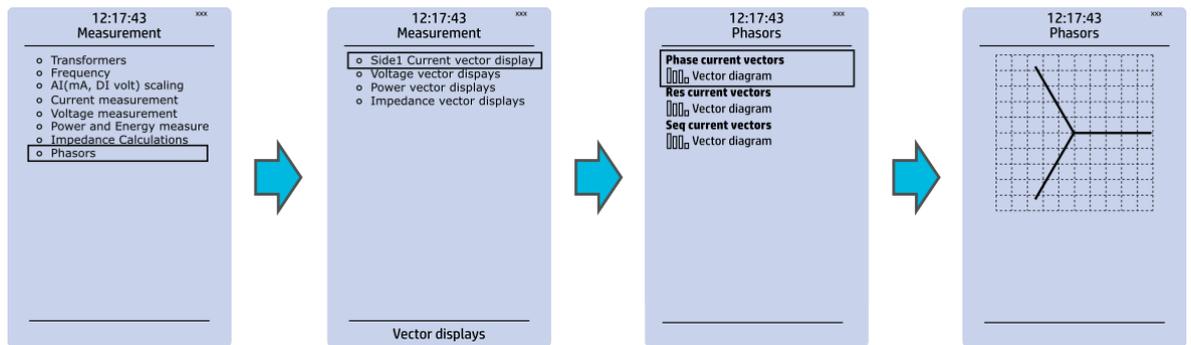
Figure. 4.6 - 39. Impedance calculations submenu.



The *Impedance calculations* submenu is divided into four sections: "Impedance calculation settings", "Phase-to-phase impedances", "Phase-to-earth impedances" and "Positive sequence impedance". You can activate impedance calculations in the first section. "Phase-to-phase impedances" display the resistances and reactances of the three phase-to-phase connections, both primary and secondary, as well as the primary and secondary impedances and impedance angles. "Phase-to-earth impedances" displays the resistances and reactances of the three phases as well the primary and secondary impedances and impedance angles. "Positive sequence impedance" displays the resistances and reactances (both primary and secondary) of the positive sequence as well as its primary and secondary impedances and the impedance angle.

Phasors

Figure. 4.6 - 40. Phasors submenu.

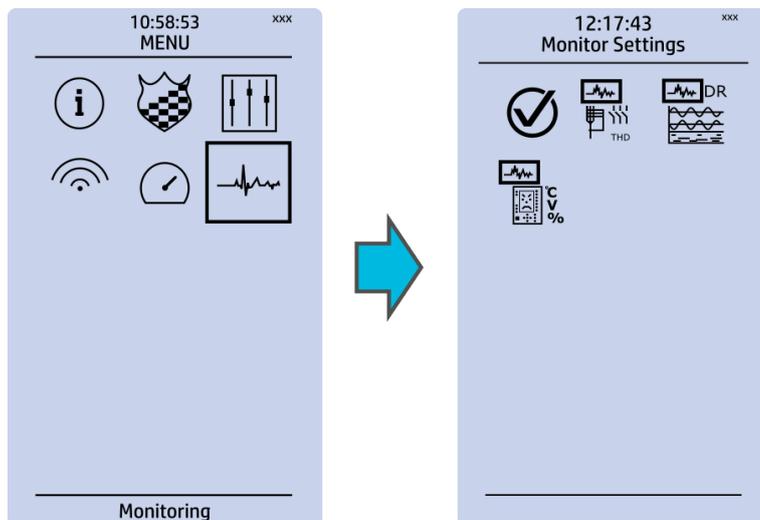


The *Phasors* submenu holds the vector displays for voltages and currents, as well as the various calculated components the IED may have (e.g. power, impedance). Phasors are helpful when solving incorrect wiring issues.

4.7 Monitoring menu

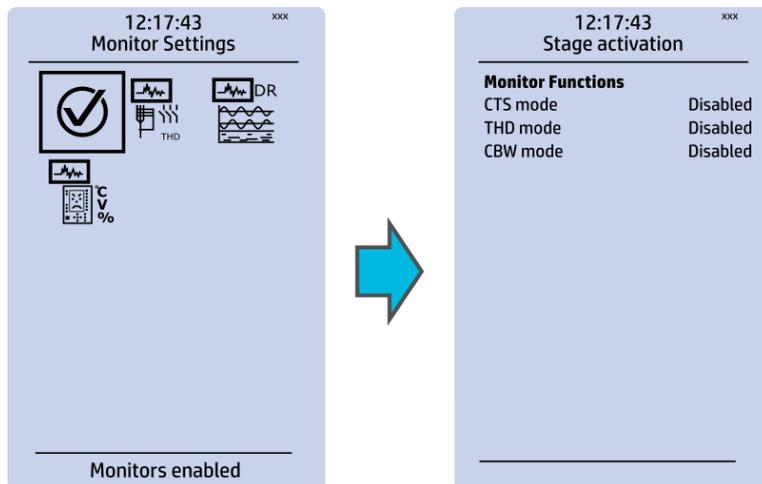
The *Monitoring* main menu includes submenus (see the image below) for enabling the various monitoring functions (*Monitors enabled*), setting the various monitoring functions (*Monitor functions*), controlling the disturbance recorder (*Disturbance REC*) and accessing the device diagnostics (*Device diagnostics*). The available monitoring functions depend on the type of the device in use.

Figure. 4.7 - 41. Monitoring menu view.



Monitors enabled

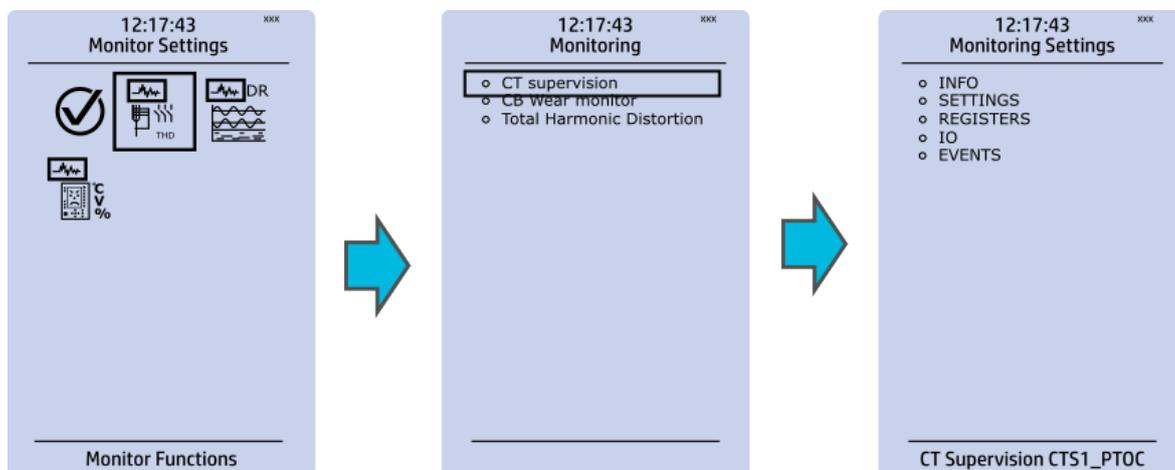
Figure. 4.7 - 42. Monitors enabled submenu.



You can activate the selected monitor functions in the *Monitors enabled* submenu. By default all the control functions are disabled. All activated functions can be viewed in the *Monitor functions* submenu (see the section "Monitor functions" below for more information).

Monitor functions

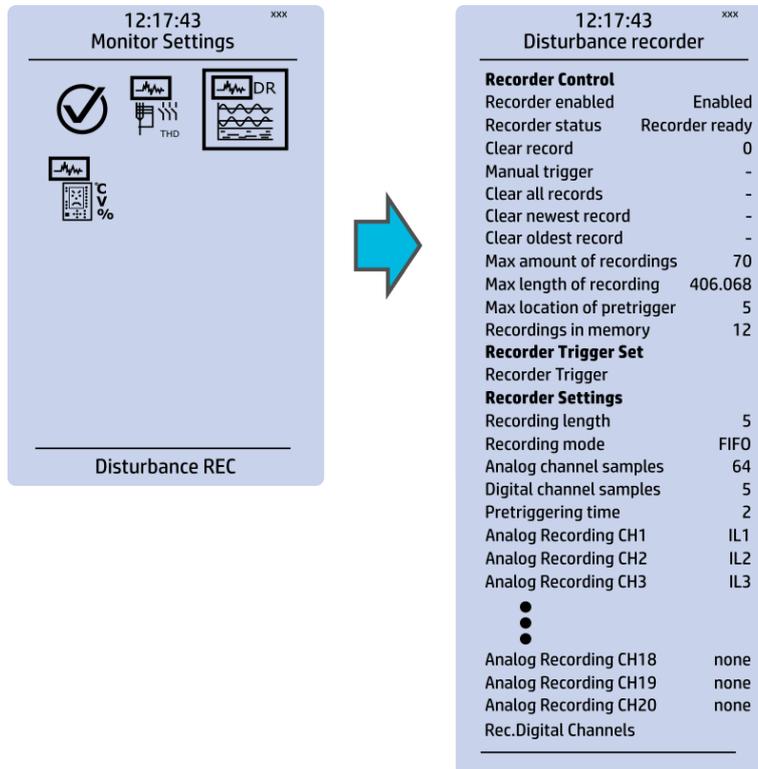
Figure. 4.7 - 43. Monitor function view.



Configuring monitor functions is very similar to configuring protection and control stages. They, too, have the five sections that display information ("Info"), set the parameters ("Settings"), show the inputs and outputs ("I/O") and present the events and registers ("Events" and "Registers").

Disturbance recorder

Figure. 4.7 - 44. Disturbance recorder settings.



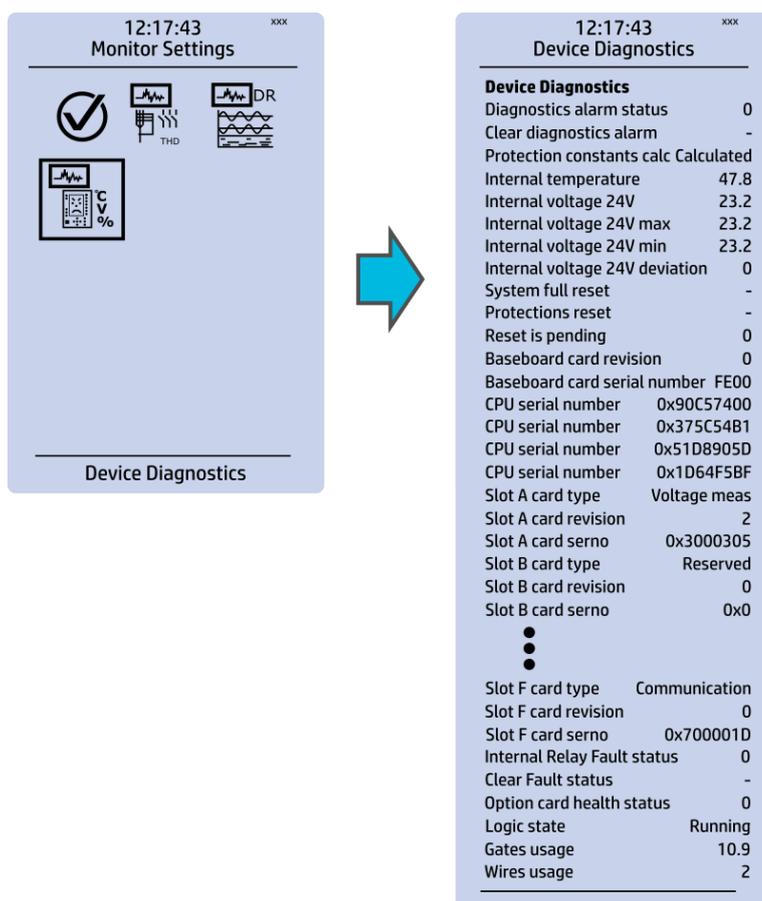
The *Disturbance recorder* submenu has the following settings:

- "Recorder enabled" enables or disables the recorder.
- "Recorder status" indicates the status of the recorder.
- "Clear record" records the chosen record in the memory.
- "Manual trigger" triggers the recorder when set to "Clear". Goes back to "-" when afterwards.
- "Clear all records", "Clear newest record" and "Clear oldest record" allows the clearing of all, the latest, or the oldest recording.
- "Max. amount of recordings" displays the maximum number of recordings; depends on the number of channels, the sample rate and the length of the file.
- "Max. length of recording" displays the maximum length of a single recording; depends on the number of chosen channels and the sample rate.
- "Recordings in memory" displays the number of recordings currently in the disturbance recorder's memory.
- "Recorder trigger" shows which signals or other states has been selected to trigger the recording (digital input, logical input or output, signals of a stage, object position, etc.); by default nothing triggers the recorder.
- "Recording length" displays the length of a single recording and can be set between 0.1...1800 seconds.
- "Recording mode" can be selected to replace the oldest recording ("FIFO") or to keep the old recordings ("FILO").
- "Analog channel samples" determines the sample rate of analog channels, and it can be selected to be 8/16/32/62 samples per cycle.
- "Digital channel samples" displays the sample rate in a digital channel; this is a fixed 5 ms.
- "Pretriggering time" can be selected between 0.1...15.0 s.
- The IED can record up to 20 (20) analog channels that can be selected from the twenty (20) available channels. Every measured current or voltage signal can be selected to be recorded.

- Enabling "Auto. get recordings" allows the device to automatically upload recordings to the designated FTP folder (which, in turn, allows any FTP client to read the recordings from the IED's memory).
- "Rec. digital channels" is a long list of the possible digital channels that can be recorded (including primary and secondary amplitudes and currents, calculated signals, TRMS values, sequence components, inputs and outputs, etc.).

Device diagnostics

Figure. 4.7 - 45. Device diagnostics submenu.



The *Device Diagnostics* submenu gives a detailed feedback of the device's current condition. It also shows whether option cards have been installed correctly without problems. If you see something out of the ordinary in the *Device diagnostics* submenu and cannot reset it, please contact the closest representative of the manufacturer or the manufacturer of the device itself.

4.8 Configuring user levels and their passwords

As a factory default, no user level is locked with a password in an IED. In order to activate the different user levels, click the **Lock** button in the device's HMI and set the desired passwords for the different user levels.

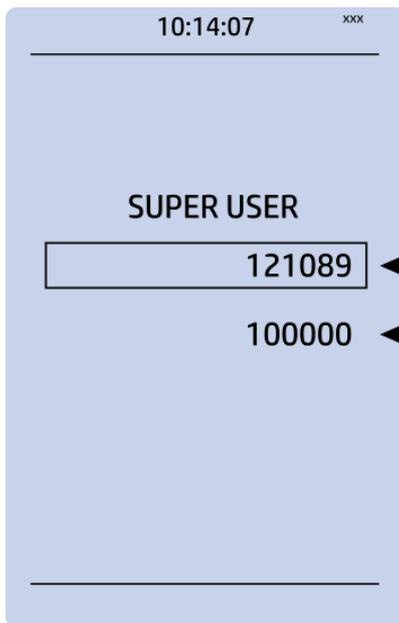
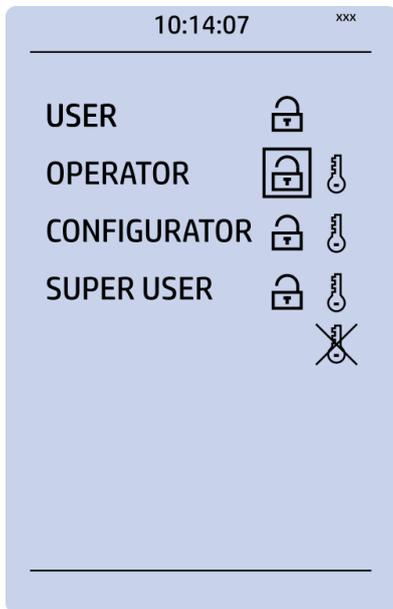


NOTE!

Passwords can only be set locally in an HMI.

A number of stars are displayed in the upper right corner of the HMI; these indicate the current user level. The different user levels and their star indicators are as follows (also, see the image below for the HMI view):

- Super user (***)
- Configurator (**)
- Operator (*)
- User (-)



← Password field - Entered password

← Password step - This is the step which determines how much will be added or subtracted from the password in the field

You can set a new password for a user level by selecting the key icon next to the user level's name. After this you can lock the user level by pressing the **Return** key while the lock is selected. If you need to change the password, you can select the key icon again and give a new password. Please note that in order to do this the user level whose password is being changed must be unlocked.

As mentioned above, the access level of the different user levels is indicated by the number of stars. The required access level to change a parameter is indicated with a star (*) symbol if such is required. As a general rule the access levels are divided as follows:

- *User*: Can view any menus and settings but cannot change any settings, nor operate breakers or other equipment.
- *Operator*: Can view any menus and settings but cannot change any settings BUT can operate breakers and other equipment.

- *Configurator*: Can change most settings such as basic protection pick-up levels or time delays, breaker control functions, signal descriptions etc. and can operate breakers and other equipment.
- *Super user*: Can change any setting and can operate breakers and other equipment.

NOTE!



Any user level with a password automatically locks itself after half an hour (30 minutes) of inactivity.

5 Functions

5.1 Functions included in AQ-E215

The AQ-E215 energy management protection IED includes the following functions as well as the number of stages for those functions. The fault indicating functions are accessible in the *Monitoring* menu (*Monitoring* → activate "Monitor mode" → *Monitor Functions* tab → *Fault Monitor* tab).

Table. 5.1 - 4. Protection functions of AQ-E215.

| Name | IEC | ANSI | Description |
|------|-----|------|----------------|
| VMEM | - | - | Voltage memory |

Table. 5.1 - 5. Fault indicating functions of AQ-E215.

| Name (number of stages) | IEC | ANSI | Description |
|-------------------------|---------------------|---------|-----------------------------|
| NOC (1) | I> | 50 | Non-directional overcurrent |
| NEF (1) | I0> | 50N | Non-directional earth fault |
| DOC (1) | I _{dir} > | 67 | Directional overcurrent |
| DEF (1) | I0 _{dir} > | 67N/32N | Directional earth fault |
| IEF (1) | I0 _{int} > | 67NT | Intermittent earth fault |
| UV (1) | U< | 27 | Undervoltage |
| NOV (1) | U0> | 59N | Neutral overvoltage |
| FLX (1) | - | 21FL | Fault locator |

Table. 5.1 - 6. Control functions of AQ-E215.

| Name | IEC | ANSI | Description |
|-----------|-----|------|---|
| SGS | - | - | Setting group selection |
| OBJ | - | - | Object control and monitoring (10 objects available) |
| CIN | - | - | Indicator object monitoring (5 indicators available) |
| PCS | - | - | Programmable control switch |
| mA output | - | - | Milliampere output control |

Table. 5.1 - 7. Monitoring functions of AQ-E215.

| Name | IEC | ANSI | Description |
|------|-----|------|---------------------------------|
| CTS | - | - | Current transformer supervision |
| VTS | - | 60 | Voltage transformer supervision |
| DR | - | - | Disturbance recorder |
| THD | - | - | Total harmonic distortion |
| MR | - | - | Measurement recorder |

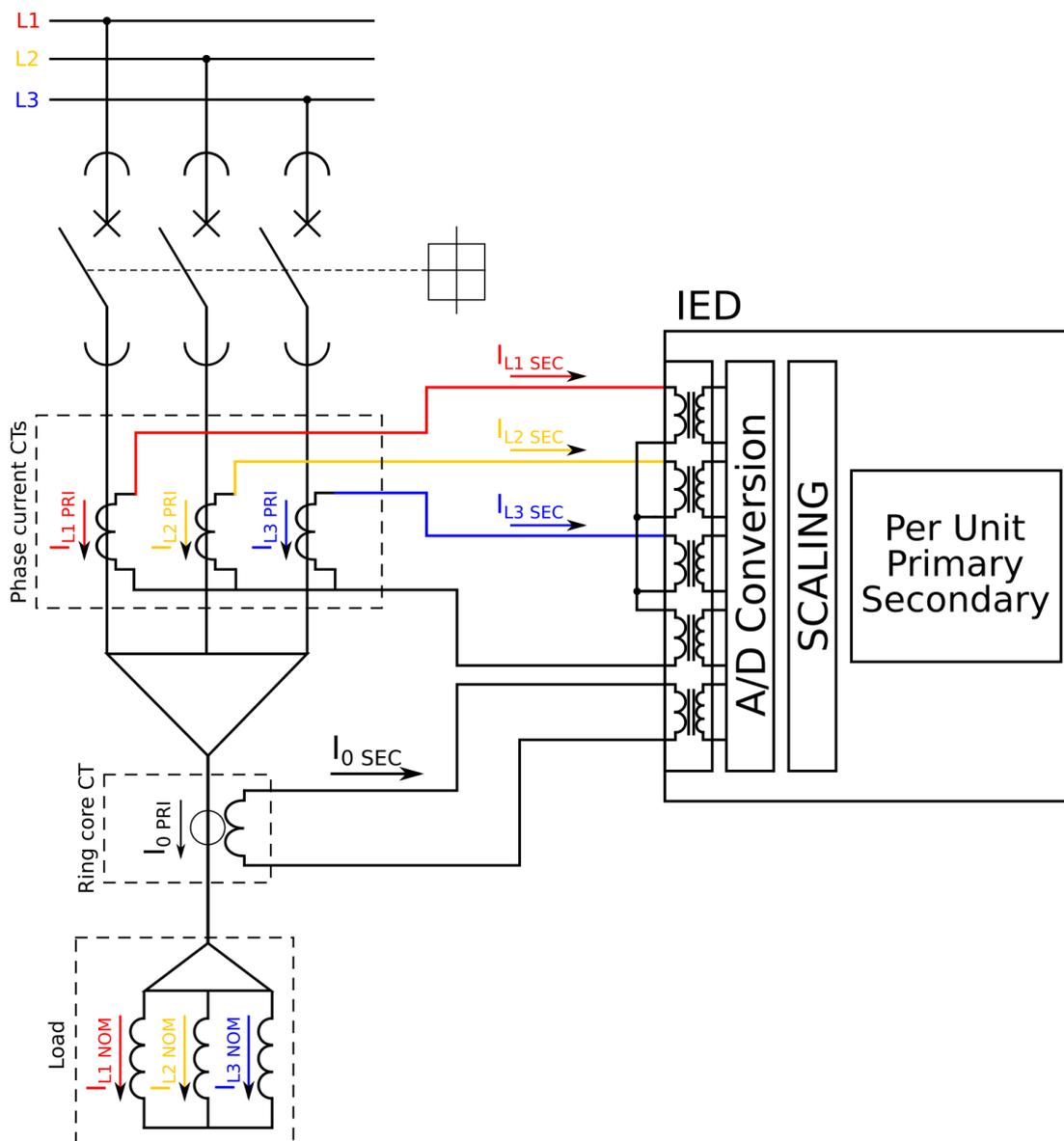
| Name | IEC | ANSI | Description |
|------|-----|------|----------------------------|
| VREC | - | - | Measurement value recorder |

5.2 Measurements

5.2.1 Current measurement and scaling

The current measurement module (CT module, or CTM) is used for measuring the currents from current transformers. The measured values are processed into the measurement database and they are used by measurement and protection functions. It is essential to understand the concept of current measurements to be able to get correct measurements.

Figure. 5.2.1 - 46. Current measurement terminology



PRI: The primary current, i.e. the current which flows in the primary circuit and through the primary side of the current transformer.

SEC: The secondary current, i.e. the current which the current transformer transforms according to its ratios. This current is measured by the protection relay.

NOM: The nominal primary current of the protected object.

For the measurements to be correct the user needs to ensure that the measurement signals are connected to the correct inputs, that the current direction is connected to the correct polarity, and that the scaling is set according to the nominal values of the current transformer.

The relay calculates the scaling factors based on the set values of the CT primary, the CT secondary and the nominal current settings. The relay measures the secondary current, the current output from the current transformer installed into application's primary circuit. The rated primary and secondary currents of the CT need to be set for the relay to "know" the primary and per-unit values. With motors and other specific electrical apparatus protections, the motor's nominal current should be set for the values to be in per unit with regards to the apparatus nominal instead of the CT nominal. This is not always mandatory as some relays still require manual calculations for the correct settings; however, setting the motors nominal current makes motor protection much easier and more straightforward. In modern protection devices this scaling calculation is done internally after the current transformer's primary current, secondary current and motor nominal current are set.

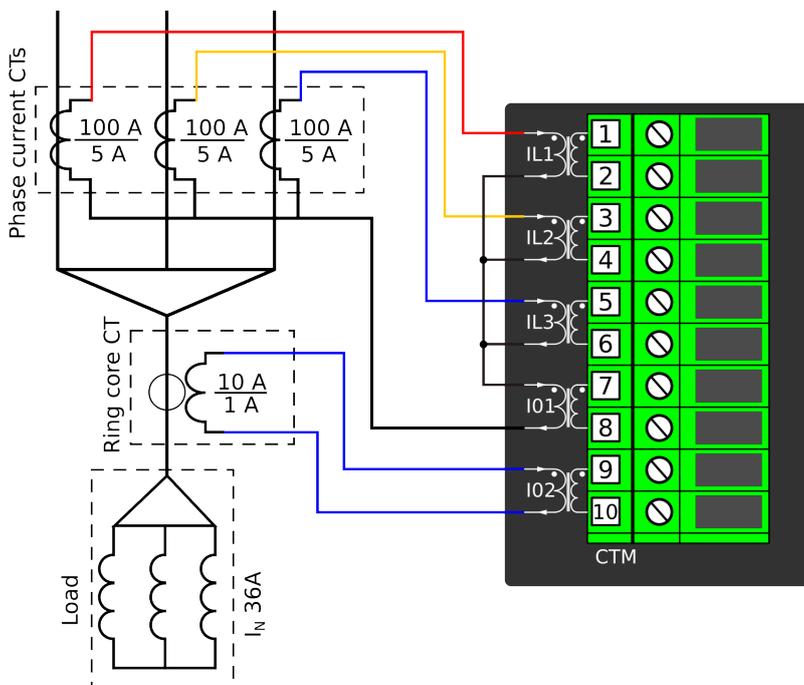
Normally, the primary current ratings for phase current transformers are 10 A, 12.5 A, 15 A, 20 A, 25 A, 30 A, 40 A, 50 A, 60 A and 75 A as well as their decimal multiples, while the secondary current ratings are 1 A and 5 A. Other, non-standard ratings can be directly connected as the scaling settings are flexible and have large ranges. For example, the ring core current transformer ratings may vary. Ring core current transformers are commonly used for sensitive earth fault protection and their rated secondary current may be as low as 0.2 A in some cases.

The following chapter is an example on how to set the scaling of the current measurements for the selected current transformer and system load.

Example of CT scaling

The following figure presents how CTs are connected to the relay's measurement inputs. It also shows example CT ratings and nominal current of the load.

Figure. 5.2.1 - 47. Connections.



The following table presents the initial data of the connection.

Table. 5.2.1 - 8. Initial data.

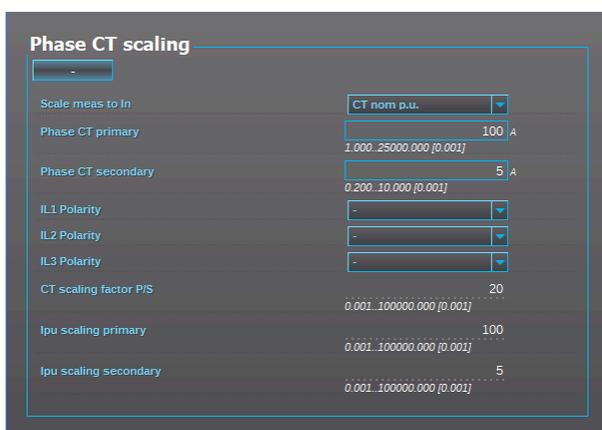
| | | |
|---|---|-------------------------------|
| Phase current CT - CT primary: 100 A - CT secondary: 5 A | Ring core CT in Input I02 - IOCT primary: 10 A - IOCT secondary: 1 A | Load (nominal) 36 A |
| - the phase currents are connected to the I01 residual via a Holmgren connection - the starpoint of the phase current CT's secondary current is towards the line | | |

Phase CT scaling

Next, to scale the current to per-unit values, we have to select whether the basis of the phase CT scaling is the protected object's nominal current or the CT primary value.

If the CT values are chosen to be the basis for the per-unit scaling, the option "CT nom. p.u." is selected for the "Scale meas to In" setting (see the image below).

Figure. 5.2.1 - 48. Setting the phase current transformer scalings to CT nominal.



Once the settings have been sent to the device, the relay calculates the scaling factors and displays them for the user. The "CT scaling factor P/S" describes the ratio between the primary current and the secondary current. The per-unit scaling factors ("Ipu scaling") for both primary and secondary values are also displayed (in this case they are the set primary and secondary currents of the CT).

If the protected object's nominal current is chosen to be the basis for the per-unit scaling, the option "Object in p.u." is selected for the "Scale meas to In" setting (see the image below).

Figure. 5.2.1 - 49. Setting the phase current transformer scalings to the protected object's nominal current.



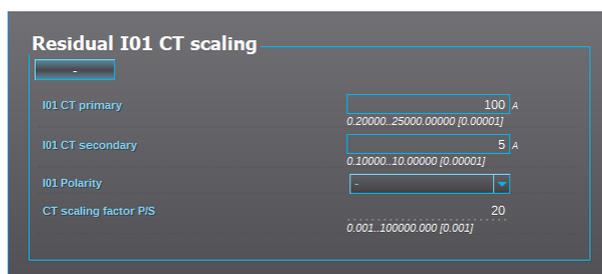
Once the measurement scaling is tied to the protected object's nominal current, the user must set the appropriate input for the "Nominal current In" setting. One can now see the differences between the two scaling options (CT nominal vs. object nominal). The "CT scaling factor P/S" is the direct ratio between the set CT current values, and the "CT scaling factor NOM" is now the ratio between the set CT primary and the nominal current. The "Ipu scaling primary" is now equal to the set nominal current, and the "Ipu scaling secondary" is the ratio between the nominal current and the "CT scaling factor P/S".

Residual I0 CT scaling

Next, we set the residual IO CT scalings according to how the phase current CTs and the ring core CT are connected to the module (see the Connections image at the beginning of this chapter).

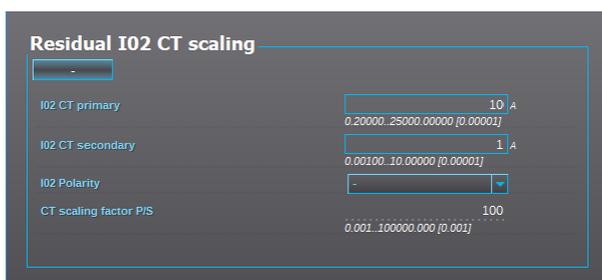
The phase current CTs are connected to the module via a Holmgren (summing) connection, which requires the use of coarse residual current measurement settings: the "I01 CT" settings are set according to the phase current CTs' ratings (100/5 A).

Figure. 5.2.1 - 50. Residual I01 CT scaling (coarse).



The ring core CT is connected to the CTM directly, which requires the use of sensitive residual current measurement settings: the "I02 CT" settings are set according to the ring core CT's ratings (10/1 A).

Figure. 5.2.1 - 51. Residual I02 CT scaling (sensitive).



Displaying the scaling

Depending on whether the scaling was done based on the CT primary values or the protected object's nominal current, the measurements are displayed slightly differently. The first of the two images shows how the measurements are displayed when the CT primary values are the basis for the scaling; the second shows them when the protected object's nominal current is the basis for the scaling.

Figure. 5.2.1 - 52. Scalings display (based on the CT nominal).

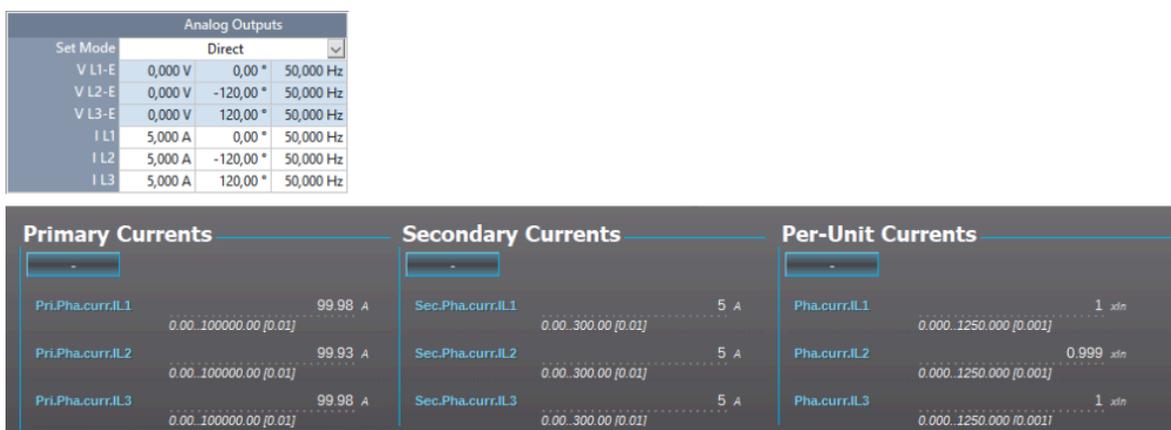


Figure. 5.2.1 - 53. Scalings display (based on the protected object's nominal current).

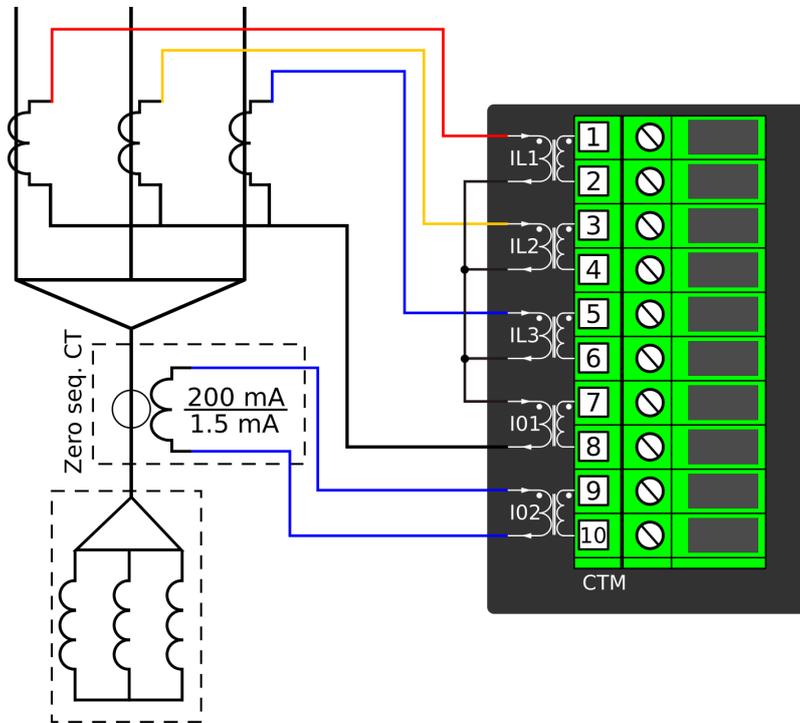


As the images above show, the scaling selection does not affect how primary and secondary currents are displayed (as actual values). The only effect is that the per-unit system in the relay is scaled either to the CT nominal or to the object nominal, making the settings input straightforward.

Example of zero sequence CT scaling

Zero sequence CT scaling (ZCT scaling) is done when a zero sequence CT instead of a ring core CT is part of the measurement connection. In such a case the zero sequence CT should be connected to the I02 channel which has lower CT scaling ranges (see the image below).

Figure. 5.2.1 - 54. Connections of ZCT scaling.



Troubleshooting

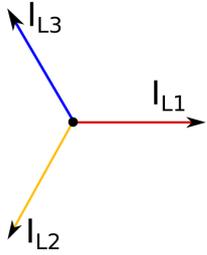
When the measured current values differ from the expected current values, the following table offers possible solutions for the problems.

NOTE!



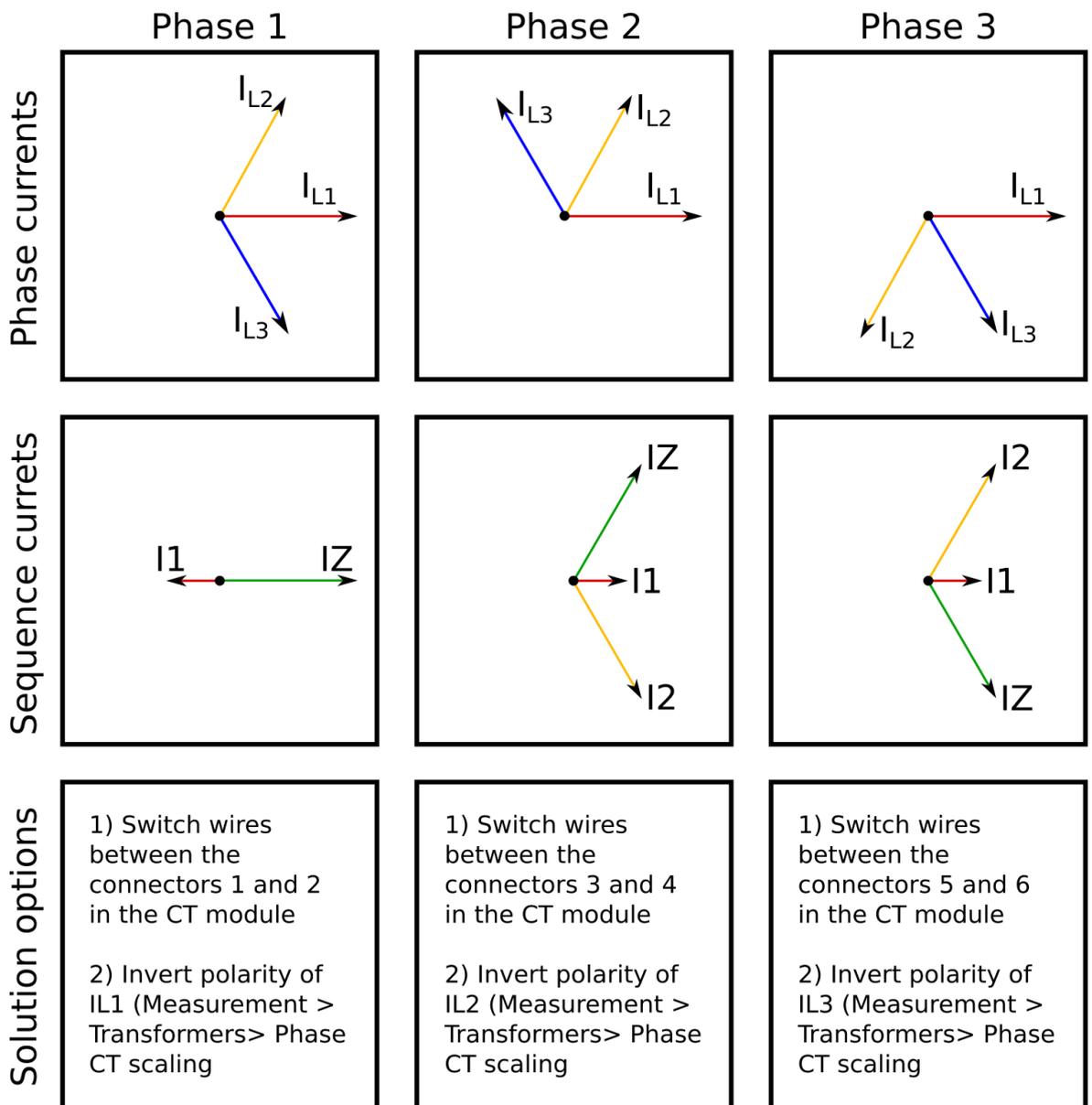
If you work with energized CTs, extreme caution needs to be taken when checking the connections! An opened CT secondary circuit may generate dangerously high voltages. A "buzzing" sound from the connector can indicate an open circuit.

| Problem | Solution |
|--|--|
| The measured current amplitude in all phases does not match the injected current. | The scaling settings may be wrong, check that the settings match with the connected current transformer (<i>Measurement</i> → <i>Transformers</i> → <i>Phase CT scaling</i>). Also check that the "Scale meas. to In" is set accordingly. If possible, check the actual CTs and their ratings as there may have been a need to change the original plan. |
| The measured current amplitude does not match one of the measured phases./ The calculated I0 is measured even though it should not. | Check the wiring connections between the injection device or the CTs and the relay. |

| Problem | Solution |
|---|---|
| <p>The measured current amplitudes are OK but the angles are strange./</p> <p>The phase unbalance protection trips immediately after activation./</p> <p>The earth fault protection trips immediately after activation.</p> | <p>The phase currents are connected to the measurement module but the order or polarity of one or all phases is incorrect. In relay settings, go to <i>Measurement</i> → <i>Phasors</i> and check the "Phase current vectors" diagram. When all connections are correct, the diagram (symmetric feeding) should look like this:</p>  <p>See the following tables for the most common problems with phase polarity and network rotation (mixed phases).</p> |

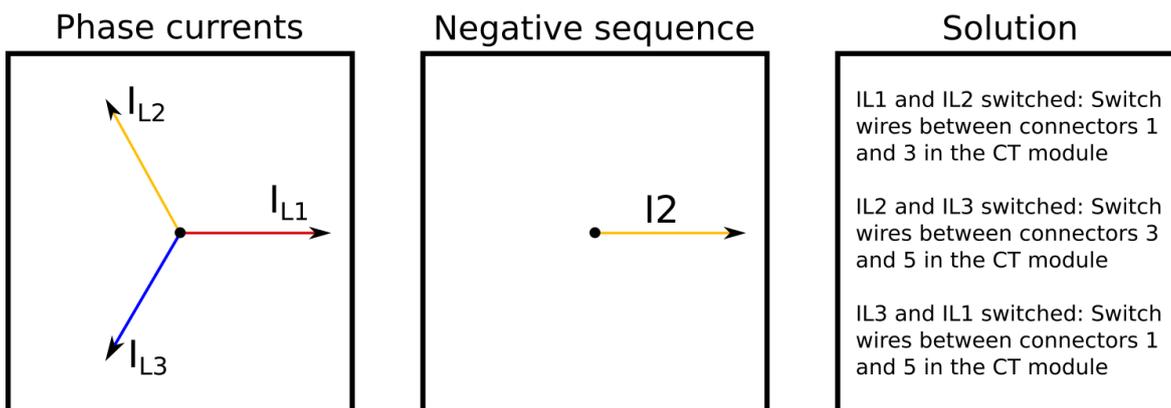
The following image presents the most common problems with phase polarity. Problems with phase polarity are easy to find because the vector diagram points towards the opposite polarity when a phase has been incorrectly connected.

Figure. 5.2.1 - 55. Common phase polarity problems.



The following image presents the most common problems with network rotation (mix phases). These problems can be difficult to find because the measurement result is always the same in the relay. If two phases are mixed together, the network rotation always follows the pattern IL1-IL3-IL2 and the measured negative sequence current is therefore always 1.00 (in. p.u.).

Figure. 5.2.1 - 56. Common network rotation (mixed phases) problems.



Settings

Table. 5.2.1 - 9. Settings of the Phase CT scaling.

| Name | Unit | Range | Step | Default | Description |
|-------------------------|------|-------------------------------------|-------|----------------|--|
| Scale measurement to In | - | 0: CT nom p.u. 1: Object In p.u. | - | 0: CT nom p.u. | The selection of the reference used in the relay's per-unit system scaling. Either the set phase current CT primary or the protected object's nominal current. |
| Phase CT primary | A | 1...25000 | 0.001 | 100 | The rated primary current of the current transformer. |
| Phase CT secondary | A | 0.2...10 | 0.001 | 5 | The rated secondary current of the current transformer. |
| Nominal current In | A | 1...25000 | 0.001 | 100 | The nominal current of the protected object. This setting is only visible if the option "Object In p.u." has been selected in the "Scale measurement to In" setting. |
| IL1 Polarity | - | 0: - 1: Invert | - | 0: - | The selection of the first current measurement channel's (IL1) polarity (direction). The default setting is for the positive current to flow from connector 1 to connector 2, with the secondary currents' starpoint pointing towards the line. |
| IL2 Polarity | - | 0: - 1: Invert | - | 0: - | The selection of the second current measurement channel's (IL2) polarity (direction). The default setting is for the positive current to flow from connector 3 to connector 4, with the secondary currents' starpoint pointing towards the line. |
| IL3 Polarity | - | 0: - 1: Invert | - | 0: - | The selection of the third current measurement channel's (IL3) polarity (direction). The default setting is for the positive current to flow from connector 5 to connector 6, with the secondary currents' starpoint pointing towards the line. |
| CT scaling factor P/S | - | - | - | - | A relay feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current. |
| CT scaling factor NOM | - | - | - | - | A relay feedback value; the calculated scaling factor that is the ratio between the set primary current and the set nominal current. This parameter is only visible if the option "Object In p.u." has been selected in the "Scale measurement to In" setting. |
| Ipu scaling primary | - | - | - | - | A relay feedback value; the scaling factor for the primary current's per-unit value. |
| Ipu scaling secondary | - | - | - | - | A relay feedback value; the scaling factor for the secondary current's per-unit value. |

Table. 5.2.1 - 10. Settings of the Residual I01 CT scaling.

| Name | Unit | Range | Step | Default | Description |
|-----------------------|------|-------------------|---------|---------|---|
| I01 CT primary | A | 0.2...25 000 | 0.00001 | 100 | The rated primary current of the current transformer. |
| I01 CT secondary | A | 0.1...10.000 | 0.00001 | 1 | The rated secondary current of the current transformer. |
| I01 Polarity | - | 0: - 1: Invert | - | 0: - | The selection of the coarse residual measurement channel's (I01) polarity (direction). The default setting is for the positive current to flow from connector 7 to connector 8. |
| CT scaling factor P/S | - | - | - | - | A relay feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current. |

Table. 5.2.1 - 11. Settings of the Residual I02 CT scaling.

| Name | Unit | Range | Step | Default | Description |
|-----------------------|------|-------------------|---------|---------|---|
| I02 CT primary | A | 0.2...25 000 | 0.00001 | 100 | The rated primary current of the current transformer. |
| I02 CT secondary | A | 0.001...10 | 0.00001 | 0.2 | The rated secondary current of the current transformer. |
| I02 Polarity | - | 0: - 1: Invert | - | 0: - | The selection of the sensitive residual measurement channel's (I02) polarity (direction). The default setting is for the positive current to flow from connector 9 to connector 10. |
| CT scaling factor P/S | - | - | - | - | A relay feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current. |

Measurements

The following measurements are available in the measured current channels.

Table. 5.2.1 - 12. Per-unit phase current measurements.

| Name | Unit | Range | Step | Description |
|--|------|------------------|-------|--|
| Phase current ILx ("Pha.curr.ILx") | × In | 0.000...1250.000 | 0.001 | The RMS current measurement (in p.u.) from each of the phase current channels. |
| Phase current ILx TRMS ("Pha.curr.ILx TRMS") | × In | 0.00...1250.00 | 0.01 | The TRMS current (inc. harmonics up to 31 st) measurement (in p.u.) from each of the phase current channels. |
| Peak-to-peak current ILx ("P-P curr.ILx") | × In | 0.00...500.00 | 0.01 | The peak-to-peak current measurement (in p.u.) from each of the phase current channels. |

Table. 5.2.1 - 13. Primary phase current measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------------|------|--|
| Primary phase current ILx ("Pri.Pha.curr.ILx") | A | 0.00...1 000 000.00 | 0.01 | The primary RMS current measurement from each of the phase current channels. |
| Primary phase current ILx TRMS ("Pha.curr.ILx TRMS Pri") | A | 0.00...1 000 000.00 | 0.01 | The primary TRMS current (inc. harmonics up to 31 st) measurement from each of the phase current channels. |

Table. 5.2.1 - 14. Secondary phase current measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------|------|--|
| Secondary phase current ILx ("Sec.Pha.curr.ILx") | A | 0.00...300.00 | 0.01 | The primary RMS current measurement from each of the phase current channels. |
| Secondary phase current ILx TRMS ("Pha.curr.ILx TRMS Sec") | A | 0.00...300.00 | 0.01 | The primary TRMS current (inc. harmonics up to 31 st) measurement from each of the phase current channels. |

Table. 5.2.1 - 15. Phase angle measurements.

| Name | Unit | Range | Step | Description |
|-----------------------------------|------|---------------|------|--|
| Phase angle ILx ("Pha.angle ILx") | deg | 0.00...360.00 | 0.01 | The phase angle measurement from each of the three phase current inputs. |

Table. 5.2.1 - 16. Per-unit residual current measurements.

| Name | Unit | Range | Step | Description |
|--|------|----------------|------|---|
| Residual current I0x ("Res.curr.I0x") | × In | 0.00...1250.00 | 0.01 | The RMS current measurement (in p.u.) from the residual current channel I01 or I02. |
| Calculated I0 | × In | 0.00...1250.00 | 0.01 | The RMS current measurement (in p.u.) from the calculated I0 current channel. |
| Phase current I0x TRMS ("Res.curr.I0x TRMS") | × In | 0.00...1250.00 | 0.01 | The TRMS current (inc. harmonics up to 31 st) measurement (in p.u.) from the residual current channel I01 or I02. |
| Peak-to-peak current I0x ("P-P curr.I0x") | × In | 0.00...500.00 | 0.01 | The peak-to-peak current measurement (in p.u.) from the residual current channel I01 or I02. |

Table. 5.2.1 - 17. Primary residual current measurements.

| Name | Unit | Range | Step | Description |
|---|------|------------------------|------|---|
| Primary residual current I0x ("Pri.Res.curr.I0x") | A | 0.00...1 000 000.00 | 0.01 | The primary RMS current measurement from the residual current channel I01 or I02. |
| Primary calculated I0 ("Pri.calc.I0") | A | 0.00...1 000 000.00 | 0.01 | The primary RMS current measurement from the calculated current channel I0. |
| Primary residual current I0x TRMS ("Res.curr.I0x TRMS Pri") | A | 0.00...1 000 000.00 | 0.01 | The TRMS current (inc. harmonics up to 31 st) measurement from the primary residual current channel I01 or I02. |

Table. 5.2.1 - 18. Secondary residual current measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------|------|---|
| Secondary residual current I0x ("Sec.Res.curr.I0x") | A | 0.00...300.00 | 0.01 | The secondary RMS current measurement from the residual current channel I01 or I02. |
| Secondary calculated I0 ("Sec.calc.I0") | A | 0.00...300.00 | 0.01 | The secondary RMS current measurement from the calculated current channel I0. |
| Secondary residual current I0x TRMS (Res.curr.I0x TRMS Sec") | A | 0.00...300.00 | 0.01 | The secondary TRMS current (inc. harmonics up to 31 st) measurement from the secondary residual current channel I01 or I02. |

Table. 5.2.1 - 19. Residual phase angle measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------|------|---|
| Residual current angle I0x ("Res.curr.angle I0x") | deg | 0.00...360.00 | 0.01 | The residual current angle measurement from the I01 or I02 current input. |
| calc.I0 Pha.angle | deg | 0.00...360.00 | 0.01 | The calculated residual current angle measurement. |

Table. 5.2.1 - 20. Per-unit sequence current measurements.

| Name | Unit | Range | Step | Description |
|---------------------------|------|----------------|------|--|
| Positive sequence current | × In | 0.00...1250.00 | 0.01 | The measurement (in p.u.) from the calculated positive sequence current. |
| Negative sequence current | × In | 0.00...1250.00 | 0.01 | The measurement (in p.u.) from the calculated negative sequence current. |
| Zero sequence current | × In | 0.00...1250.00 | 0.01 | The measurement (in p.u.) from the calculated zero sequence current. |

Table. 5.2.1 - 21. Primary sequence current measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------------|------|--|
| Primary positive sequence current ("Pri.Positive sequence curr.") | A | 0.00...1 000 000.00 | 0.01 | The primary measurement from the calculated positive sequence current. |
| Primary negative sequence current ("Pri.Negative sequence curr.") | A | 0.00...1 000 000.00 | 0.01 | The primary measurement from the calculated negative sequence current. |
| Primary zero sequence current ("Pri.Zero sequence curr.") | A | 0.00...1 000 000.00 | 0.01 | The primary measurement from the calculated zero sequence current. |

Table. 5.2.1 - 22. Secondary sequence current measurements.

| Name | Unit | Range | Step | Description |
|--|------|---------------|------|--|
| Secondary positive sequence current ("Sec.Positive sequence curr.") | A | 0.00...300.00 | 0.01 | The secondary measurement from the calculated positive sequence current. |
| Secondary negative sequence current ("Sec.Negative sequence curr") | A | 0.00...300.00 | 0.01 | The secondary measurement from the calculated negative sequence current. |
| Secondary zero sequence current ("Sec.Zero sequence curr.") | A | 0.00...300.00 | 0.01 | The secondary measurement from the calculated zero sequence current. |

Table. 5.2.1 - 23. Sequence phase angle measurements.

| Name | Unit | Range | Step | Description |
|---|------|---------------|------|---|
| Positive sequence current angle ("Positive sequence curr.angle") | deg | 0.00...360.00 | 0.01 | The calculated positive sequence current angle. |
| Negative sequence current angle ("Negative sequence curr.angle") | deg | 0.00...360.00 | 0.01 | The calculated negative sequence current angle. |
| Zero sequence current angle ("Zero sequence curr.angle") | deg | 0.00...360.00 | 0.01 | The calculated zero sequence current angle. |

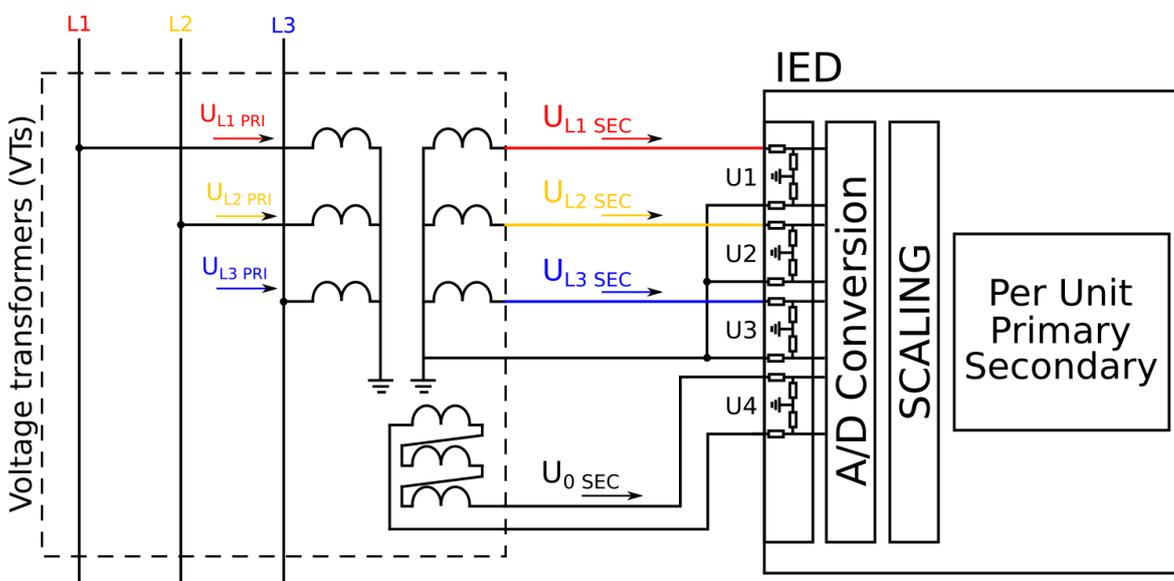
Table 5.2.1 - 24. Harmonic current measurements.

| Name | Range | Step | Default | Description |
|--|--|------|-------------|--|
| Harmonics calculation values ("Harm Abs.or Perc.") | - 0: Percent 1: Absolute | - | 0: Percent | Defines whether the harmonics are calculated as percentage or absolute values. |
| Harmonics display | - 0: Per unit 1: Primary A 2: Secondary A | - | 0: Per unit | Defines how the harmonics are displayed: in p.u values, as primary current values, or as secondary current values. |
| Maximum harmonics value ("Ixx maximum harmonic") | A 0.00...100 000.00 | 0.01 | - | Displays the maximum harmonics value of the selected current input ILx or IOx. |
| Fundamental frequency ("Ixx fundamental") | A 0.00...100 000.00 | 0.01 | - | Displays the current value of the fundamental frequency (RMS) from the selected current input ILx or IOx. |
| Ixx harmonics (2 nd ...31 st harmonic) | A 0.00...100 000.00 | 0.01 | - | Displays the selected harmonic from the current input ILx or IOx. |

5.2.2 Voltage measurement and scaling

The voltage measurement module (VT module, or VTM) is used for measuring the voltages from voltage transformers. The measured values are processed into the measurement database and they are used by measurement and protection functions (the protection function availability depends of the relay type). It is essential to understand the concept of voltage measurements to be able to get correct measurements.

Figure 5.2.2 - 57. Voltage measurement terminology



PRI: The primary voltage, i.e. the voltage in the primary circuit which is connected to the primary side of the voltage transformer.

SEC: The secondary voltage, i.e. the voltage which the voltage transformer transforms according to the ratio. This voltage is measured by the protection relay.

For the measurements to be correct the user needs to ensure that the measurement signals are connected to the correct inputs, that the voltage direction correct, and that the scaling is set correctly.

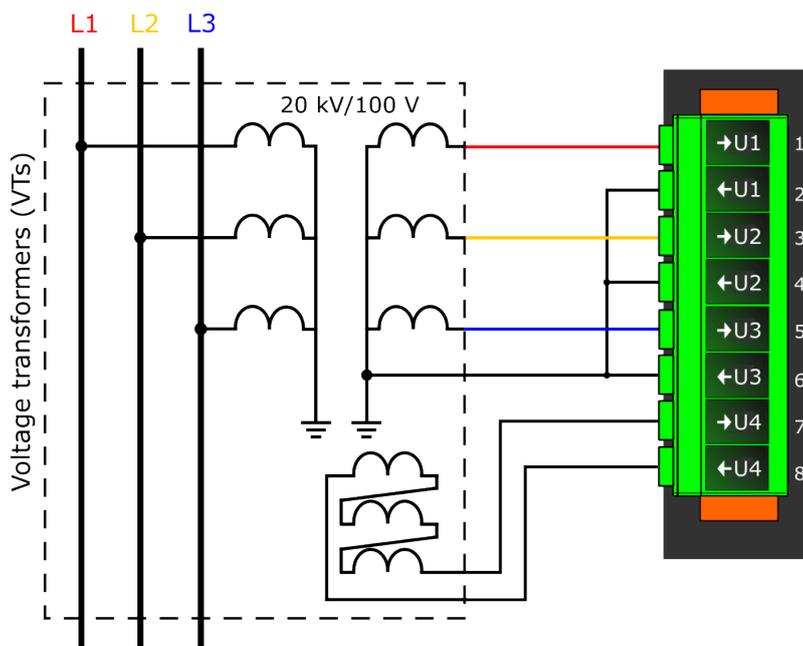
The relay calculates the scaling factors based on the set VT primary, and secondary voltage values. The relay measures secondary voltages, which are the voltage outputs from the VT installed into the application's primary circuit. The voltage can be measured directly from the system (up to 400 V) as well. The rated primary and secondary voltages of the VT need to be set for the relay to "know" the primary and per-unit values. In modern protection devices this scaling calculation is done internally after the voltage transformer's primary and secondary voltages are set.

Normally, the primary line-to-line voltage rating for VTs is 400 V...60 kV, while the secondary voltage ratings are 100 V...210 V. Non-standard ratings can also be directly connected as the scaling settings are flexible and have large ranges.

Example of VT scaling

The following figure presents how VTs are connected to the relay's measurement inputs. It also shows the VT ratings. In the figure below, three line-to-neutral voltages are connected along with the zero sequence voltage; therefore, the 3LN+U4 mode must be selected and the U4 channel must be set as U0. Other possible connections are presented later in this chapter.

Figure. 5.2.2 - 58. Connections.



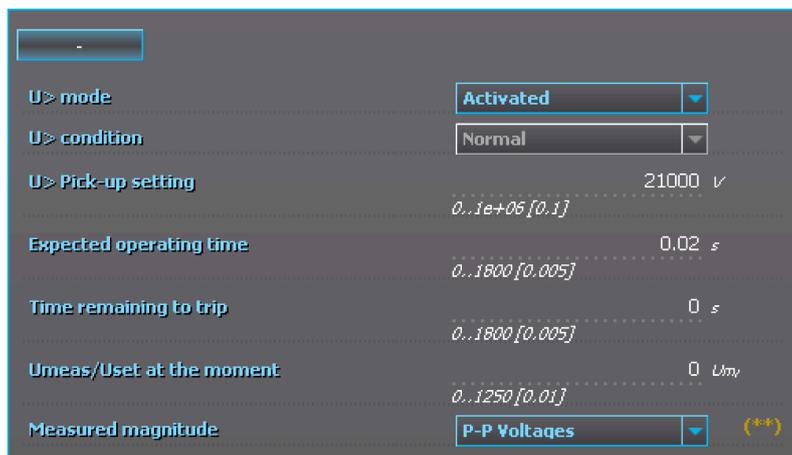
The following table presents the initial data of the connection.

Table. 5.2.2 - 25. Initial data.

| Phase voltage VT | Zero sequence voltage VT |
|---|---------------------------|
| - VT primary: 20 000 V | - U4 VT primary: 20 000 V |
| - VT secondary: 100 V | - U4 VT secondary: 100 V |
| - the zero sequence voltage is connected similarly to line-to-neutral voltages (+U0). | |
| - in case wiring is incorrect, all polarities can be individually switched by 180 degrees in the relay. | |

If the protection is voltage-based, the supervised voltage can be based either on line-to-line voltages or on line-to-earth voltages. This selection is defined in the "Measured magnitude" of each protection stage menu separately (*Protection* → *Voltage* → [protection stage menu] → *INFO*; see the image below). The number of available protection functions depends on the relay type.

Figure. 5.2.2 - 59. Selecting the measured magnitude.

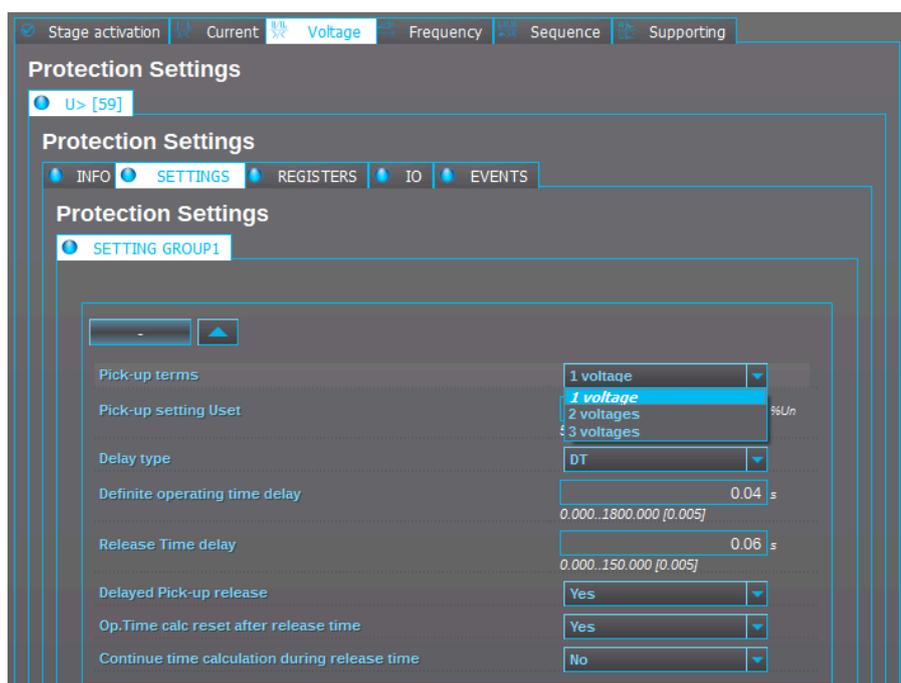


Voltage protection itself is based on the nominal voltage. A 20 000 V nominal voltage equals a 100 % setting in voltage-based protection functions. A 120 % trip setting in the overvoltage stage equals to 24 000 V on the primary level (in this case a 20 % increase equals 4000 V).

Once the settings have been sent to the device, relay calculates the scaling factors and displays them for the user. The "VT scaling factor P/S" describes the ratio between the primary voltage and the secondary voltage. The per-unit scaling factors ("VT scaling factor p.u.") for both primary and secondary values are also displayed.

The triggering of a voltage protection stage can be based on one, two, or three voltages (the "Pick-up terms" setting at *Protection* → *Voltage* → [protection stage menu] → *Settings*). Fault loops are either line-to-line or line-to-neutral according to the "Measured magnitude" setting. As a default, the activation of any one voltage trips the voltage protection stage.

Figure. 5.2.2 - 60. Selecting the operating mode.

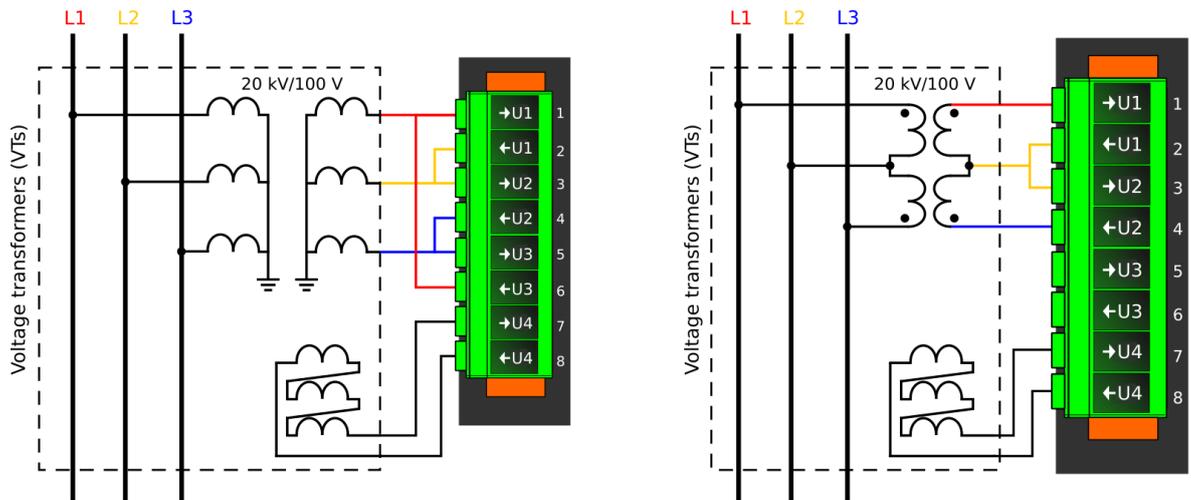


There are several different ways to use all four voltage channels. The voltage measurement modes are the following:

- 3LN+U4 (three line-to-neutral voltages and U4 can be used for either zero sequence voltage or synchrochecking)
- 3LL+U4 (three line-to-line voltages and U4 can be used either for zero sequence voltage or synchrochecking)
- 2LL+U3+U4 (two line-to-line voltages and the U3 and the U4 channels can be used for synchrochecking, zero sequence voltage, or for both)

The 3LN+U0 is the most common voltage measurement mode. See below for example connections of voltage line-to-line measurement (3LL on the left, 2LL on the right).

Figure. 5.2.2 - 61. Example connections for voltage line-to-line measurement.

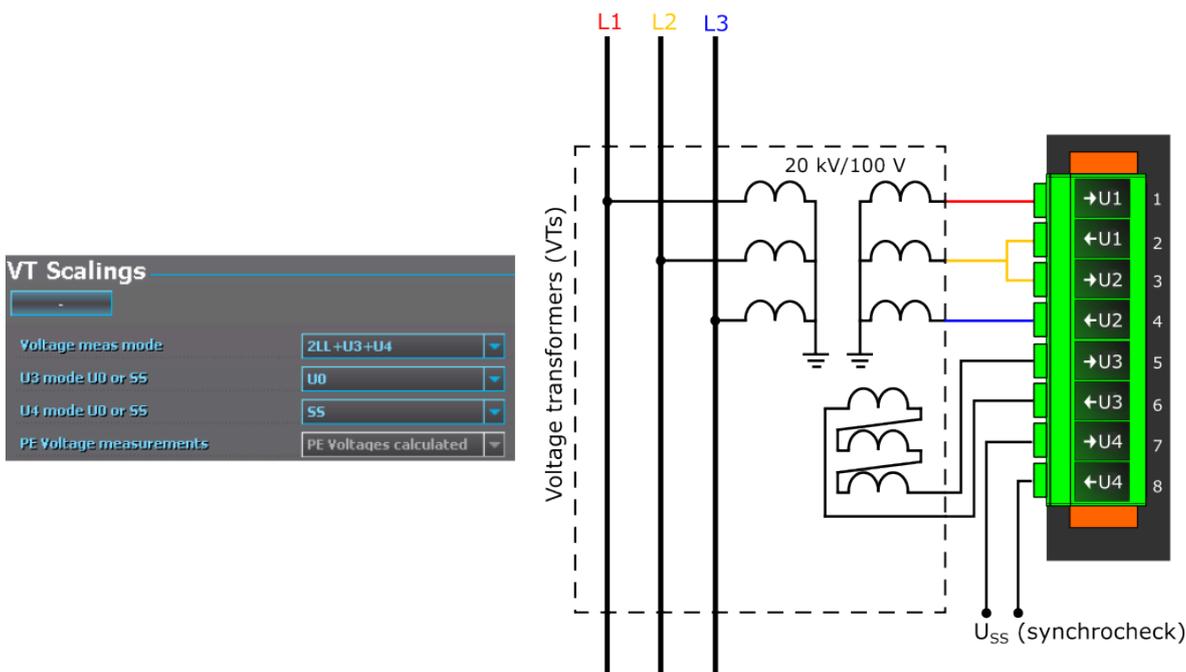


If only two line-to-line voltages are measured, the third one (U_{L31}) is calculated based on the U_{L12} and U_{L23} vectors. When measuring line-to-line voltages, the line-to-neutral voltages can also be calculated as long as the value of U_0 is measured and known.

The voltage measurement channel U4 can also be used to measure either the zero sequence voltage (U_0) or the side 2 voltage of the circuit breaker (Synchrocheck). If the 2LL+U3+U4 mode is selected, the third channel (U3) can be used for this purpose. Please note that U_0 can only be measured by using a single channel.

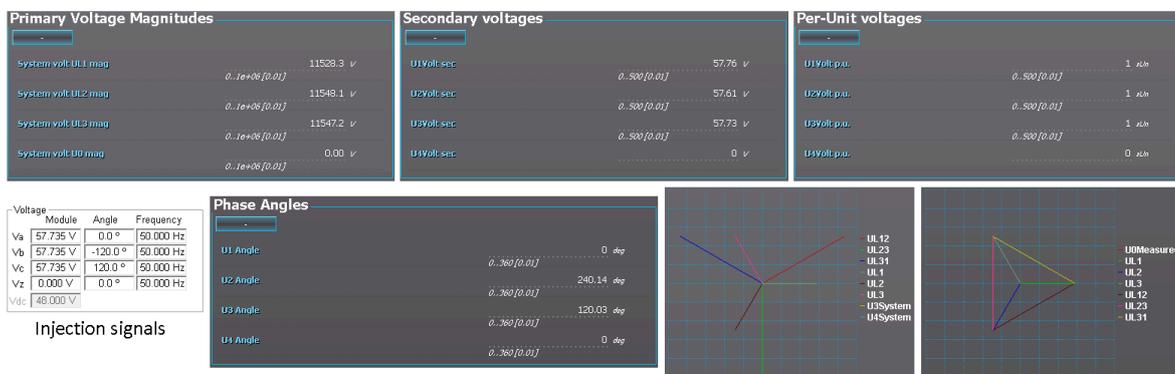
In the image below is an example of 2LL+U0+SS, that is, two line-to-line measurements with the zero sequence voltage and voltage from side 2 for Synchrocheck. Since U_0 is available, line-to-neutral voltages can be calculated.

Figure. 5.2.2 - 62. 2LL+U0+SS settings and connections.



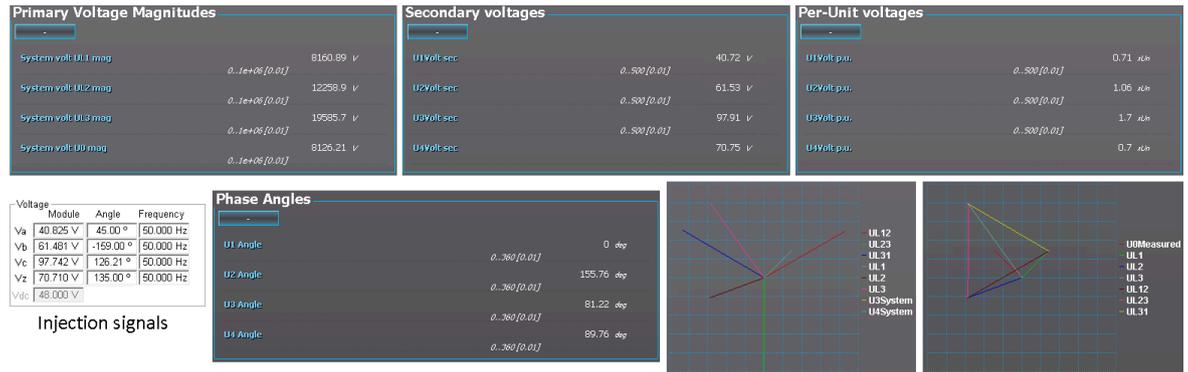
The image collection below presents the relay's behavior when nominal voltage is injected into the relay via secondary test equipment. The measurement mode is 3LN+U4 which means that the relay is measuring line-to-neutral voltages. The VT scaling has been set to 20 000 : 100 V. The U4 channel measures the zero sequence voltage which has the same ratio (20 000 : 100 V).

Figure. 5.2.2 - 63. Relay behavior when nominal voltage injected.



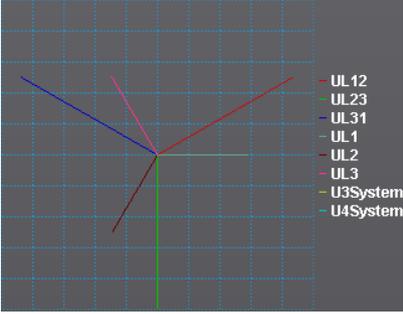
The image collection below presents the relay's behavior when voltage is injected into the relay via secondary test equipment during an earth fault. The measurement mode is 3LN+U4 which means that the relay is measuring line-to-neutral voltages. The VT scaling has been set to 20 000 : 100 V. The U4 channel measures the zero sequence voltage which has the same ratio (20 000 : 100 V).

Figure. 5.2.2 - 64. Relay behavior when voltage injected during an earth fault.



Troubleshooting

When the measured voltage values differ from the expected voltage values, the following table offers possible solutions for the problems.

| Problem | Check / Resolution |
|--|--|
| The measured voltage amplitude in all phases does not match the injected voltage. | The scaling settings or the voltage measurement mode may be wrong, check that the settings match with the connected voltage transformer (<i>Measurement</i> → <i>Transformers</i> → <i>VT Module</i>). |
| The measured voltage amplitude does not match one of the measured phases./ The calculated U0 is measured even though it should not. | Check the wiring connections between the injection device or the VTs and the relay. |
| The measured voltage amplitudes are OK but the angles are strange./ The voltage unbalance protection trips immediately after activation./ The earth fault protection trips immediately after it is activated and voltage calculated. | The voltages are connected to the measurement module but the order or polarity of one or all phases is incorrect. In relay settings, go to <i>Measurement</i> → <i>Phasors</i> and check the "System voltage vectors" diagram. When all connections are correct, the diagram (symmetric feeding) should look like this:  |

Settings

Table. 5.2.2 - 26. Settings of the VT scaling.

| Name | Range | Step | Default | Description |
|--------------------------|--|------|--------------|--|
| Voltage measurement mode | 0: 3LN+U4 1: 3LL+U4 2: 2LL+U3+U4 | - | 0: 3LN+U4 | The relay's voltage wiring method. The voltages are scaled according the set voltage measurement mode. |

| Name | Range | Step | Default | Description |
|--------------------------|--|------|-----------------|--|
| U3 mode U0 or SS | 0: Not Used 1: U0 2: SS | - | 0: Not Used | The voltage channel U3 can be used to measure zero sequence voltage (U0) or the Synchrocheck voltage (SS). If neither is needed, the (default) option "Not Used" should be active. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U0 (U3) Measured from | 0: Broken Delta 1: Neutral point 2: Open delta | - | 0: Broken delta | Defines how the secondary voltage is scaled to the primary. Does not affect how protection operates, it only affects the displayed primary voltages. This parameter is visible when the "U3 mode U0 or SS" has been set to the "U0" mode. |
| U4 mode U0 or SS | 0: Not Used 1: U0 2: SS | - | 0: Not Used | The voltage channel U4 can be used to measure zero sequence voltage (U0) or the Synchrocheck voltage (SS). If neither is needed, the (default) option "Not Used" should be active. |
| U0 (U4) Measured from | 0: Broken Delta 1: Neutral point 2: Open delta | - | 0: Broken delta | Defines how the secondary voltage is scaled to the primary. Does not affect how protection operates, it only affects the displayed primary voltages. This parameter is visible when the "U4 mode U0 or SS" has been set to the "U0" mode. |
| Voltage memory | 0: Disabled 1: Activated | - | 0: Disabled | Activates the voltage memory. The "Voltage memory" chapter describes the function in more detail. |
| P-E Voltage measurements | 0: No P-E voltages available 1: P-E Voltages calculated 2: P-E Voltages measured | - | - | Indicates whether or not phase-to-earth voltages are available. Also indicates whether P-E voltages are measured from the voltage channels directly or if they are calculated from measured line-to-line and zero sequence voltages. |
| VT primary | 1...1 000 000.0V | 0.1V | 20 000.0V | The rated primary voltage of the voltage transformer. |
| VT secondary | 0.2...400.0V | 0.1V | 100.0V | The rated secondary voltage of the voltage transformer. |
| U3 Res/SS VT primary | 1...1 000 000V | 0.1V | 20 000.0V | The primary nominal voltage of the connected U0 or SS VT. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U3 Res/SS VT secondary | 0.2...400V | 0.1V | 100.0V | The secondary nominal voltage of the connected U0 or SS VT. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U4 Res/SS VT primary | 1...1 000 000V | 0.1V | 20 000.0V | The primary nominal voltage of the connected U0 or SS VT. |
| U4 Res/SS VT secondary | 0.2...400V | 0.1V | 100.0V | The secondary nominal voltage of the connected U0 or SS VT. |
| U1 Polarity | 0: - 1: Invert | - | 0: - | The selection of the first voltage measurement channel's (U1) polarity (direction). The default setting is for the positive voltage to flow from connector 1 to connector 2, with the secondary voltage's starpoint pointing towards the line. |
| U2 Polarity | 0: - 1: Invert | - | 0: - | The selection of the second voltage measurement channel's (U2) polarity (direction). The default setting is for the positive voltage to flow from connector 1 to connector 2, with the secondary voltage's starpoint pointing towards the line. |
| U3 Polarity | 0: - 1: Invert | - | 0: - | The selection of the third voltage measurement channel's (U3) polarity (direction). The default setting is for the positive voltage to flow from connector 1 to connector 2, with the secondary voltage's starpoint pointing towards the line. |
| U4 Polarity | 0: - 1: Invert | - | 0: - | The selection of the fourth voltage measurement channel's (U4) polarity (direction). The default setting is for the positive voltage to flow from connector 1 to connector 2, with the secondary voltage's starpoint pointing towards the line. |

| Name | Range | Step | Default | Description |
|--------------------------------|-------|------|---------|--|
| VT scaling factor P/S | - | - | - | A relay feedback value; the calculated scaling factor that is the ratio between the primary voltage and the secondary voltage. |
| VT scaling factor p.u. Pri | - | - | - | A relay feedback value; the scaling factor for the primary voltage's per-unit value. |
| VT scaling factor p.u. Sec | - | - | - | A relay feedback value; the scaling factor for the secondary voltage's per-unit value. |
| U3 VT scaling factor P/S U0/SS | - | - | - | A relay feedback value; the scaling factor that is the ratio between the U3 channel's primary and secondary voltages. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U3 scaling factor p.u. Pri | - | - | - | A relay feedback value for channel U3; the scaling factor for the primary voltage's per-unit value. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U3 scaling factor p.u. Sec | - | - | - | A relay feedback value for channel U3; the scaling factor for the secondary voltage's per-unit value. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U4 VT scaling factor P/S U0/SS | - | - | - | A relay feedback value; the scaling factor that is the ration between the U4 channel's primary and secondary voltages. This setting is only valid is the "2LL+U3+U4" mode is selected. |
| U4 scaling factor p.u. Pri | - | - | - | A relay feedback value for channel U4; the scaling factor for the primary voltage's per-unit value. This setting is only valid if the "2LL+U3+U4" mode is selected. |
| U4 scaling factor p.u. Sec | - | - | - | A relay feedback value for channel U4; the scaling factor for the secondary voltage's per-unit value. This setting is only valid if the "2LL+U3+U4" mode is selected. |

Measurements

The following measurements are available in the measured voltage channels.

Table. 5.2.2 - 27. Per-unit voltage measurements.

| Name | Unit | Range | Step | Description |
|--------------------------------------|--------------|--------------|------|--|
| Voltage Ux ("UxVolt p.u.") | $\times U_n$ | 0.00...500.0 | 0.01 | The RMS voltage measurement (in p.u.) from each of the voltage channels. |
| Voltage Ux TRMS ("UxVolt TRMS p.u.") | $\times U_n$ | 0.00...500.0 | 0.01 | The TRMS voltage (inc. harmonics up to 31 st) measurement (in p.u.) from each of the voltage channels. |

Table. 5.2.2 - 28. Secondary voltage measurements.

| Name | Unit | Range | Step | Description |
|---|------|--------------|------|--|
| Secondary voltage Ux ("Ux Volt sec") | V | 0.00...500.0 | 0.01 | The secondary RMS voltage measurement from each of the voltage channels. |
| Secondary voltage Ux TRMS ("UxVolt TRMS sec") | V | 0.00...500.0 | 0.01 | The secondary TRMS voltage (inc. harmonics up to 31 st) measurement from each of the voltage channels. |

Table. 5.2.2 - 29. Voltage phase angle measurements.

| Name | Unit | Range | Step | Description |
|----------|------|---------------|------|---|
| Ux Angle | deg | 0.00...360.00 | 0.01 | The phase angle measurement from each of the four voltage inputs. |

Table. 5.2.2 - 30. Per-unit sequence voltage measurements.

| Name | Unit | Range | Step | Description |
|--|--------------|--------------|------|--|
| Positive sequence voltage ("Pos.seq.Volt.p.u.") | $\times U_n$ | 0.00...500.0 | 0.01 | The measurement (in p.u.) from the calculated positive sequence voltage. |
| Negative sequence voltage ("Neg.seq.Volt.p.u.") | $\times U_n$ | 0.00...500.0 | 0.01 | The measurement (in p.u.) from the calculated negative sequence voltage. |
| Zero sequence voltage ("Zero.seq.Volt.p.u.") | $\times U_n$ | 0.00...500.0 | 0.01 | The measurement (in p.u.) from the calculated zero sequence voltage. |

Table. 5.2.2 - 31. Primary sequence voltage measurements.

| Name | Unit | Range | Step | Description |
|---|------|-----------------------|------|--|
| Primary positive sequence voltage ("Pos.seq.Volt.pri") | V | 0.00...1 000000.00 | 0.01 | The primary measurement from the calculated positive sequence voltage. |
| Primary negative sequence voltage ("Neg.seq.Volt.pri") | V | 0.00...1 000000.00 | 0.01 | The primary measurement from the calculated negative sequence voltage. |
| Primary zero sequence voltage ("Zero.seq.Volt.pri") | V | 0.00...1 000000.00 | 0.01 | The primary measurement from the calculated zero sequence voltage. |

Table. 5.2.2 - 32. Secondary sequence voltage measurements.

| Name | Unit | Range | Step | Description |
|---|------|---------------|------|--|
| Secondary positive sequence voltage ("Pos.seq.Volt.sec") | V | 0.00...4800.0 | 0.01 | The secondary measurement from the calculated positive sequence voltage. |
| Secondary negative sequence voltage ("Neg.seq.Volt.sec") | V | 0.00...4800.0 | 0.01 | The secondary measurement from the calculated negative sequence voltage. |
| Secondary zero sequence voltage ("Zero.seq.Volt.sec") | V | 0.00...4800.0 | 0.01 | The secondary measurement from the calculated zero sequence voltage. |

Table. 5.2.2 - 33. Sequence voltage angle measurements.

| Name | Unit | Range | Step | Description |
|---|------|--------------|------|---|
| Positive sequence voltage angle ("Pos.seq.Volt.Angle") | deg | 0.00...360.0 | 0.01 | The calculated positive sequence voltage angle. |
| Negative sequence voltage angle ("Neg.seq.Volt.Angle") | deg | 0.00...360.0 | 0.01 | The calculated negative sequence voltage angle. |
| Zero sequence voltage angle ("Zero.seq.Volt.Angle") | deg | 0.00...360.0 | 0.01 | The calculated zero sequence voltage angle. |

Table. 5.2.2 - 34. System primary voltage measurements.

| Name | Unit | Range | Step | Description |
|--|------|-----------------------|------|--|
| System voltage magnitude UL12 ("System volt UL12 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-line UL12 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude UL23 ("System volt UL23 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-line UL23 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude UL31 ("System volt UL31 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-line UL31 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude UL1 ("System volt UL1 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-neutral UL1 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude UL2 ("System volt UL2 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-neutral UL2 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude UL3 ("System volt UL3 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS line-to-neutral UL3 voltage (measured or calculated). You can also select the row where the unit for this is kV. |
| System voltage magnitude U0 ("System volt U0 mag") | V | 0.00...1 000000.00 | 0.01 | The primary RMS zero sequence U0 voltage (measured or calculated). You can also select the row where the unit for this is kV. There is also a row where the unit is %. |
| System voltage magnitude U3 ("System volt U3 mag") | V | 0.00...1 000000.00 | 0.01 | The primary measured RMS Synchrocheck voltage (SS). This magnitude is displayed only when the "2LL+U3+U4" mode is selected and both U3 and U4 are in use. You can also select the row where the unit for this is kV. |

| Name | Unit | Range | Step | Description |
|--|------|-------------------|------|--|
| System voltage magnitude U4 ("System volt U4 mag") | V | 0.00...1000000.00 | 0.01 | The primary measured RMS Synchrocheck voltage (SS). This magnitude is displayed only when the "2LL+U3+U4" mode is selected and both U3 and U4 are in use. You can also select the row where the unit for this is kV. |

Table. 5.2.2 - 35. Primary system voltage angles.

| Name | Unit | Range | Step | Description |
|--|------|--------------|------|---|
| System voltage angle UL12 ("System volt UL12 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-line angle UL12 (measured or calculated). |
| System voltage angle UL23 ("System volt UL23 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-line angle UL23 (measured or calculated). |
| System voltage angle UL31 ("System volt UL31 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-line angle UL23 (measured or calculated). |
| System voltage angle UL1 ("System volt UL1 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-neutral angle UL1 (measured or calculated). |
| System voltage angle UL2 ("System volt UL2 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-neutral angle UL2 (measured or calculated). |
| System voltage angle UL3 ("System volt UL3 ang") | deg | 0.00...360.0 | 0.01 | The primary line-to-neutral angle UL3 (measured or calculated). |
| System voltage angle U0 ("System volt U0 ang") | deg | 0.00...360.0 | 0.01 | The primary zero sequence angle U0 (measured or calculated). |
| System voltage angle U3 ("System volt U3 ang") | deg | 0.00...360.0 | 0.01 | The primary measured Synchrocheck angle SS. This magnitude is only valid when the "2LL+U3+U4" mode is selected and both U3 and U4 are in use. |
| System voltage angle U4 ("System volt U4 ang") | deg | 0.00...360.0 | 0.01 | The primary measured Synchrocheck angle SS. This magnitude is displayed only when the "2LL+U3+U4" mode is selected and both U3 and U4 are in use. |

Table. 5.2.2 - 36. Harmonic voltage measurements.

| Name | Unit | Range | Step | Default | Description |
|---|------|---|-----------|-------------|---|
| Harmonics calculation values ("Harm Abs.or Perc.") | - | 0: Percent 1: Absolute | - | 0: Percent | Defines whether the harmonics are calculated as percentages or absolute values. |
| Harmonics display | - | 0: Per unit 1: Primary V 2: Secondary V | - | 0: Per unit | Defines how the harmonics are displayed: in p.u. values, as primary voltage values, or as secondary voltage values. |
| Maximum harmonics value ("UxMaxH") | V | 0.00...100000.00 V | 0.01 V | - | Displays the maximum harmonics value of the selected voltage input Ux. |
| Fundamental frequency ("Ux Fund") | V | 0.00...100000.00 V | 0.01 V | - | Displays the voltage value of the fundamental frequency value (RMS) of the selected voltage input Ux. |
| Ux harmonics (2 nd ...31 st harmonic) | V | 0.00...100000.00 V | 0.01 V | - | Displays the selected harmonic from the voltage input Ux. |

5.2.3 Power and energy calculation

The relays that are equipped with both a voltage and a current measurement card can calculate power, and can therefore have power-based protection and monitoring functions (the number of available functions depends of the relay type). In addition to power calculations, energy magnitudes are also calculated.

Power is divided into three magnitudes: apparent power (S), active power (P) and reactive power (Q). Energy measurement calculates magnitudes for active and reactive energy. Energy can flow to the forward direction (exported) or to the reverse direction (imported).

If a unit has more than one CT measurement module, the user can choose which module's current measurement is used by the power calculation.

Line-to-neutral voltages available

Power is calculated from line-to-neutral voltages and phase currents. If line-to-line voltages are connected, the relay can calculate line-to-neutral voltages based on the measured zero sequence voltage. The following equations apply for power calculations with the line-to-neutral mode and the line-to-line voltage mode (with U0 connected and measured):

Figure. 5.2.3 - 65. Three-phase power (S) calculation.

$$S_{L1} = U_{L1} \times I_{L1}$$

$$S_{L2} = U_{L2} \times I_{L2}$$

$$S_{L3} = U_{L3} \times I_{L3}$$

$$S = S_{L1} + S_{L2} + S_{L3}$$

Figure. 5.2.3 - 66. Three-phase active power (P) calculation.

$$P_{L1} = U_{L1} \times I_{L1} \cos \varphi$$

$$P_{L2} = U_{L2} \times I_{L2} \cos \varphi$$

$$P_{L3} = U_{L3} \times I_{L3} \cos \varphi$$

$$P = P_{L1} + P_{L2} + P_{L3}$$

In these equations, phi (φ) is the angle difference between voltage and current.

Figure. 5.2.3 - 67. Three-phase reactive power (Q) calculation.

$$Q_{L1} = U_{L1} \times I_{L1} \sin \varphi$$

$$Q_{L2} = U_{L2} \times I_{L2} \sin \varphi$$

$$Q_{L3} = U_{L3} \times I_{L3} \sin \varphi$$

$$Q = Q_{L1} + Q_{L2} + Q_{L3}$$

Active power can be to the forward or the reverse direction. The direction of active power can be indicated with the power factor (Cos (φ), or Cosine phi), which is calculated according the following formula:

$$3PH \cos(\varphi) = P/S$$

$$L1 \cos(\varphi) = P_{L1}/S_{L1}$$

$$L2 \cos(\varphi) = P_{L2}/S_{L2}$$

$$L3 \cos(\varphi) = P_{L3}/S_{L3}$$

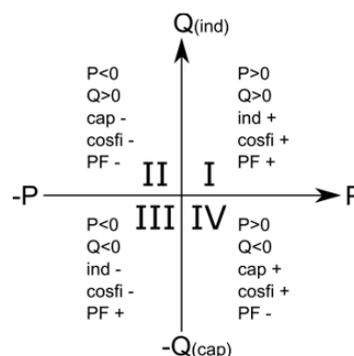
The direction of reactive power is divided into four quadrants. Reactive power may be inductive or capacitive on both forward and reverse directions. Reactive power quadrant can be indicated with Tan (φ) (tangent phi), which is calculated according the following formula:

$$3PH \tan(\varphi) = Q/P$$

$$L1 \tan(\varphi) = Q_{L1}/P_{L1}$$

$$L2 \tan(\varphi) = Q_{L2}/P_{L2}$$

$$L3 \tan(\varphi) = Q_{L3}/P_{L3}$$



Power factor calculation is done similarly to the Cosine phi calculation but the polarity is defined by the reactive power direction. Therefore, the power factor is calculated with the following formula:

$$3PH PF = P/S * Q/|Q|$$

$$L1 PF = P_{L1}/S_{L1} * Q_{L1}/|Q_{L1}|$$

$$L2 PF = P_{L2}/S_{L2} * Q_{L2}/|Q_{L2}|$$

$$L3 PF = P_{L3}/S_{L3} * Q_{L3}/|Q_{L3}|$$

Only line-to-line voltages available

If the line-to-line voltages are measured but the zero sequence voltage is not measured or is not otherwise known, the three-phase power calculation is based on Aron's theorem:

$$S = U_{23} \times I_{L1} \cos(30) + U_{31} \times I_{L2} \cos(30)$$

$$P = U_{23} \times I_{L1} \cos(30 - \varphi) + U_{31} \times I_{L2} \cos(30 + \varphi)$$

$$Q = U_{23} \times I_{L1} \sin(30 - \varphi) + U_{31} \times I_{L2} \sin(30 + \varphi)$$

Both $\cos(\varphi)$ and $\tan(\varphi)$ are calculated in the same way as in the line-to-neutral mode.

Troubleshooting

Check the "Troubleshooting" section in chapters "Current measurement and scaling" and "Voltage measurement and scaling" for more information. Most power and energy measurement problems are usually related to the same issues (i.e. wiring errors, wrong measurement modes, faulty frequency settings, etc.).

Settings

Table. 5.2.3 - 37. Power and energy measurement settings

| Name | Range | Step | Default | Description |
|----------------------------------|--------------------------------|---------|-----------------|--|
| 3ph active energy measurement | 0: Disabled 1: Enabled | - | 0: Disabled | Enables/disables the active energy measurement. |
| 3ph reactive energy measurement | 0: Disabled 1: Enabled | - | 0: Disabled | Enables/disables the reactive and apparent energy measurement. |
| 3ph energy megas or kilos | 0: Mega 1: Kilo | - | 0: Mega | Defines whether energy is measured with the prefix 'kilo' (10^3) or 'mega' (10^6). |
| Edit energy values | 0: Disabled 1: Enabled | - | 0: Disabled | When this parameter is enabled it is possible to manually edit exported and imported active energy values. NOTE: "E 3ph M or k" parameter has to be set to "kilo" for this feature to function. |
| Invert imp/exp energy directions | 0: Not inverted 1: Inverted | - | 0: Not inverted | Inverts the direction of imported and exported energy without affecting the direction of power calculation. |
| Nominal power kVA | 0.10...500000.00kVA | 0.01kVA | 100kVA | Defines the nominal power of the protected object. |

| Name | Range | Step | Default | Description |
|--|--|------|-----------------|--|
| PQ Quadrant | 0: Undefined 1: Q1 Fwd Ind 2: Q2 Rev Cap 3: Q3 Rev Ind 4: Q4 Fwd Cap | - | 0: Undefined | Indicates what the power PQ quadrant is at that moment. |
| VA Quadrant | 0: Undefined 1: Q1 Fwd Cap AV 2: Q2 Rev Ind AV 3: Q3 Rev Cap VA 4: Q4 Fwd Ind VA | - | 0: Undefined | Indicates what the power VA quadrant is at that moment. |
| Reset energy calculators ("Reset 3ph Energies") | 0: - 1: Reset | - | 0: - | Resets the memory of the three-phase energy calculators. Goes automatically back to the "-" state after the reset is finished. |
| Phase active energy measurement | 0: Disabled 1: Enabled | - | 0: Disabled | Enables/disables the active energy per phase measurement. |
| Phase reactive energy measurement | 0: Disabled 1: Enabled | - | 0: Disabled | Enables/disables the reactive energy per phase measurement. |
| Phase energies megas or kilos | 0: Mega 1: Kilo | - | 0: Mega | Defines whether energy (per phase) is measured with the prefix 'kilo' (10^3) or 'mega' (10^6). |
| Reset energy calculators (per phase) ("Reset E per phase") | 0: - 1: Reset | - | 0: - | Resets the memory of the individual phase energy calculator. Goes automatically back to the "-" state after the reset is finished. |

Table. 5.2.3 - 38. Energy Dose Counter 1 settings

| Name | Range | Step | Default | Description |
|------------------------------|--|-----------------|----------------------|--|
| Energy dose counter mode | 0: Disabled 1: Activated | - | 0: Disabled | Enables/disables energy dose counters generally. |
| Clear pulse counter | 0: - 1: Clear | - | 0: - | Resets the "DC 1...4 Pulses sent" counters back to zero. |
| DC 1...4 enable | 0: Disabled 1: Enabled | - | 0: Disabled | Enables/disables the energy dose counter 1...4 individually. |
| DC 1...4 Input signal select | 0: 3PH.Fwd.Act.EP 1: 3PH.Rev.Avt.EP 2: 3PH.Fwd.React.EQ.CAP 3: 3PH.Fwd.React.EQ.IND 4: 3PH.Rev.React.EQ.CAP 5: 3PH.Rev.React.EQ.IND | - | 0: 3PH.Fwd.Act.EP | Selects whether the energy is active or reactive, whether the direction of the energy is forward of reverse, and whether reactive energy is inductive or capacitive. |
| DC 1...4 Input signal | $-1 \times 10^6 \dots 1 \times 10^6$ | 0.01 | - | The total amount of energy consumed. |
| DC 1...4 Pulse magnitude | 0...1800kW/var | 0.005kW/ var | 1kW/Var | The set pulse size. An energy pulse is given every time the set magnitude is exceeded. |
| DC 1...4 Pulse length | 0...1800s | 0.005s | 1s | The total length of a control pulse. |

| Name | Range | Step | Default | Description |
|---------------------|-------------------|------|---------|--|
| DC1...4 Pulses sent | 0...4 294 967 295 | 1 | - | Indicates the total number of pulses sent. |

Table. 5.2.3 - 39. DC 1...4 Pulse out settings

| Name | Range | Step | Default | Description |
|--------------------|-------------|------|---------------|---|
| DC 1...4 Pulse out | OUT1...OUTx | - | None selected | The selection of the controlled physical outputs. |

Power measurements

The following power calculations are available when the voltage and the current cards are available.

Table. 5.2.3 - 40. Three-phase power calculations.

| Name | Unit | Range | Step | Description |
|----------------------------|------|---|--------|--|
| 3PH Apparent power (S) | kVA | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The total three-phase apparent power in kilo-volt-ampere |
| 3PH Active power (P) | kW | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The total three-phase active power in kilowatts |
| 3PH Reactive power (Q) | kVar | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The total three-phase reactive power in kilovars |
| 3PH Apparent power (S MVA) | MVA | -1x10 ⁵ ...1x10 ⁵ | 0.01 | The total three-phase apparent power in megawatts |
| 3PH Active power (P MW) | MW | -1x10 ⁵ ...1x10 ⁵ | 0.01 | The total three-phase active power in mewatts |
| 3PH Reactive power (QMVar) | MVar | -1x10 ⁵ ...1x10 ⁵ | 0.01 | The total three-phase active power in megavars |
| 3PH Tan(phi) | - | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The direction of three-phase active power |
| 3PH Cos(phi) | - | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The direction of three-phase reactive power |
| 3PH Power factor | - | -1x10 ⁶ ...1x10 ⁶ | 0.0001 | The three-phase power factor |

Table. 5.2.3 - 41. Single-phase power calculations (L1...L3).

| Name | Unit | Range | Step | Description |
|-----------------------|------|---|--------|---|
| Lx Apparent power (S) | kVA | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The apparent power of Phase Lx in kilo-volt-amperes |
| Lx Active power (P) | kW | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The active power of Phase Lx in kilowatts |
| Lx Reactive power (Q) | kVar | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The reactive power of Phase Lx kilovars |
| Lx Tan(phi) | - | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The direction of Phase Lx's active power |
| Lx Cos(phi) | - | -1x10 ⁶ ...1x10 ⁶ | 0.01 | The direction of Phase Lx's reactive power |
| Lx Power factor | - | -1x10 ⁶ ...1x10 ⁶ | 0.0001 | The power factor of Phase Lx |

Energy measurements

The following energy calculations are available when the voltage and the current cards are available. Please note that the unit prefix is determined by the user's selection between 'kilo' and 'mega' in "Three-phase energy prefix ("E 3ph M or k")" under the general "Power and energy measurement settings".

Table. 5.2.3 - 42. Three-phase energy calculations.

| Name | Range | Step | Description |
|---|--|------|---|
| Exported Active Energy (P) (kWh or MWh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of exported active energy. |
| Imported Active Energy (P) (kWh or MWh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of imported active energy. |
| Active Energy (P) Export/Import balance (kWh or MWh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The sum of imported and exported active energy. |
| Exported (Q) while Export (P) (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of exported reactive energy while active power is exported. |
| Imported (Q) while Export (P). (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | Total amount of imported reactive energy while active energy is exported. |
| Reactive energy (Q) balance while export (P) (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The sum of imported and exported reactive capacitive energy while active power is exported. |
| Exported (Q) while Import (P) (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of exported reactive energy while active energy is imported. |
| Imported (Q) while Import (P) (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of imported reactive energy while active energy is imported. |
| Reactive energy (Q) balance while Import (P) (kVarh or MVarh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The sum of imported and exported reactive energy while active energy is imported. |
| Apparent Energy (S) while Export (P) (kVAh or MVAh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of exported apparent energy while active energy is exported. |
| Apparent Energy (S) while Import (P) (kVAh or MVAh) | -999 999 995 904.00...999 999 995 904.00 | 0.01 | The total amount of exported apparent energy while active energy is imported. |

Table. 5.2.3 - 43. Single-phase energy calculations (L1...L3).

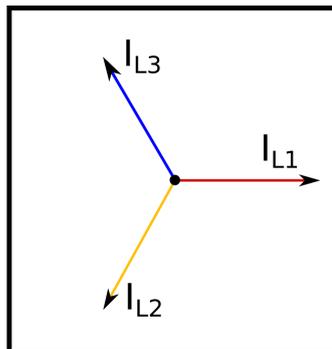
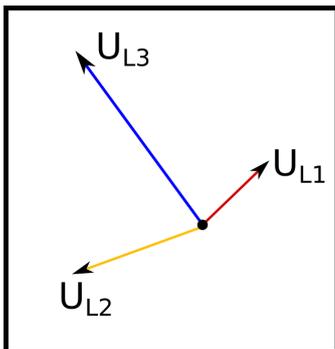
| Name | Range | Step | Description |
|--|---|------|---|
| Export Active Energy Lx (kWh or MWh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The exported active energy of the phase. |
| Import Active Energy (kWh or MWh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The imported active energy of the phase. |
| Active Energy (P) Export/Import balance (kWh or MWh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The sum of the phase's imported and exported active energy. |
| Exported (Q) while Export (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The exported reactive energy of the phase while active energy is exported. |
| Imported (Q) while Export (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The imported reactive energy of the phase while active energy is exported. |
| Reactive Energy (Q) balance while Export (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The sum of the phase's imported and exported reactive energy while active energy is exported. |
| Exported (Q) while Import (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The exported reactive energy of the phase while active energy is imported. |
| Imported (Q) while Import (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The imported reactive energy of the phase while active energy is imported. |

| Name | Range | Step | Description |
|--|---|------|---|
| Reactive energy (Q) balance while Import (P) Lx (kVarh or MVarh) | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The sum of the phase's imported and exported reactive energy while active energy is imported. |
| Apparent Energy (S) while Export (P) Lx | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The apparent energy of the phase while active energy is exported. |
| Apparent Energy (S) while Import (P) Lx | -1x10 ⁹ ...1x10 ⁹ | 0.01 | The apparent energy of the phase while active energy is imported. |

Calculation examples

Here is an example of power calculation. Both wiring methods (line-to-line and line-to-neutral) are checked with the same signal injection. The voltage scaling is set to 20 000 : 100 V and the current scaling is set to 1000 : 5 A.

| Voltages (line-to-neutral): | Currents: |
|--------------------------------------|-----------------------------------|
| U _{L1} = 40.825 V, 45.00° | I _{L1} = 2.5 A, 0.00° |
| U _{L2} = 61.481 V, -159.90° | I _{L2} = 2.5 A, -120.00° |
| U _{L3} = 97.742 V, 126.21° | I _{L3} = 2.5 A, 120.00° |



$$S_{L1} = U_{L1} \times I_{L1} = 40.825 \text{ V} \times 2.5 \text{ A} = 102 \text{ VA (secondary)} \quad \mathbf{4.08 \text{ MVA (primary)}}$$

$$P_{L1} = U_{L1} \times I_{L1} \cos \varphi = 40.825 \text{ V} \times 2.5 \text{ A} \cos(45^\circ - 0^\circ) = 72.2 \text{ W (secondary)} \quad \mathbf{2.89 \text{ MW (primary)}}$$

$$Q_{L1} = U_{L1} \times I_{L1} \sin \varphi = 40.825 \text{ V} \times 2.5 \text{ A} \sin(45^\circ - 0^\circ) = 72.2 \text{ var (secondary)} \quad \mathbf{2.89 \text{ MVar (primary)}}$$

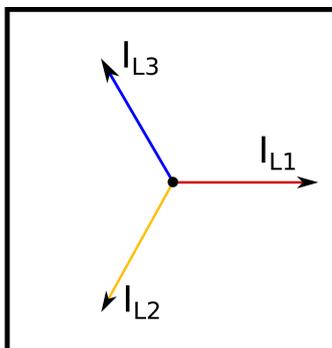
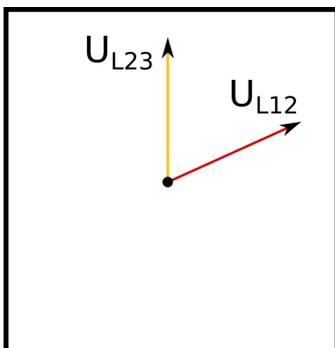
$$L1 \tan(\phi) = Q_{L1}/P_{L1} = 2.89/2.89 = \mathbf{1.00}$$

$$L1 \cos(\phi) = P_{L1}/S_{L1} = 2.89/4.08 = \mathbf{0.71}$$

| Name | Value | Name | Value | Name | Value | Name | Value |
|--------|-----------|--------|------------|--------|-----------|---------|-----------|
| L1 (S) | 4.08 MVA | L2 (S) | 6.15 MVA | L3 (S) | 9.77 MVA | 3PH (S) | 20.00 MVA |
| L1 (P) | 2.89 MW | L2 (P) | 4.72 MW | L3 (P) | 9.71 MW | 3PH (P) | 17.32 MW |
| L1 (Q) | 2.89 Mvar | L2 (Q) | -3.94 Mvar | L3 (Q) | 1.06 Mvar | 3PH (Q) | 0.01 Mvar |
| L1 Tan | 1.00 | L2 Tan | -0.83 | L3 Tan | 0.11 | 3PH Tan | 0.00 |
| L1 Cos | 0.71 | L2 Cos | 0.77 | L3 Cos | 0.99 | 3PH Cos | 0.87 |

| Voltages (line-to-line): | Currents: |
|-------------------------------------|--------------------------------|
| U _{L12} = 100.00 V, 30.00° | I _{L1} = 2.5 A, 0.00° |

| Voltages (line-to-line): | Currents: |
|--|---|
| $U_{L23} = 100.00 \text{ V}, -90.00^\circ$ | $I_{L2} = 2.5 \text{ A}, -120.00^\circ$ |
| | $I_{L3} = 2.5 \text{ A}, 120.00^\circ$ |



$$S = U_{12} \times I_{L1} + U_{23} \times I_{L2}$$

$$S = 100 \text{ V} \times 2.5 \text{ A} + 100 \text{ V} \times 2.5 \text{ A} = 500 \text{ VA (sec)} \quad \mathbf{20.00 \text{ MVA (pri)}}$$

$$P = U_{12} \times I_{L1} \cos(-\varphi) + U_{23} \times I_{L2} \cos(\varphi)$$

$$P = 100 \text{ V} \times 2.5 \text{ A} \cos-(30^\circ - 0^\circ) + 100 \text{ V} \times 2.5 \text{ A} \cos(270^\circ - 240^\circ) = 433 \text{ W (sec)} \quad \mathbf{17.32 \text{ MW (pri)}}$$

$$Q = U_{12} \times I_{L1} \sin(-\varphi) + U_{23} \times I_{L2} \sin(\varphi)$$

$$Q = 100 \text{ V} \times 2.5 \text{ A} \sin-(30^\circ - 0^\circ) + 100 \text{ V} \times 2.5 \text{ A} \sin(270^\circ - 240^\circ) = 0 \text{ var (sec)} \quad \mathbf{0 \text{ Mvar (pri)}}$$

$$3PH \tan(\phi) = Q/P = 0.01/17.32 = \mathbf{0.00}$$

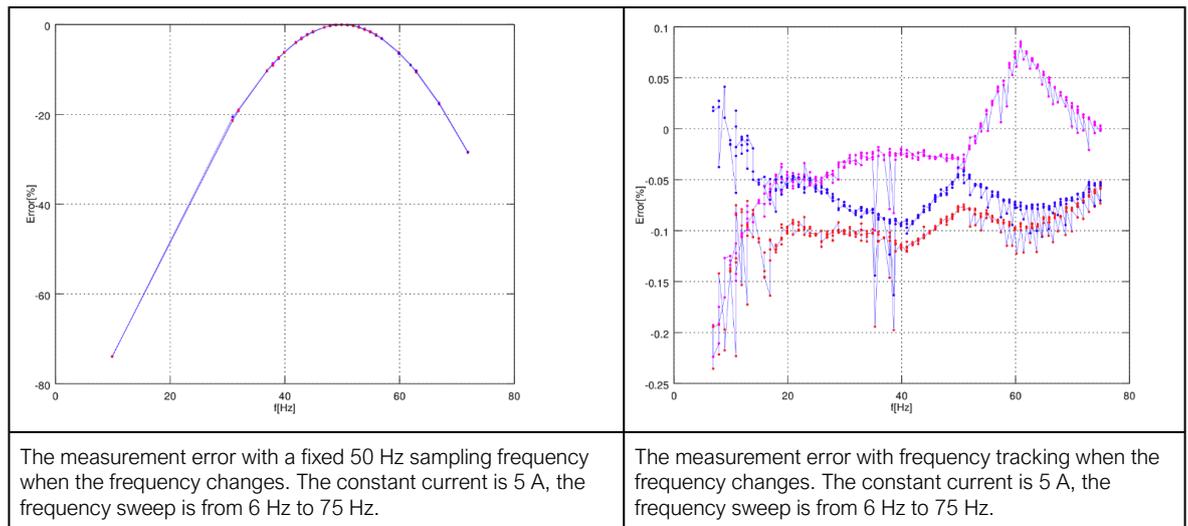
$$3PH \cos(\phi) = P/S = 17.32/20.00 = \mathbf{0.87}$$

| Name | Values |
|---------|-----------|
| 3PH (S) | 20.00 MVA |
| 3PH (P) | 17.32 MW |
| 3PH (Q) | 0.00 Mvar |
| 3PH Tan | 0.00 |
| 3PH Cos | 0.87 |

5.2.4 Frequency tracking and scaling

Measurement sampling can be set to the frequency tracking mode or to the fixed user-defined frequency sampling mode. The benefit of frequency tracking is that the measurements are within a pre-defined accuracy range even when the fundamental frequency of the power system changes.

Table. 5.2.4 - 44. Frequency tracking effect (FF changes from 6 Hz to 75 Hz).



As the figures above show, the sampling frequency has a major effect on the relay's measurement accuracy. If the sampling is not tracked to the system frequency, for example a 10 Hz difference between the measured and the set system frequency can give a measurement error of over 5 %. The figures also show that when the frequency is tracked and the sampling is adjusted according to the detected system frequency, the measurement accuracy has an approximate error of 0.1...- 0.2 % error in the whole frequency range.

AQ -200 series devices have a measurement accuracy that is independent of the system frequency. This has been achieved by adjusting the sample rate of the measurement channels according to the measured system frequency; this way the FFT calculation always has a whole power cycle in the buffer. The measurement accuracy is further improved by Arcteq's patented calibration algorithms that calibrate the analog channels against eight (8) system frequency points for both magnitude and angle. This frequency-dependent correction compensates the frequency dependencies in the used, non-linear measurement hardware and improves the measurement accuracy significantly. Combined, these two methods give an accurate measurement result that is independent of the system frequency.

Troubleshooting

When the measured current, voltage or frequency values differ from the expected values, the following table offers possible solutions for the problems.

| Problem | Check / Resolution |
|---|--|
| The measured current or voltage amplitude is lower than it should be./ The values are "jumping" and are not stable. | The set system frequency may be wrong. Please check that the frequency settings match the local system frequency, or change the measurement mode to "Tracking" (<i>Measurement</i> → <i>Frequency</i> → "Smpl mode") so the relay adjusts the frequency itself. |
| The frequency readings are wrong. | In Tracking mode the relay may interpret the frequency incorrectly if no current is injected into the CT (or voltage into the VT). Please check the frequency measurement settings (<i>Measurement</i> → <i>Frequency</i>). |

Settings

Table. 5.2.4 - 45. Settings of the frequency tracking.

| Name | Range | Step | Default | Description |
|---------------|-------------------------|------|----------|---|
| Sampling mode | 0: Fixed 1: Tracking | - | 0: Fixed | Defines which measurement sampling mode is in use: the fixed user-defined frequency, or the tracked system frequency. |

| Name | Range | Step | Default | Description |
|------------------------------|---|---------|-------------------------------|--|
| System nominal frequency | 7.000...75.000Hz | 0.001Hz | 50Hz | The user-defined system nominal frequency that is used when the "Sampling mode" setting has been set to "Fixed". |
| Tracked system frequency | 0.000...75.000Hz | 0.001Hz | - | Displays the rough measured system frequency. |
| Sampling frequency in use | 0.000...75.000Hz | 0.001Hz | - | Displays the tracking frequency that is in use at that moment. |
| Frequency reference 1 | 0: None 1: CT1IL1 2: CT2IL1 3: VT1U1 4: VT2U1 | - | 1: CT1IL1 | The first reference source for frequency tracking. |
| Frequency reference 2 | 0: None 1: CT1IL2 2: CT2IL2 3: VT1U2 4: VT2U2 | - | 1: CT1IL2 | The second reference source for frequency tracking. |
| Frequency reference 3 | 0: None 1: CT1IL3 2: CT2IL3 3: VT1U3 4: VT2U3 | - | 1: CT1IL3 | The third reference source for frequency tracking. |
| Frequency tracking quality | 0: No trackable channels 1: Reference 1 trackable 2: Reference 2 trackable 3: References 1 & 2 trackable 4: Reference 3 trackable 5: Reference 1 & 3 trackable 6: References 2 & 3 trackable 7: All references trackable | - | - | Defines the frequency tracker quality. If the measured current (or voltage) amplitude is below the threshold, the channel tracking quality is 0 and cannot be used for frequency tracking. If all channels' magnitudes are below the threshold, there are no trackable channels. |
| Frequency measurement in use | 0: No track ch 1: Ref1 2: Ref2 3: Ref3 | - | - | Indicates which reference is used at the moment for frequency tracking. |
| Start behavior | 0: Start tracking immediately 1: First nominal or tracked | - | 0: Start tracking immediately | Defines the how the tracking starts. Tracking can start immediately, or there can be a set delay time between the receiving of the first trackable channel and the start of the tracking. |
| Start sampling with | 0: Use track frequency 1: Use nom frequency | - | 0: Use track frequency | Defines the start of the sampling. Sampling can begin with a previously tracked frequency, or with a user-set nominal frequency. |
| Use nominal frequency until | 0...1800.000s | 0.005s | 0.100s | Defines how long the nominal frequency is used after the tracking has started. This setting is only valid when the "Sampling mode" setting is set to "Tracking" and when the "Start behavior" is set to "First nominal or tracked". |
| Tracked f channel A | 0.000...75.000Hz | 0.001Hz | - | Displays the rough value of the tracked frequency in Channel A. |
| Tracked f channel B | 0.000...75.000Hz | 0.001Hz | - | Displays the rough value of the tracked frequency in Channel B. |

| Name | Range | Step | Default | Description |
|---------------------------|--|---------|---------|---|
| Tracked f channel C | 0.000...75.000Hz | 0.001Hz | - | Displays the rough value of the tracked frequency in Channel C. |
| Alg f fast | 0.000...75.000Hz | 0.001Hz | - | Frequency measurement built from tracked frequencies and U4 voltage channel samples. |
| Alg f avg | 0.000...75.000Hz | 0.001Hz | - | Averaged frequency measurement built from tracked frequencies and U4 voltage channel samples. |
| System measured frequency | 0: One f measured 1: Two f measured 2: Three f measured | - | - | Displays the amount of frequencies that are measured. |
| f.atm. Protections | 0.000...75.000Hz | 0.001Hz | - | Frequency measurement value used by protection functions. When frequency is not measurable this value returns to value set to "System nominal frequency" parameter. |
| f.atm. Display | 0.000...75.000Hz | 0.001Hz | - | Frequency measurement value used in display. When frequency is not measurable this value is "0 Hz". |
| f measurement from | 0: Not measurable 1: Avg Ref 1 2: Avg Ref 2 3: Avg Ref 3 4: Track Ref 1 5: Track Ref 2 6: Track Ref 3 7: Fast Ref 1 8: Fast Ref 2 9: Fast Ref 3 | - | - | Displays which reference is used for frequency measurement. |
| SS1.meas.frqs | 0.000...75.000Hz | 0.001Hz | - | Displays frequency used by "system set" channel 1 and 2. |
| SS2.meas.frqs | | | | |
| SS1f meas.from | 0: Not measurable 1: Fast Ref U3 2: Fast Ref U4 | - | - | Displays which voltage channel frequency reference is used by "system set" voltage channel. |
| SS2f meas.from | 0: Not measurable 1: Fast Ref U4 | - | - | Displays if U4 channel frequency reference is measurable or not when the channel has been set to "system set" mode. |

5.3 Fault indicating functions

5.3.1 Non-directional overcurrent indicator ($I > 50$)

The non-directional overcurrent function is used for instant overcurrent and short-circuit fault alarms. The output of the function is the ALARM signal. The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user or user-defined logic can change function parameters while the function is running. The non-directional overcurrent function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- saturation check
- threshold comparator
- output processing.

The basic design of the supervision function is the three-pole operation.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed current magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and user logic programming. The function generates general time-stamped ON/OFF events to the common event buffer from the output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for ALARM events.

Measured input

The function block uses analog current measurement values. However, when peak-to-peak mode is selected for the function's "Measured magnitude" setting, the values are taken directly from the samples. The monitored magnitude is equal to RMS values. The operating decisions are based on phase current magnitudes which the function constantly measures.

Table. 5.3.1 - 46. Measurement inputs of the I> function.

| Signal | Description | Time base |
|--------|---|-----------|
| IL1RMS | RMS measurement of phase L1 (A) current | 5ms |
| IL2RMS | RMS measurement of phase L2 (B) current | 5ms |
| IL3RMS | RMS measurement of phase L3 (C) current | 5ms |

Pick-up

The I_{set} setting parameter controls the the pick-up of the I> function. This defines the maximum allowed measured current before action from the function. The function constantly calculates the ratio between the I_{set} and the measured magnitude (I_m) for each of the three phases. The reset ratio of 97 % is built into the function and is always relative to the I_{set} value. The setting value is common for all measured phases. When the I_m exceeds the I_{set} value (in single, dual or all phases) it triggers the pick-up operation of the function.

Table. 5.3.1 - 47. Pick-up setting.

| Name | Description | Range | Step | Default |
|-----------|-----------------|---------------------|-------------|-------------|
| I_{set} | Pick-up setting | 0.10...40.00× I_n | 0.01× I_n | 1.20× I_n |

The pick-up activation of the function is not directly equal to the START signal generation of the function. The START signal is allowed if the blocking condition is not active.

Events and registers

The I> function (abbreviated EMON in event block names) generates events and registers from the status changes in ALARM events. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.1 - 48. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|--------------------|
| 8640 | 135 | EMON1 | 0 | I> (50) Detect ON |
| 8641 | 135 | EMON1 | 1 | I> (50) Detect OFF |

The function registers its operation into the last twelve (12) time stamped registers. The ON event process data for ALARM is recorded in the register of the function.

Table. 5.3.1 - 49. Register content.

| Date and time | Event code | Fault type | Max I_m/I_{set} | Used SG |
|----------------------------|---------------------|-----------------|--|--------------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8640-8641 Descr. | L1-E...L1-L2-L3 | The ratio between the highest phase current and the pick-up value. | Setting group 1...8 active. |

5.3.2 Non-directional earth fault indicator ($I_{0>}$; 50N/51N)

The non-directional earth fault function is used for instant and time-delayed earth fault alarms. The operating decisions are based on the selected residual current magnitudes, which the function constantly measures. The monitored current magnitude is equal to RMS values. The monitored residual current measurement channel can be selected to be the I01 or the I02 channel; the user can also choose the I0Calc channel which is the residual current calculated from phase current channels. The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user or user-defined logic can change function parameters while the function is running.

The output of the function is the ALARM signal. The non-directional earth fault function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- saturation check
- threshold comparator
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed current magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and also for user logic programming. The function generates general time-stamped ON/OFF events to the common event buffer from the output signal. The function also provides a resettable cumulative counter for ALARM events.

Measured input

The function block uses analog current measurement values. However, when the peak-to-peak mode is selected for the function's "Measured magnitude" setting, the values are taken directly from the samples. The monitored magnitude is equal to RMS values of phase current measurement channels.

Table. 5.3.2 - 50. Measurement inputs of the I0> function.

| Signal | Description | Time base |
|--------|---|-----------|
| I01RMS | RMS measurement of coarse residual current measurement input I01 | 5ms |
| I02RMS | RMS measurement of sensitive residual current measurement input I02 | 5ms |
| I0Calc | RMS value of the calculated zero sequence current from the three phase currents | 5ms |

The selection of the used AI channel is made with a setting parameter.

Pick-up

The I_{0set} setting parameter controls the pick-up of the I0> function. This defines the maximum allowed measured current before action from the function. The function constantly calculates the ratio between the I_{0set} and the measured magnitude (I_m) of the selected residual current. The reset ratio of 97 % is built into the function and is always relative to the I_{0set} value.

Table. 5.3.2 - 51. Pick-up settings.

| Name | Description | Range | Step | Default |
|------------|-----------------|-------------------------------|--------------------|-------------------|
| I_{0set} | Pick-up setting | $0.10 \dots 40.00 \times I_n$ | $0.001 \times I_n$ | $1.20 \times I_n$ |

Events and registers

The non-directional earth fault function (abbreviated "EMON" in event block names) generates events and registers from the status changes in ALARM events. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.2 - 52. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|----------------------|
| 8642 | 135 | EMON1 | 2 | I0> (50N) Detect ON |
| 8643 | 135 | EMON1 | 3 | I0> (50N) Detect OFF |

The function registers its operation into the last twelve (12) time-stamped registers. The table below presents the structure of the I0> function's register content.

Table. 5.3.2 - 53. Register content.

| Date and time | Event code | Fault type | Max I_{0m}/I_{0set} | Used SG |
|----------------------------|---------------------|-----------------|---|----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8642-8643 Descr. | L1-E...L1-L2-L3 | The ratio between the maximum residual current and the pick-up current value. | Setting group 1...8 active |

5.3.3 Directional overcurrent indicator (Idir>; 67)

The directional overcurrent function is used for directional overcurrent and short-circuit alarms. The operating decisions are based on phase current magnitudes which the function constantly measures. The monitored phase current magnitudes are equal to RMS values. The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user or user-defined logic can change function parameters while the function is running.

The output of the function is the ALARM signal. The directional overcurrent function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude and angle processing
- saturation check
- threshold comparator
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed current magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and user logic programming. The function generates general time-stamped ON/OFF events to the common event buffer from the output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for ALARM events.

Measured input

The function block uses analog current measurement values. However, when the peak-to-peak mode is selected for the function's "Measured magnitude" setting, the values are taken directly from the samples. The monitored magnitude is equal to the RMS value.

The fault current angle is based on a comparison between the positive sequence voltage U_1 and positive sequence current I_1 . If the positive sequence voltage is not available (three line-to-line voltages but no U_0), the voltage angle is based on a faulty phase line-to-line voltage. If the voltage drops below 1 V in the secondary side during a fault, the voltage memory is used for 0.5 seconds. After that the reference angle of the voltage is forced to 0° .

Table. 5.3.3 - 54. Measurement inputs of the Idir> function.

| Signal | Description | Time base |
|--------------------|--|-----------|
| IL1RMS | RMS measurement of phase L1 (A) current | 5ms |
| IL2RMS | RMS measurement of phase L2 (B) current | 5ms |
| IL3RMS | RMS measurement of phase L3 (C) current | 5ms |
| U ₁ RMS | RMS measurement of voltage U ₁ /V | 5ms |
| U ₂ RMS | RMS measurement of voltage U ₂ /V | 5ms |
| U ₃ RMS | RMS measurement of voltage U ₃ /V | 5ms |
| U ₄ RMS | RMS measurement of voltage U ₄ /V | 5ms |

Pick-up

The I_{set} setting parameter controls the pick-up of the $I >$ function. This defines the maximum allowed measured current before action from the function. The function constantly calculates the ratio between the I_{set} and the measured magnitude (I_m) for each of the three phases. The reset ratio of 97 % is built into the function and is always relative to the I_{set} value. The setting value is common for all measured phases, and when the I_m exceeds the I_{set} value (in single, dual or all phases) it triggers the pick-up operation of the function.

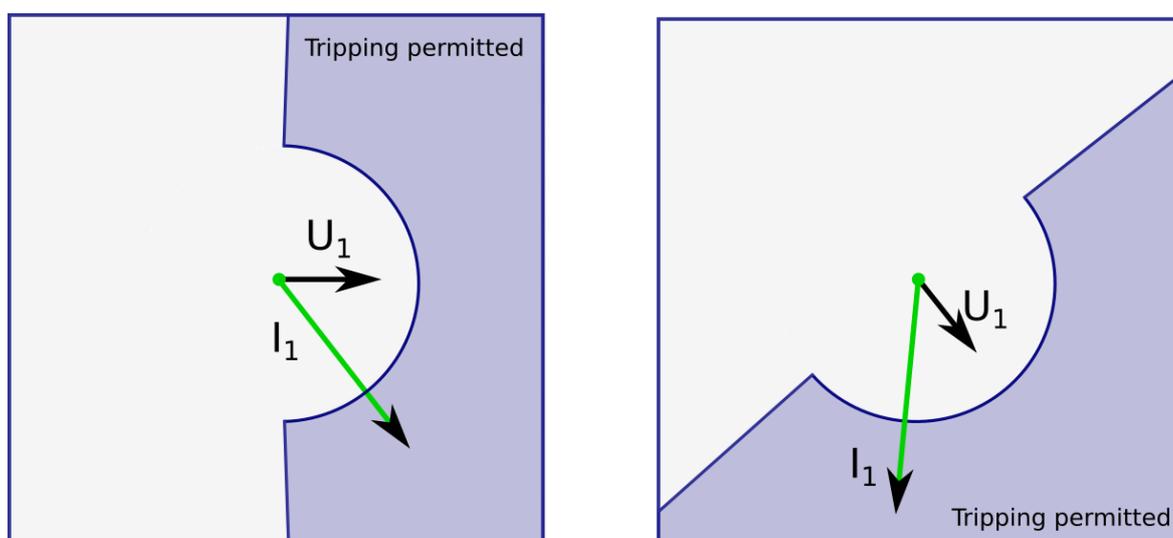
The fault has to be in the monitored direction and it must fulfill the terms in order for the alarm to trigger. The fault direction can be set to forward or reverse. The fault detection area is user settable with *Operating sector size* parameter (± 88 degrees by default). The reference angle is based on the angle of the calculated positive sequence voltage U_1 . If the U_1 voltage is not available and only line-to-line voltages are measured, the reference angle is based on a healthy line-to-line voltage. During a short-circuit the reference angle is based on impedance calculation. If the voltage drops below 1 V in the secondary side, the angle memory is used for 0.5 seconds. The angle memory forces the reference angle to be equal to the value measured or calculated before the fault. The angle memory captures the measured voltage angle 100 ms before the fault starts. After 0.5 seconds the angle memory is no longer used and the reference angle is forced to 0° . The inbuilt reset ratio for the fault detection angle is 2° .

Table. 5.3.3 - 55. Pick-up settings.

| Name | Range | Step | Default | Description |
|-----------------------------------|--|-------------------|-------------------|--|
| Characteristic direction | 0: Forward 1: Reverse 2: Non-directional | - | 0: Forward | Selects the direction of the characteristic. |
| Operating sector size (\pm) | 1.0...170.0deg | 0.1deg | 88deg | The size of the pick-up area. |
| Operating sector center (\pm) | -180.0...180.0deg | 0.1deg | 0.0deg | The center of the pick-up area. |
| Pick-up $>$ (I_{set}) | 0.10...40.00 $\times I_n$ | 0.01 $\times I_n$ | 1.20 $\times I_n$ | The pick-up setting. |

The pick-up activation of the function is not directly equal to the START signal generation of the function. The START signal is allowed if the blocking condition is not active.

Figure. 5.3.3 - 68. Angle tracking of $I_{dir} >$ function (3LN/3LL + U_0 mode).



Please note in the picture above that the tripping area is linked to the angle of the positive sequence voltage U_1 . The angle of the positive sequence current I_1 is compared to U_1 angle, and if the fault is in the correct direction, it is possible to perform a trip when the amplitude of I_{L1} , I_{L2} or I_{L3} increases above the pick-up limit.

If the 3LL mode is used without the U_0 measurement in a single-phase fault situation, the voltage reference comes from the healthy phase and the current reference from the faulty phase. In a short-circuit the angle comes from impedance calculation.

Events and registers

The directional overcurrent function (abbreviated "EMON" in event block names) generates events and registers from the status changes in ALARM events. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.3 - 56. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|-----------------------|
| 8644 | 135 | EMON1 | 4 | ldir> (67) Detect ON |
| 8645 | 135 | EMON1 | 5 | ldir> (67) Detect OFF |

The function registers its operation into the last twelve (12) time-stamped registers. The table below presents the structure of the function's register content.

Table. 5.3.3 - 57. Register content.

| Date and time | Event code | Fault type | Max I_m/I_{set} | Operating angle | Used SG |
|----------------------------|---------------------|-----------------|--|-----------------|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8644-8645 Descr. | L1-E...L1-L2-L3 | The ratio between the highest phase current and the pick-up value. | 0...250° | Setting group 1...8 active. |

5.3.4 Directional earth fault indicator (I0dir>; 67N/32N)

The directional earth fault function is used for earth fault alarms. The operating decisions are based on the selected neutral current or the selected voltage magnitudes, both of which the function measures constantly. The monitored residual current magnitudes are equal to the RMS values from inputs I01 and I02 (residual current measurement) or from I0Calc (residual currents calculated from phase current measurement channels). The current angle is based on the angle of the measured or calculated zero sequence voltage. In addition, a certain amount of zero sequence voltage has to be present to activate the alarm. The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user or user-defined logic can change function parameters while the function is running.

The output of the function is the ALARM signal. The directional earth fault function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- threshold comparator
- angle check
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed current magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and user logic programming. The function generates general time stamped ON/OFF events to the common event buffer from the output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for events.

Measured input

The function block uses analog current measurement values. The monitored magnitude is equal to RMS values. A -20 ms averaged value of the selected magnitude is used for pre-fault data registering.

The fault current angle is based on the neutral voltage U_0 . Both I_0 and U_0 must be above the squelch limit to be able to detect the angle. The squelch limit for the I_0 current is $0.01 \times I_n$ and for the U_0 voltage $0.01 \times U_n$.

Table. 5.3.4 - 58. Measurement inputs of the I0dir> function.

| Signal | Description | Time base |
|--------|---|-----------|
| I01RMS | RMS measurement of coarse residual current measurement input I01 | 5ms |
| I02RMS | RMS measurement of sensitive residual current measurement input I02 | 5ms |
| U0RMS | RMS measurement of zero sequence voltage measurement input U0 | 5ms |
| U0Calc | RMS value of the calculated zero sequence voltage from the three phase voltages | 5ms |

The selection of the used AI channel is made with a setting parameter.

Pick-up

The pick-up of the I0dir> function is controlled by the $I0_{set}$ setting parameter and the $U0_{set}$ setting parameter. The former defines the maximum allowed measured current, while the latter defines the maximum allowed measured voltage and checks the angle difference before action from the function. The function constantly calculates the ratio between the pick-up settings ($I0_{set}$ and $U0_{set}$) and the measured magnitudes (I_m and U_m). The reset ratio of 97 % is built into the function and is always relative to the pick-up setting ($I0_{set}$ and $U0_{set}$). When the I_m exceeds the $I0_{set}$ value and the U_m exceeds the $U0_{set}$ value and the angle between the voltage and the current match with the earthing type, the function triggers its pick-up operation.

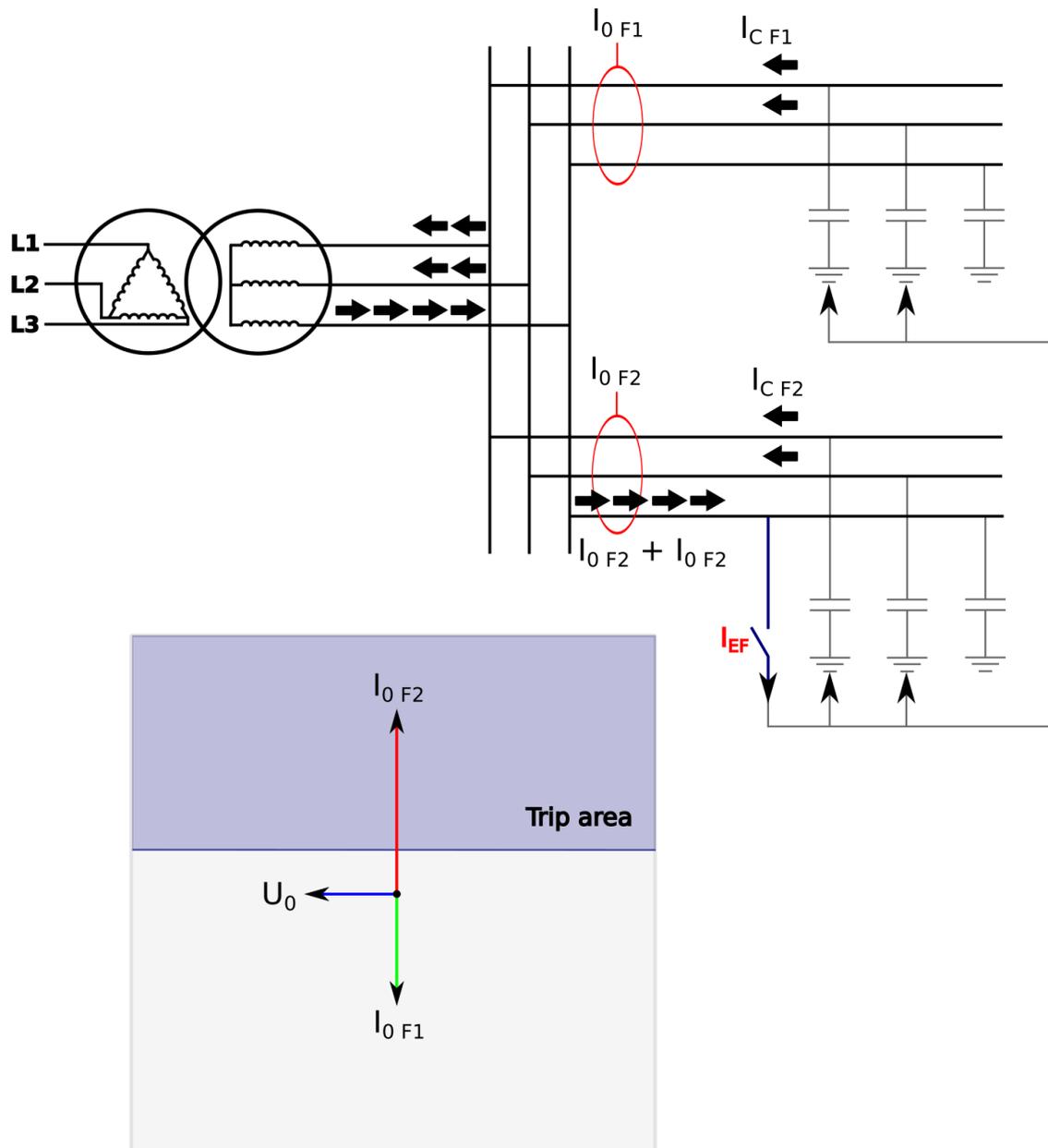
Table. 5.3.4 - 59. Pick-up settings.

| Name | Range | Step | Default | Description |
|---------------|---|---------------------|---------------------|---|
| $I0_{set}$ | $0.005 \dots 40.000 \times I0_n$ | $0.001 \times I0_n$ | $1.200 \times I0_n$ | The pick-up setting for I0. |
| $U0_{set}$ | $1 \dots 75\% U0_n$ | $0.01\% U0_n$ | $20.00\% U0_n$ | The pick-up setting for U0. |
| Earthing type | 1: Unearthed 2: Petersen coil earthed 3: Earthed 4: $I0_{Cos}$ & $I0_{Sin}$ broad range mode | - | 1: Unearthed | Selects the earthing method of the network. |

| Name | Range | Step | Default | Description |
|---|------------------------|-----------|-------------|--|
| Multi-criteria detection | 1: Not used 2: Used | - | 1: Not used | Activation via detecting healthy or unhealthy feeder by analyzing symmetrical components of currents and voltages. This setting is only visible when "I0Cos & I0Sin broad range mode" is the selected earthing type. |
| Compensated/ Unearthed pick-up setting U0set (I0Cosfi/ I0sinfi) | 1.00...75.00%U0n | 0.01%U0n | 20.00%U0n | The compensated or unearthed pick-up setting for U0. This setting is only visible when "I0Cos & I0Sin broad range mode" is the selected earthing type. |
| Compensated/ Unearthed pick-up setting I0set (I0Cosfi/ I0sinfi) | 0.005...40.000×I0n | 0.001×I0n | 1.200×I0n | The compensated or unearthed pick-up setting for I0. This setting is only visible when "I0Cos & I0Sin broad range mode" is the selected earthing type. |
| Fault area size (+/-) | ±45.0...135.0deg | 0.1deg | ±88deg | Selects the preferred size for the tripping area. This setting is only visible when "Earthed" is the selected earthing type. |
| Fault area center | 0.0...360.0deg | 0.1deg | 0deg | Selects the preferred direction for the tripping area. This setting is only visible when "Earthed" is the selected earthing type. |
| I0 angle blinder | -90.0...0.0deg | 0.1deg | -90deg | The I0 angle blinder. This setting is only visible when "Earthed" or "I0Cos & I0Sin broad range mode" is the selected earthing type. |

Unearthed network (32N Varmetric)

Figure. 5.3.4 - 69. Angle tracking of I_{0dir} function (unearthed network model).



When the unearthed (capacitive) network mode is chosen, the relay expects the fault current to be lagging zero sequence voltage by 90 degrees. Healthy phases of healthy feeders produce capacitive current during earth fault just like a faulty feeder but the current is floating towards the busbar and through an incoming transformer or a earthing transformer and into a faulty feeder. Healthy feeders do not trip since capacitive current is floating to the opposite direction and selective tripping can be ensured.

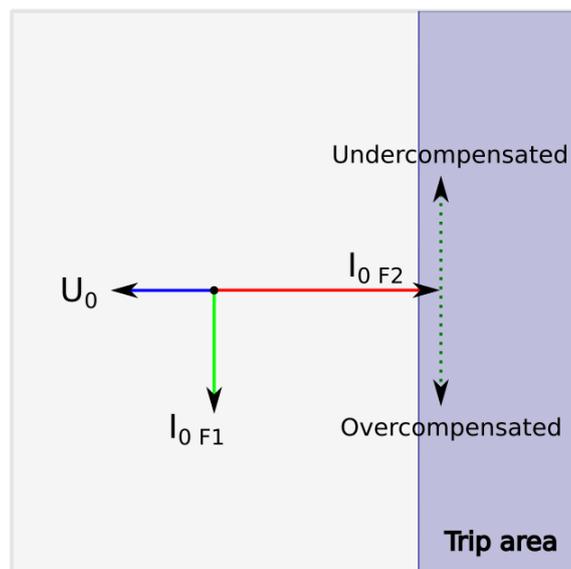
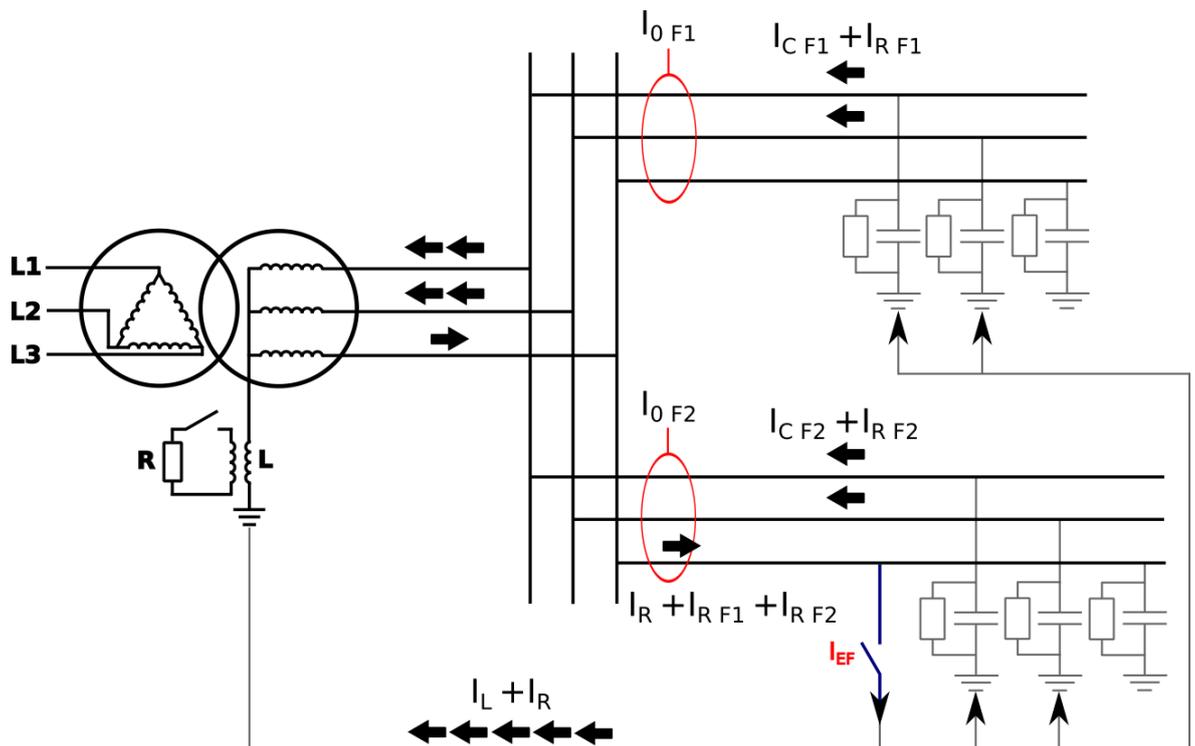
The amplitude of the fault current depends on the capacitance of the network. The outgoing feeders are the sources for capacitive currents. The bigger the network the greater the capacitive current during a fault. Each outgoing feeder produces capacitance according to the zero sequence capacitive reactance of the line (ohms per kilometer). It is normal that in cable networks fault currents are higher than in overhead lines.

The resistance of the fault affects the size of the voltage drop during a fault. In direct earth fault the zero sequence voltage amplitude is equal to the system's line-to-earth voltage. In direct earth fault the voltage of a faulty phase drops close to zero and healthy phase voltages increase to the amplitude of line-to-line voltages.

Petersen coil earthed (compensated) network (32N Wattmetric)

There are many benefits to a Petersen coil earthed network. The amount of automatic reclosing is highly decreased and the maintenance of the breakers is therefore diminished. Arc faults die on their own, and cables and equipment suffer less damage. In emergency situations a line with earth fault can be used for a specific time.

Figure. 5.3.4 - 70. Angle tracking of I_{0dir} function (Petersen coil earthed network model).

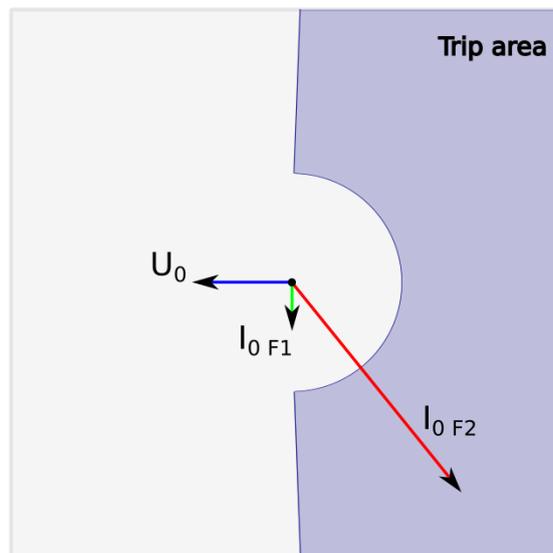
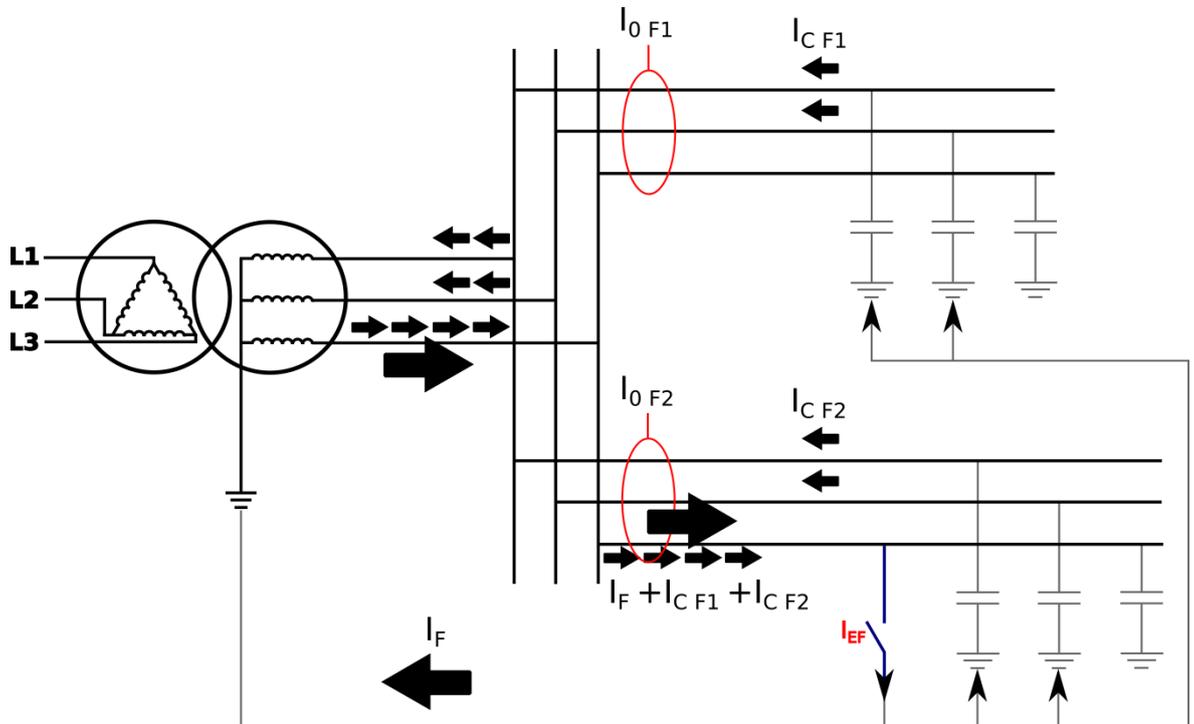


When the Petersen coil earthed (compensated) network mode is chosen, the relay expects the fault current to be in the opposite direction to the zero sequence voltage. Healthy phases of both healthy and faulty feeders produce a capacitive current similar to the unearthed network. The inductance of the Petersen coil compensates the capacitive current and therefore the residual current in a fault location is close to zero. The size of the inductance is chosen according to the prospective earth fault current of the network. The desired compensation grade is achieved when the K factor is close to 1.0 and the network is fully compensated. The network is overcompensated when the K factor is greater than 1.0, and undercompensated when the K factor is smaller than 1.0.

The inductance connected to the star point of an incoming transformer or -as in most cases- to a earthing transformer compensates the capacitance of the network; however, this prevents the capacitive fault current to be measured. The fault detection is handled by connecting the resistance in parallel with the inductance. This resistance includes the amplitude of the fault current. In undercompensated or overcompensated situations the resistive component does not change during the fault; therefore, selective tripping is ensured even when the network is slightly undercompensated or overcompensated.

Directly earthed or small impedance network (67N)

Figure. 5.3.4 - 71. Angle tracking of I_{0dir} function (directly earthed or small impedance network).



In a directly earthed network the amplitude of a single-phase fault current is similar to the amplitude of a short-circuit current. Directly earthed or small impedance network schemes are normal in transmission, distribution and industry.

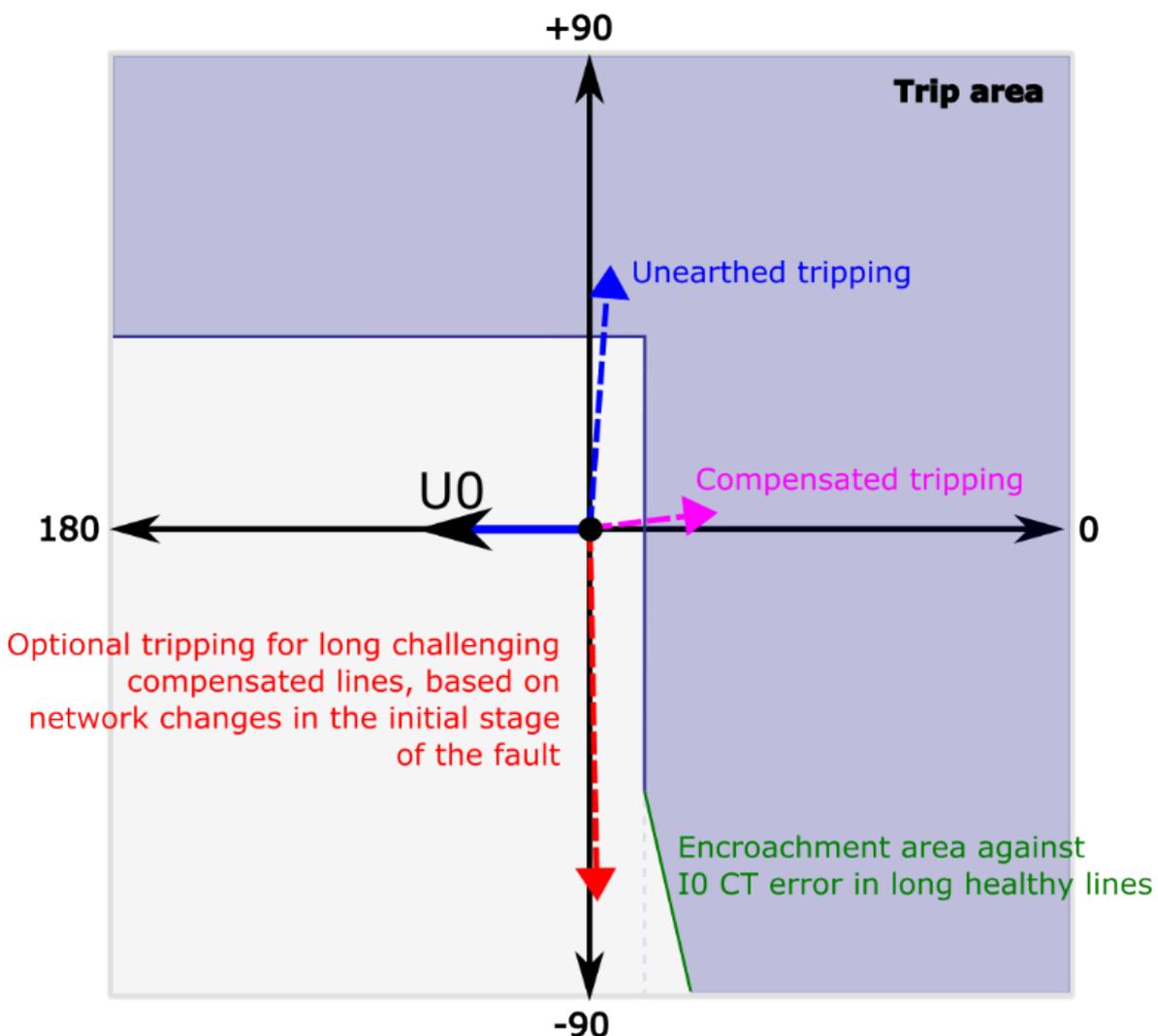
The phase angle setting of the trip area is adjustable as is the base direction of the area (angle offset).

Broad range mode with multi-criteria detection for unearthed (varmetric) and compensated networks (wattmetric)

When detecting earth faults in compensated long-distance cables and overhead lines, it is in some cases difficult to distinguish between a healthy and a faulty feeder. Merely measuring the angle and the magnitude of residual voltage and currents is not always enough, as changes in symmetrical components of phase currents and voltages are also needed. Additionally, when protecting feeders from earth faults, two modes are used depending on the network status (unearthed or compensated). When changing between these two statuses the setting group must be changed, and especially with distributed compensation the change may be difficult or impossible to arrange. Finally, in a compensated network protection the relay with traditional algorithms may sporadically detect an earth fault in a long healthy feeder due to CT errors. For all these reasons, Arcteq has developed an improved alternative to these traditional directional earth fault protections.

Figure. 5.3.4 - 72. Angle tracking of the I_{0dir} function (broad range mode).

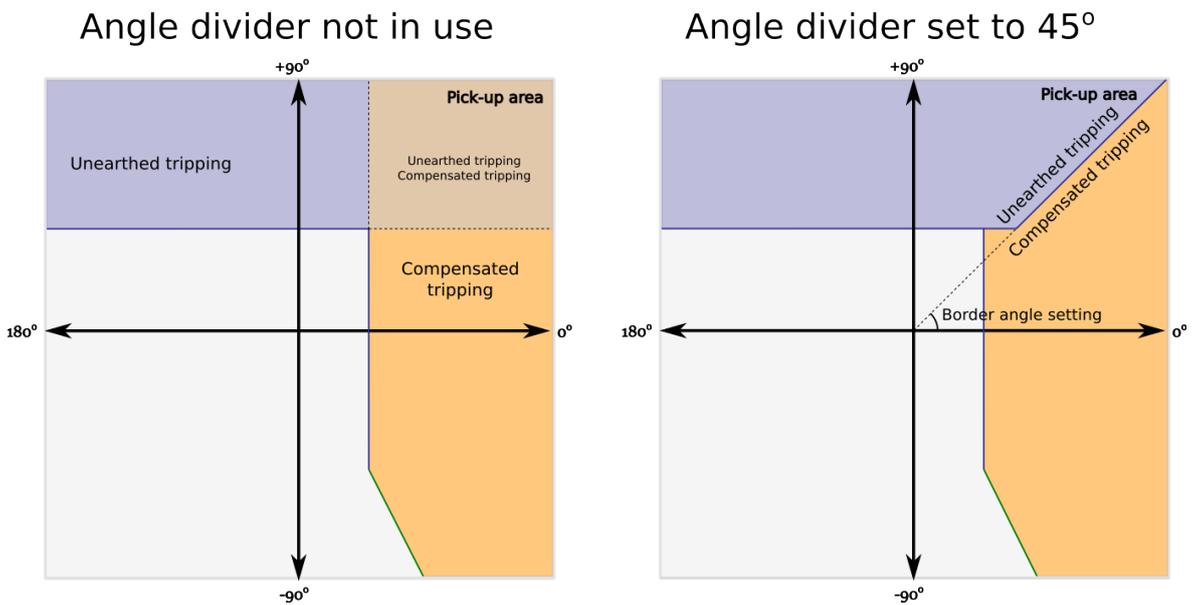
New broadrange mode



The new broad range mode is capable of detecting an earth fault directionally in both unearthed and compensated networks not only by combining the two stages together but by using a new multi-criteria detection. This optional additional fault detecting condition for compensated networks uses Arcteq's patented, high-resolution intermittent earth fault algorithm with added symmetrical component calculation of phase currents and voltages. If this mode is activated, the alarming criteria is comprised of a measured residual current in the fourth quadrant and the symmetrical components of voltages and currents detecting a fault. No extra parameterization is required compared to the traditional method. The multi-criteria algorithm can be tested with COMTRADE files supplied by Arcteq. The function requires a connection of three-phase currents, residual current and residual voltage to operate correctly.

To avoid unnecessary alarms the user can add an encroachment area against IO CT errors in compensated long healthy lines.

Figure. 5.3.4 - 73. Effect of angle divider when in use and when disabled.



To receive a more accurate indication as to whether the fault was in a compensated or an unearthed network the angle divider can divide the area which would otherwise be overlapped between the two network models. By default the setting is 45 degrees. When the divider is disabled the angle is set to zero degrees.

Events and registers

The directional earth fault function (abbreviated "EMON" in event block names) generates events and registers from the status changes in ALARM events. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.4 - 60. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|-----------------------------|
| 8646 | 135 | EMON1 | 6 | I0dir> (67N/32N) Detect ON |
| 8647 | 135 | EMON1 | 7 | I0dir> (67N/32N) Detect OFF |

The function registers its operation into the last twelve (12) time-stamped registers. The register of the function records the ALARM event process data. The table below presents the structure of the function's register content.

Table. 5.3.4 - 61. Register content.

| Date and time | Event code | Fault type | Max I_{0m}/I_{0set} | Fault U_0 (%) | Operating angle | Used SG |
|----------------------------|---------------------|-----------------|---|------------------|-----------------|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8644-8645 Descr. | L1-G...L1-L2-L3 | The ratio between the highest measured current and the pick-up value. | Residual voltage | 0...250° | Setting group 1...8 active. |

5.3.5 Intermittent earth fault indicator (I_{0int} ; 67NT)

The intermittent earth fault is a transient type of a single-phase-to-earth fault where the actual fault phenomenon lasts for about a few hundred microseconds. The intermittent earth fault is commonly seen in Petersen coil grounded (compensated) medium voltage networks. The intermittent earth fault is commonly thought only as a cable network problem but it can also occur in overhead line networks. The key point for this type of fault appearance is the compensation of earth fault currents with a Petersen coil.

This phenomenon is becoming more frequent as more utilities networks are replacing overhead lines with cables dug into the ground. This development in distribution networks is very understandable as overhead lines are more vulnerable to possible seasonal storm damages. Also, the annual maintenance costs as well as the annual power-down time are both significantly lower with underground cable networks than with overhead line networks. However, the problem at hand is caused by the increasing amount of cabling in the network which in turn causes dramatic increases in the capacitive earth fault currents in the distribution networks. When the capacitive earth fault current increases in the network, it becomes necessary to detect the earth fault current with a Petersen coil.

Problems caused by intermittent earth fault are normally seen in compensated network substations: an earth fault can trip multiple feeders simultaneously, or an entire substation can be tripped by residual voltage back-up protection from the incomer. This is typical of old-fashioned relay protection as it is not capable of differentiating between a normal consistent earth fault and an intermittent earth fault. As the intermittent earth fault is a transient type of fault where the actual fault lasts only for a few hundred microseconds, this causes traditional directional earth fault protection relays to lose their directional sensitivity, and as a result their directional decision algorithms go haywire and the trip decisions will be completely random. Typically, when a whole substation goes dark the logs of all protection relays show how they have experienced multiple incorrect directional earth fault starts and releases, as well as an incomer relay residual voltage trip. This is also the worst case scenario. In another typical scenario a few feeders, including the correct faulty feeder, have tripped at the same time. In this case, as in the previous, all the relays' logs show various incorrect directional earth fault starts and releases.

Previously, these scenarios were usually ignored and filed under 'Mysteries of the universe' because they only occurred once or twice a year and because disturbance recordings were not commonly used in normal medium-voltage substations for fault verification. However, when disturbance recorders were introduced as a common feature of protection relays this phenomenon received a name and defined characteristics. One such characteristic is the occurrence of high magnitude current spikes, which –compared to residual voltage– are in the opposite direction of the current spike in faulty feeders and concurrent in healthy feeders. Handling these unique characteristics requires a completely different set of tools than what traditional directional earth fault protection can offer. The following figures present three intermittent earth fault situations experienced by relays in a substation.

Figure. 5.3.5 - 74. An intermittent earth fault in a medium size network tuned close to resonance, as seen by a faulty feeder relay.

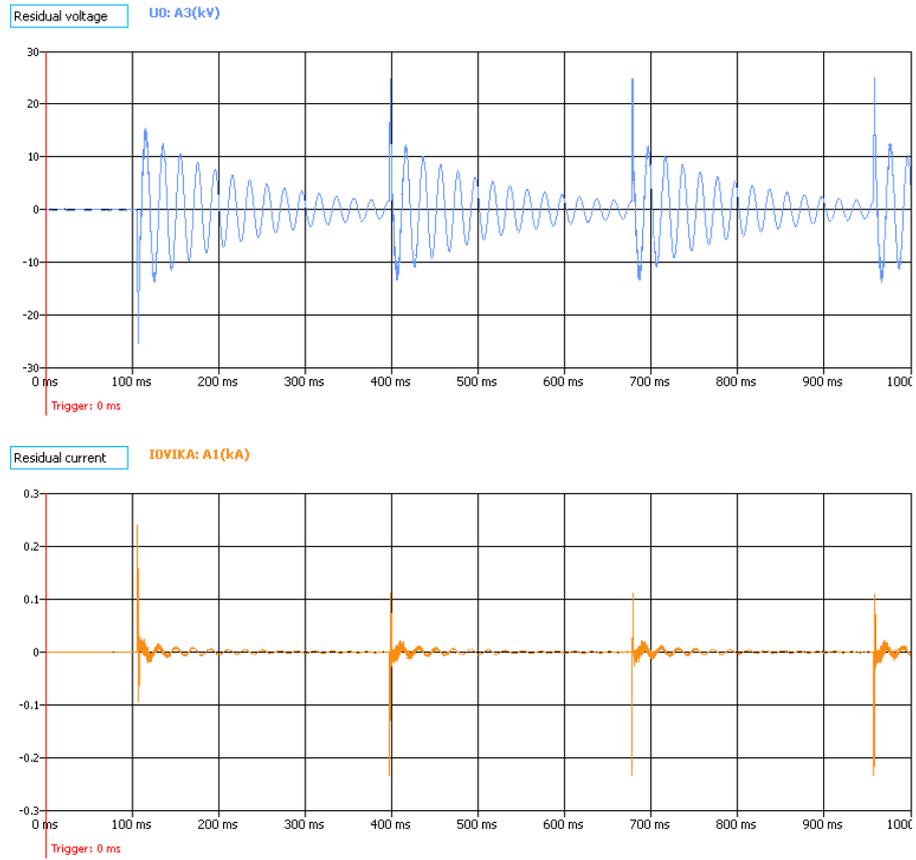


Figure. 5.3.5 - 75. An intermittent earth fault in a network tuned close to resonance, as seen by a healthy feeder relay.

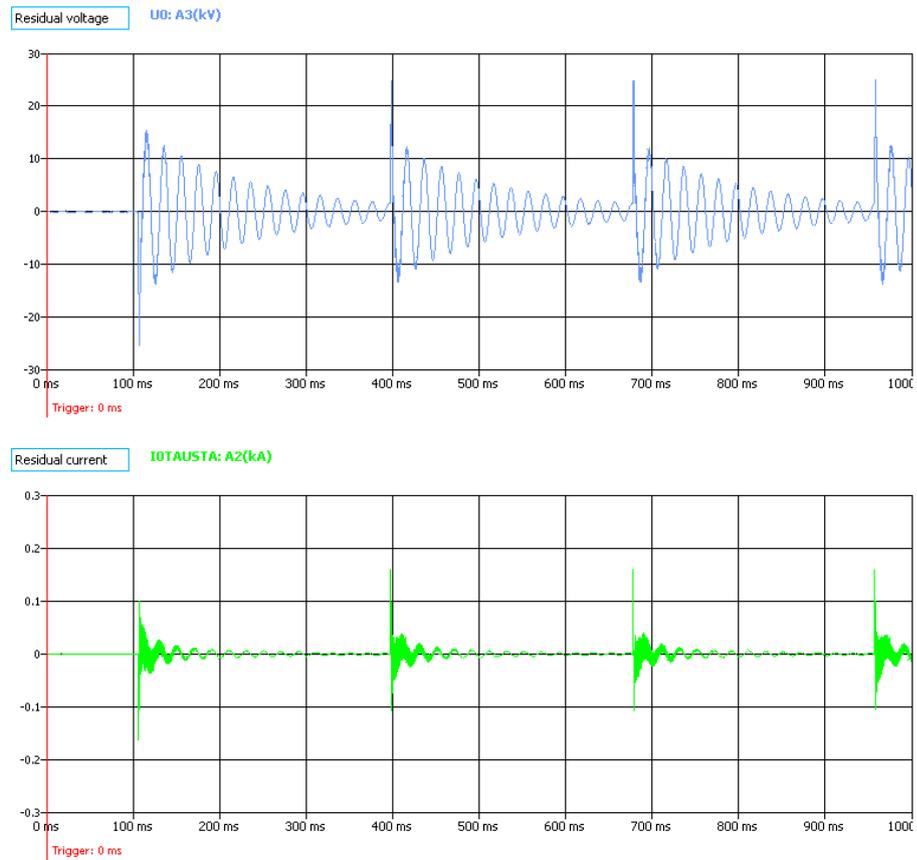


Figure. 5.3.5 - 76. An intermittent earth fault in an undercompensated medium size network, as seen by a faulty feeder relay.

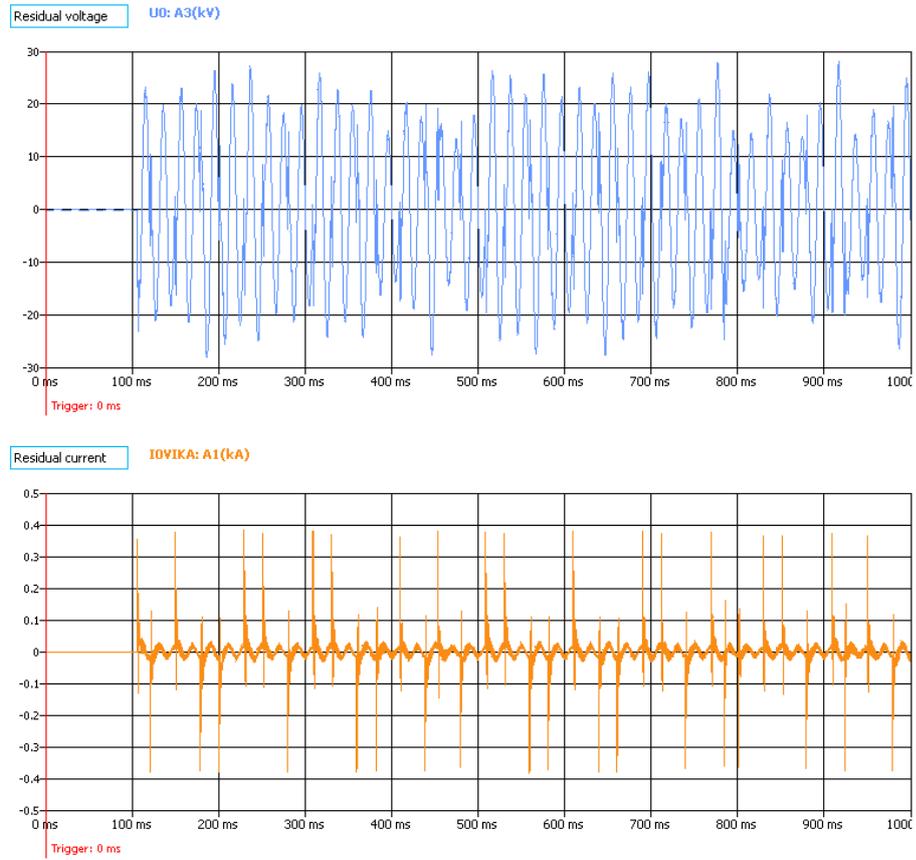
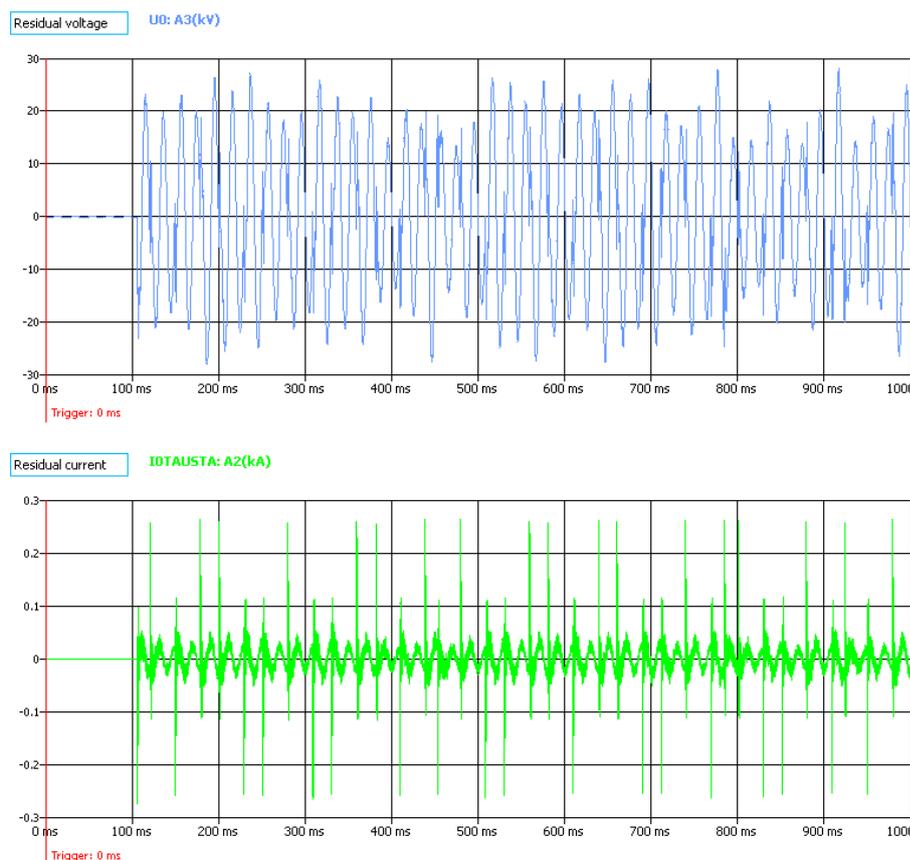


Figure. 5.3.5 - 77. Undercompensated medium size network intermittent earth fault seen by healthy feeder relay.



As can be seen from the figures above, the residual voltage is high both in the network tuned close to resonance and in the undercompensated network. In the case of a normal directional earth fault protection, a network tuned close to resonance would probably not even pick up on the fault, and if it did it would release before the set operating time. The residual voltage stays on for a longer period of time. Although the release would most likely come before the set tripping time, this situation could last for quite some time and put a lot of unnecessary stress on the network, possibly causing an insulator breakdown in another part of the network.

In undercompensated and overcompensated networks the residual voltage stays near the maximum level all the time, and current flashover spikes occur every power cycle. In this case, normal FFT-based directional earth fault protection algorithms lose their directional sense because an FFT-processed input signal expects the power cycle to provide long, stable data for accurate directional output. There are multiple zero crossings during a normal power cycle and therefore the FFT result may be anything from 0 to 180 degrees. When analyzing the situation from the point of view of normal directional earth fault protection, the result may be an expected trip in a faulty feeder, a false trip in a healthy feeder, or no trip whatsoever, all equally probable.

Description of the patented intermittent earth fault algorithm.

The algorithm relates to a method for identifying transient-type earth faults in an electrical network and for selectively tripping a faulty branch line (A/D). The absolute value (I_{0max}) and its index in a zero-current buffer are retrieved from the samples of a zero-current sampling buffer. This is done by means of value-depicting the admittance-delta which is calculated using the ratio $\Delta I_0 / \Delta U_0$: that is, the ratio between the zero current I_0 difference ΔI_0 and the residual voltage U_0 difference ΔU_0 . A negative admittance-delta is classified as forward (FWD). A transient-type earth fault is detected in the branch line with the aid of at least one forward (FWD) spike during a selected time (FWDreset).

More detailed information of the patent can be found on the European Patent Office webpages. The patent's data code is EP3213381 (A1).
A link to the patent: https://worldwide.espacenet.com/publicationDetails/biblio?II=2&ND=3&adjacent=true&locale=en_EP&FT=D&date=20170906&CC=EP&NR=3213381A1&KC=A1.

Setting principles

The intermittent earth fault protection will be coordinated with busbar residual voltage protection. This way, during an intermittent earth fault, a faulty feeder's protection function will trip in all three previously described scenarios. Also, an intermittent earth fault protection function tripping before the residual voltage protection function results in a sufficient safety margin. However, since an intermittent earth fault causes significant network stress the protection trip should be performed as fast as possible.

The strike-through time of an intermittent earth fault in a network tuned close to resonance sets the limit for the minimum operating time for an intermittent earth fault protection stage. To ensure a correct protection operation in all cases, the reset time of an intermittent earth fault stage will be set according to the network in question, to such a level that ensures that the fault has disappeared and no new strike-throughs are expected after a prescribed reset time.

The size of the network is a dominant factor in defining the time interval of a strike-through. One can expect less frequent strike-throughs in larger (in amperes) networks. The following can be presented as a rule of a thumb: in a small or medium size network (<60 A) the strike-through interval is appr. 250...350 ms, in a large network (~100 A) it is appr. 500 ms. It is recommended that the reset time of an intermittent earth fault stage should not be set lower than 450 ms in order to obtain a network independent setting. Using this recommended value one can ensure that the function will not reset too early even in resonance tuned networks.

Usually the maximum operating time of an intermittent earth fault function is dictated by the residual voltage protection of the busbar. If the residual voltage protection is set to very fast tripping, it may be necessary to also prolong its set value. It is recommended that the operating time of an intermittent earth fault stage should be 500 ms counting from the first strike-through. Using this recommended value the protection tripping requires a minimum of two strike-throughs even in resonance tuned networks in which strike-throughs occur less frequently. If the residual voltage protection is set to very fast tripping (<1 s), it may be necessary to verify the reset value of the residual voltage protection. The residual voltage protection operating time should never be faster than the sum of the following: the prescribed intermittent earth fault operating time, the circuit breaker operating time, and the reset time of the residual voltage protection stage.

If an intermittent earth fault protection start is used to block regular non-intermittent directional earth fault protection, the blocking should be applied to both healthy and faulty feeder relays. In general, if intermittent earth fault protection is not used to block directional earth fault protection, it should be verified that the operating time of regular directional earth fault protection is longer than the set intermittent earth fault protection operating time. It is recommended to block regular directional earth fault protection to avoid start events in directional earth fault protection during intermittent earth faults (if start events are considered disturbing), or if directional non-intermittent earth fault protection is set to a faster operating time than intermittent earth fault protection.

If intermittent earth fault protection would be set for optimal operation, sensitive pick-up settings should be avoided. General setting parameter values are presented below.

| Setting parameter | Value |
|-------------------------------|---------------------|
| U ₀ Detect spike > | 60% |
| I ₀ Detect spike > | 0.5×I _{0n} |
| FWD reset time | 0.250s |
| REV reset time | 0.250s |
| Spikes to indicate > | 2 |

The best verification for the settings is a field test with a test system capable of intermittent earth faults. One network characteristic may vary significantly from another. By following the basic rules presented in this chapter it should be easier to define the correct setting range.

It is also important to check that the reset time settings are never set longer than the desired operating time delay setting.

Measured input

The function block uses analog current measurement values from the residual magnitudes. The residual voltage has to be measured for this function to operate correctly. Either the I01 or the I02 channel can be selected for residual current samples.

Table. 5.3.5 - 62. Measurement inputs of the I0int> function.

| Signal | Description | Time base |
|-------------|--|-----------|
| U0 samples | U ₀ residual voltage circular buffer of samples (in p.u.) | 5ms |
| I01 samples | I ₀ residual voltage circular buffer of samples (in p.u.) | 5ms |
| I02 samples | I ₀ residual voltage circular buffer of samples (in p.u.) | 5ms |

The selection of the used AI channel is made with a setting parameter.

Pick-up

The setting parameters *U0 Detect spike>* and *I0 Detect spike>* control the pick-up of the I0int> function. They define the maximum allowed measured residual current and voltage before action from the function. The function constantly calculates the ratio between the setting and the maximum value of the circular buffer.

Table. 5.3.5 - 63. Pick-up settings.

| Name | Range | Step | Default | Description |
|-------------------|-------------------------------|----------------------|-----------------------|--------------------------------|
| U0 Detect spike > | 1.00...100.00%U _{0n} | 0.01%U _{0n} | 80.00%U _{0n} | Pick-up setting U ₀ |
| I0 Detect spike > | 0.05...40.00xI _{0n} | 0.01xI _{0n} | 0.50xI _{0n} | Pick-up setting I ₀ |

The pick-up activation of the function is not directly equal to the START signal generation of the function. The START signal is allowed if the blocking condition is not active and if the threshold of the admittance delta calculated by the input signal exceeds these settings:

- I0 Detect spike > = set admittance delta threshold
- U0 Detect spike > = set admittance delta threshold.

Operating time characteristics for alarming

The operating timers' behavior of the function can be set for trip signal and also for the release of the function in case the pick-up element is reset before the trip time has been reached. The table below presents the setting parameters for the function time characteristics.

Table. 5.3.5 - 64. Setting parameters for operating time characteristics.

| Name | Range | Step | Default | Description |
|----------------|-------------------|--------|---------|--|
| FWD reset time | 0.000...1800.000s | 0.005s | 0.300s | Forward start detection reset time. Starts to count from the first detected forward (faulty feeder) spike. If another spike is detected during counting, it resets and starts from beginning. If it runs to the end, it resets the function START signals. |

| Name | Range | Step | Default | Description |
|----------------------|-------------------|--------|---------|--|
| REV reset time | 0.000...1800.000s | 0.005s | 0.300s | Reverse start detection reset time. Starts to count from the first detected reverse (healthy feeder) spike. If another spike is detected during counting, it resets and starts from beginning. If it runs to the end, it resets the function START signals. |
| Spikes to indicate > | 1...50 | 1 | 2 | A calculated cumulative spikes comparator. In order to trip this a set number of spikes must be exceeded. If the set operating time is reached but the set number of spikes has not been reached, this setting function will release without tripping when the FWD reset time has elapsed. |

Events and registers

The intermittent earth fault function (abbreviated "EMON" in event block names) generates events and registers from the status changes in the FWD alarm and in the REV alarm. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.5 - 65. Event codes.

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|------------------------------|
| 8648 | 135 | EMON1 | 8 | I0int> (67NT) Detect FWD ON |
| 8649 | 135 | EMON1 | 9 | I0int> (67NT) Detect FWD OFF |
| 8650 | 135 | EMON1 | 10 | I0int> (67NT) Detect REV ON |
| 8651 | 135 | EMON1 | 11 | I0int> (67NT) Detect REV OFF |

The table below presents the structure of the function's register content. This information is available for the last twelve (12) recorded events for all provided instances separately.

Table. 5.3.5 - 66. Register content.

| Date and time | Event code | Trip time remaining | Started FWD | Spikes FWD | Started REV | Spikes to trip | Used SG |
|----------------------------|---------------------|---|---|---|---|--|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8648-8651 Descr. | Time remaining from the set operating time. | Yes / No indication of forward start in this fault. | Calculated cumulative number of forward (faulty feeder) spikes. | Yes / No indication of reverse start in this fault. | Set spikes to trip subtracted by cumulative forward spikes. If 0, there are enough spikes to trip. | Setting group 1...8 active. |

5.3.6 Undervoltage indicator (U<; 27)

The undervoltage function is used for undervoltage alarms. The undervoltage function is based on line-to-line voltage RMS or on a line-to-neutral voltage RMS. If the supervision is based on line-to-line voltage, the undervoltage function is not affected by an earth fault in isolated or compensated networks. The undervoltage function stage has two blocking instances: internal blocking that is based on voltage measurement, and external blocking that takes place during, for example, a voltage transformer fuse failure. The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user can change parameters while the station is running.

The output of the function is the ALARM signal. The setting parameters are static inputs for the function which can only be changed by the user in the setup phase of the function. The undervoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- threshold comparator
- two block signal check
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed voltage magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and also for user logic programming. The function registers its operation into the last twelve (12) time stamped registers and also generates general time stamped ON/OFF events to the common event buffer from the output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for ALARM events.

Measured input

The function block uses analog current measurement values. The monitored magnitude is equal to RMS values.

Table. 5.3.6 - 67. Analog magnitudes used by the U< function.

| Signal | Description | Time base |
|--------------------|--|-----------|
| U ₁ RMS | RMS measurement of voltage U ₁ /V | 5ms |
| U ₂ RMS | RMS measurement of voltage U ₂ /V | 5ms |
| U ₃ RMS | RMS measurement of voltage U ₃ /V | 5ms |

Pick-up

The U_{set} setting parameter controls the pick-up of the U< function. It defines the minimum allowed measured voltage before action from the function. The function constantly calculates the ratio between the U_{set} and the measured magnitude (U_m) for each of the three voltages. The reset ratio of 103 % is built into the function and is always relative to the U_{set} value. The setting value is common for all measured amplitudes. When any U_m decreases below the U_{set} value it triggers the pick-up operation of the function.

Table. 5.3.6 - 68. Pick-up settings.

| Name | Range | Step | Default | Description |
|---------------------|--|---------------------|-------------------|---|
| Undervoltage set U< | 0.00...120.00%U _n | 0.01%U _n | 20%U _n | The pick-up setting for undervoltage. |
| No voltage set U< | 0.00...80.00%U _n | 0.01%U _n | 1%U _n | The pick-up setting for no voltage. |
| Measured magnitude | 0: P-P voltages 1: P-E voltages | - | 0: P-P voltages | Selects the measured magnitude. |
| Pick-up terms | 0: 1 voltage 1: 2 voltages 2: 3 voltages | - | 0: 1 voltage | Selects the number of voltages to be protected. |

Events and registers

The undervoltage function (abbreviated "EMON" in event block names) generates events and registers from the status changes in ALARM events and NO VOLTAGE signals. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.6 - 69. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|---------------------------------|
| 8652 | 135 | EMON1 | 12 | U< (27) detected ON |
| 8653 | 135 | EMON1 | 13 | U< (27) detected OFF |
| 8654 | 135 | EMON1 | 14 | U< (27) No voltage detected ON |
| 8655 | 135 | EMON1 | 15 | U< (27) No voltage detected OFF |

The table below presents the structure of the function's register content. This information is available in the last twelve (12) recorded events for all provided instances separately.

Table. 5.3.6 - 70. Register content.

| Date and time | Event code | Fault type | U_{meas}/U_{set} | Used SG |
|----------------------------|---------------------|---------------|---|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8652-8655 Descr. | A...A-B- C | The ratio between the measured voltage and the pick-up setting. | Setting group 1...8 active. |

5.3.7 Neutral overvoltage indicator (U0>; 59N)

The neutral overvoltage function is used for non-directional earth fault alarms. The function constantly measures phase-to-ground voltage magnitudes and calculates the zero sequence component. The neutral overvoltage protection is scaled to the level of line-to-line voltage RMS. If the line-to-line voltage of the system is 100 V in the secondary side, the earth fault is 100% of the U_n when the calculated zero sequence voltage reaches $V = 57.74$ V.

The formula for symmetric component calculation (and therefore to zero sequence voltage calculation) is presented below.

$$U_0 = 1/3(U_{L1} + U_{L2} + U_{L3})$$

$$U_{L1...3} = \text{Line to neutral voltages}$$

See the zero sequence calculation examples below.

Figure. 5.3.7 - 78. Normal situation.

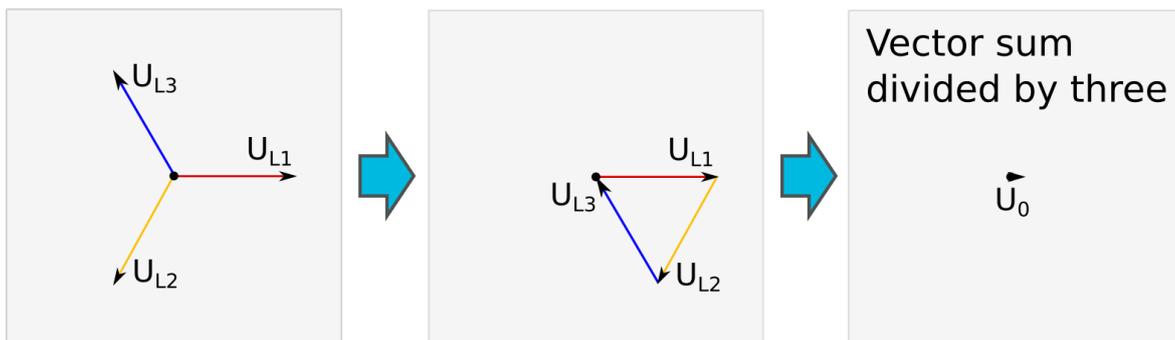


Figure. 5.3.7 - 79. Earth fault in an isolated network.

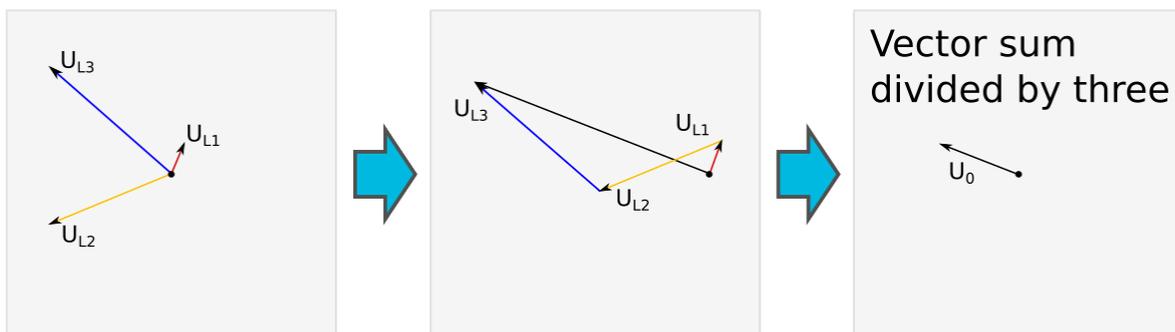
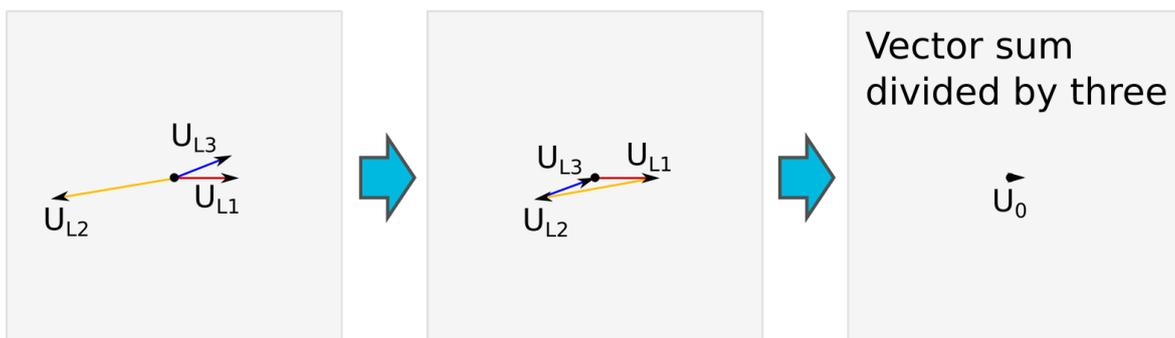
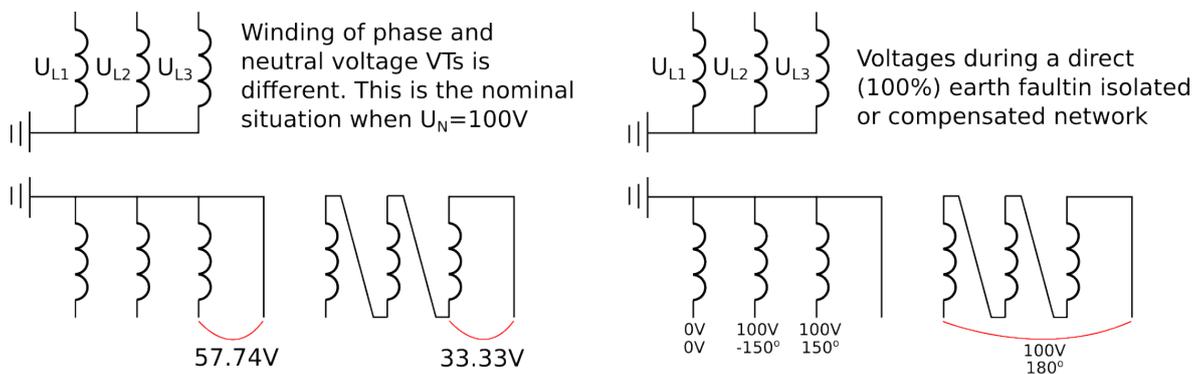


Figure. 5.3.7 - 80. Close distance short-circuit between phases 1 and 3.



The U_0 function is also capable of using the measured neutral voltage. If the line-to-line voltage of the system is 100 V in the secondary side, the earth fault is 100% of the U_n when the measured neutral voltage is 100 V (see picture below).

Figure. 5.3.7 - 81. An example of measured neutral voltage.



The setting group selection controls the operating characteristics of the function during normal operation, i.e. the user can change parameters while the station is running.

The output of the function is the ALARM signal. The setting parameters are static inputs for the function which can only be changed by the user in the setup phase of the function. The neutral overvoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- threshold comparator
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed voltage magnitudes.

The function's output ALARM signal can be used for direct I/O controlling and user logic programming. The function registers its operation into the last twelve (12) time-stamped registers and also generates general time-stamped ON/OFF events to the common event buffer from the output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for ALARM events.

Measured input

The function block uses analog voltage measurement values and always uses RMS values.

Table. 5.3.7 - 71. Measurement inputs of the U0> function.

| Signal | Description | Time base |
|--------|------------------------------------|-----------|
| UORMS | RMS measurement of voltage U_0/V | 5ms |

Pick-up

The U_{set} setting parameter controls the pick-up of the U0> function. This defines the maximum allowed measured voltage before action from the function. The function constantly calculates the ratio between the U_{set} and the measured magnitude (U_m) for each of the three voltages. The reset ratio of 97 % is built into the function and is always relative to the U_{set} value. When the U_m exceeds the U_{set} value it triggers the pick-up operation of the function.

Table. 5.3.7 - 72. Pick-up settings.

| Name | Description | Range | Step | Default |
|-----------|-----------------|---------------------|-------------|-----------|
| U_{set} | Pick-up setting | 1.00...99.00% U_n | 0.01% U_n | 20% U_n |

Events and registers

The neutral overvoltage function (abbreviated "EMON" in event block names) generates events and registers from the status changes in the ALARM signal. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.7 - 73. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|------------------------|
| 8656 | 135 | EMON1 | 16 | U0> (59N) detected ON |
| 8657 | 135 | EMON1 | 17 | U0> (59N) detected OFF |

The table below presents the structure of the function's register content. This information is available for the last twelve (12) recorded events for all provided instances separately.

Table. 5.3.7 - 74. Register content.

| Date and time | Event code | U0 _{meas} /U0 _{set} | Used SG |
|----------------------------|---------------------|---|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 8656-8657 Descr. | The ratio between the residual voltage and the pick-up setting. | Setting group 1...8 active. |

5.3.8 Fault locator (21FL)

The fault locator is used for recording an estimated distance to the point where a fault has occurred. It is mostly used with directional overcurrent protection or with distance protection applications but it can be triggered by other protections as well. The function can be used if three phase currents and three phase voltages have been connected to the relay. The triggering signals, the triggering current and reactance per kilometer must be set in the configuration.

The operational logic consists of the following:

- input magnitude processing
- threshold comparator
- output processing.

The inputs for the function are the following:

- operating mode selections
- setting parameters
- digital inputs and logic signals
- measured and pre-processed voltage and current magnitudes.

The function registers its operation into the last twelve (12) time-stamped registers and also generates general time-stamped ON/OFF events to the common event buffer from the triggering output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for fault locator triggering events.

Measured input

Function block uses analog current and voltage measurements and calculated phase-to-phase or phase-to-earth loop impedances.

Table. 5.3.8 - 75. Measurement magnitudes used by the fault locator function.

| Signals | Description | Time base |
|-----------------|---|-----------|
| VT1 U1,U2,U3 | The line-to-neutral or line-to-line voltages of the first voltage transformer module. | 5ms |
| CT1 IL1,IL2,IL3 | The measurements of the phase currents L1 (A), L2 (B) and L3 (C). | 5ms |

Fault locator triggering

There are several conditions that have to be met in order for the fault locator to trigger and record the distance. After receiving a triggering signal the function checks whether the calculation is blocked (calculation blocking signals are determined by the user in the *Block calculation* matrix). Then the function checks whether phase-to-earth voltages are available. If not available, the fault locator can only record phase-to-phase impedance loops; if available, the fault locator can also record phase-to-neutral impedance loops. The recorded impedance loop is chosen from the available options depending on which of the measured phase currents exceeded the set *Trigger current*> at the time the triggering signal was received. See the tables below.

Table. 5.3.8 - 76. Pick-up settings.

| Name | Range | Step | Default | Description |
|------------------|---------------------------|--------------------|--------------------|---|
| Trigger current> | 0.0...40.0×I _N | 0.1×I _N | 1.0×I _N | Affects the decision which impedance loop is recorded, or if anything is recorded at all (see the table below). |
| Reactance per km | 0.001...5.000Ω/km | 0.001Ω/km | 0.125Ω/km | Used to calculate the distance to a fault. |

Table. 5.3.8 - 77. Current conditions needed to trigger impedance recording.

| Currents over limit | P-E voltages available | P-E Voltage not available |
|---------------------|------------------------|---------------------------|
| | Recorded impedance | Recorded impedance |
| IL 1, IL 2, IL 3 | XL 12 | XL 12 |
| IL 1, IL 2 | XL 12 | XL 12 |
| IL 2, IL 3 | XL 23 | XL 23 |
| IL 1, IL 3 | XL 31 | XL 31 |
| IL 1 | XL 1 | No trigger |
| IL 2 | XL 2 | No trigger |
| IL 3 | XL 3 | No trigger |

If none of the current measurement requirements are fulfilled when the function receives a triggering signal, it will not record impedance.

Events and registers

The fault locator function (abbreviated "EMON" in event block names) generates events and registers from the status changes in triggering calculation. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.3.8 - 78. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|-------------------------|
| 8658 | 135 | EMON1 | 18 | FL (21FL) Triggered ON |
| 8659 | 135 | EMON1 | 19 | FL (21FL) Triggered OFF |

The table below presents the structure of the function's register content. This information is available for the last twelve (12) recorded events.

Table. 5.3.8 - 79. Register content.

| Date and time | Event code | Fault type | Fault direction | Fault reactance | Fault distance | Used SG |
|----------------------------|---------------------|--|-----------------------------------|-----------------|----------------|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 6336-6383 Descr. | L1-L2; L2-L3; L3-L1; L1-N; L2-N; L3-N; L1-L2-L3 | Not detected; Forward; Reverse | In ohms | In kilometers | Setting group 1...8 active. |

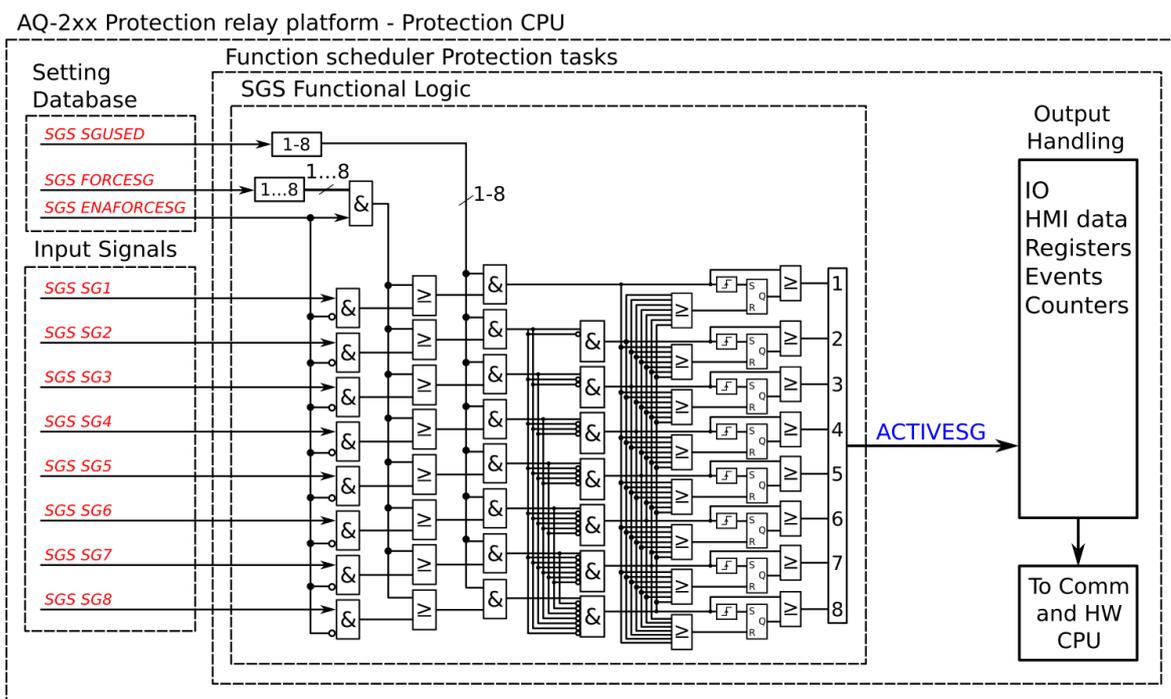
5.4 Control functions

5.4.1 Setting group selection

All relay types support up to eight (8) separate setting groups. The Setting group selection function block controls the availability and selection of the setting groups. By default, only Setting group 1 (SG1) is active and therefore the selection logic is idle. When more than one setting group is enabled, the setting group selector logic takes control of the setting group activations based on the logic and conditions the user has programmed.

The following figure presents a simplified function block diagram of the setting group selection function.

Figure. 5.4.1 - 82. Simplified function block diagram of the setting group selection function.

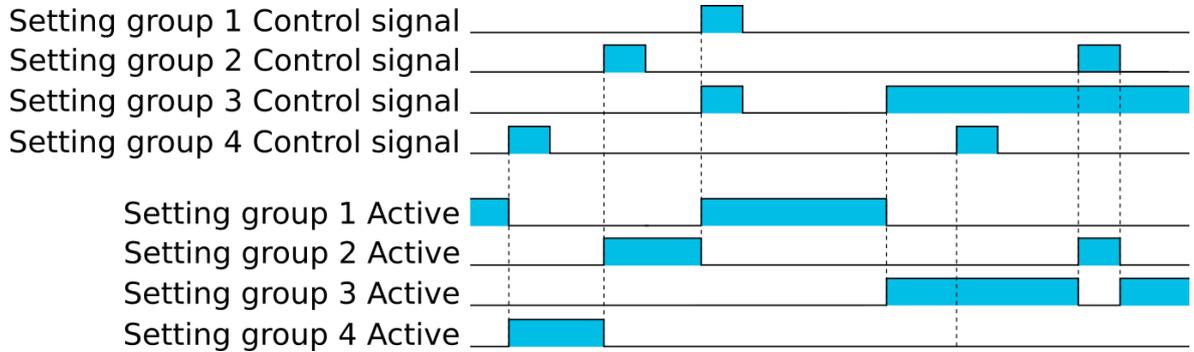


Setting group selection can be applied to each of the setting groups individually by activating one of the various internal logic inputs and connected digital inputs. The user can also force any of the setting groups on when the "Force SG change" setting is enabled by giving the wanted quantity of setting groups as a number in the communication bus or in the local HMI, or by selecting the wanted setting group from *Control* → *Setting groups*. When the forcing parameter is enabled, the automatic control of the local device is overridden and the full control of the setting groups is given to the user until the "Force SG change" is disabled again.

Setting groups can be controlled either by pulses or by signal levels. The setting group controller block gives setting groups priority values for situations when more than one setting group is controlled at the same time: the request from a higher-priority setting group is taken into use.

Setting groups follow a hierarchy in which setting group 1 has the highest priority, setting group 2 has second highest priority etc. If a static activation signal is given for two setting groups, the setting group with higher priority will be active. If setting groups are controlled by pulses, the setting group activated by pulse will stay active until another setting groups receives an activation signal.

Figure. 5.4.1 - 83. Example sequences of group changing (control with pulse only, or with both pulses and static signals).



Settings and signals

The settings of the setting group control function include the active setting group selection, the forced setting group selection, the enabling (or disabling) of the forced change, the selection of the number of active setting groups in the application, as well as the selection of the setting group changed remotely. If the setting group is forced to change, the corresponding setting group must be enabled and the force change must be enabled. Then, the setting group can be set from communications or from HMI to any available group. If the setting group control is applied with static signals right after the "Force SG" parameter is released, the application takes control of the setting group selection.

Table. 5.4.1 - 80. Settings of the setting group selection function.

| Name | Range | Step | Default | Description |
|----------------------------|--|------|-------------|--|
| Active setting group | | | SG1 | Displays which setting group is active. |
| Force setting group | 0: None 1: SG1 2: SG2 3: SG3 4: SG4 5: SG5 6: SG6 7: SG7 8: SG8 | - | 0: None | The selection of the overriding setting group. After "Force SG change" is enabled, any of the configured setting groups in the relay can be overridden. This control is always based on the pulse operating mode. It also requires that the selected setting group is specifically controlled to ON after "Force SG" is disabled. If there are no other controls, the last set setting group remains active. |
| Force setting group change | 0: Disabled 1: Enabled | - | 0: Disabled | The selection of whether the setting group forcing is enabled or disabled. This setting has to be active before the setting group can be changed remotely or from a local HMI. This parameter overrides the local control of the setting groups and it remains on until the user disables it. |
| Used setting groups | 0: SG1 1: SG1...2 2: SG1...3 3: SG1...4 4: SG1...5 5: SG1...6 6: SG1...7 7: SG1...8 | - | 0: SG1 | The selection of the activated setting groups in the application. Newly-enabled setting groups use default parameter values. |

| Name | Range | Step | Default | Description |
|-----------------------------|---|------|---------|---|
| Remote setting group change | 0: None 1: SG1 2: SG2 3: SG3 4: SG4 5: SG5 6: SG6 7: SG7 8: SG8 | - | 0: None | This parameter can be controlled through SCADA to change the setting group remotely. Please note that if a higher priority setting group is being controlled by a signal, a lower priority setting group cannot be activated with this parameter. |

Table. 5.4.1 - 81. Signals of the setting group selection function.

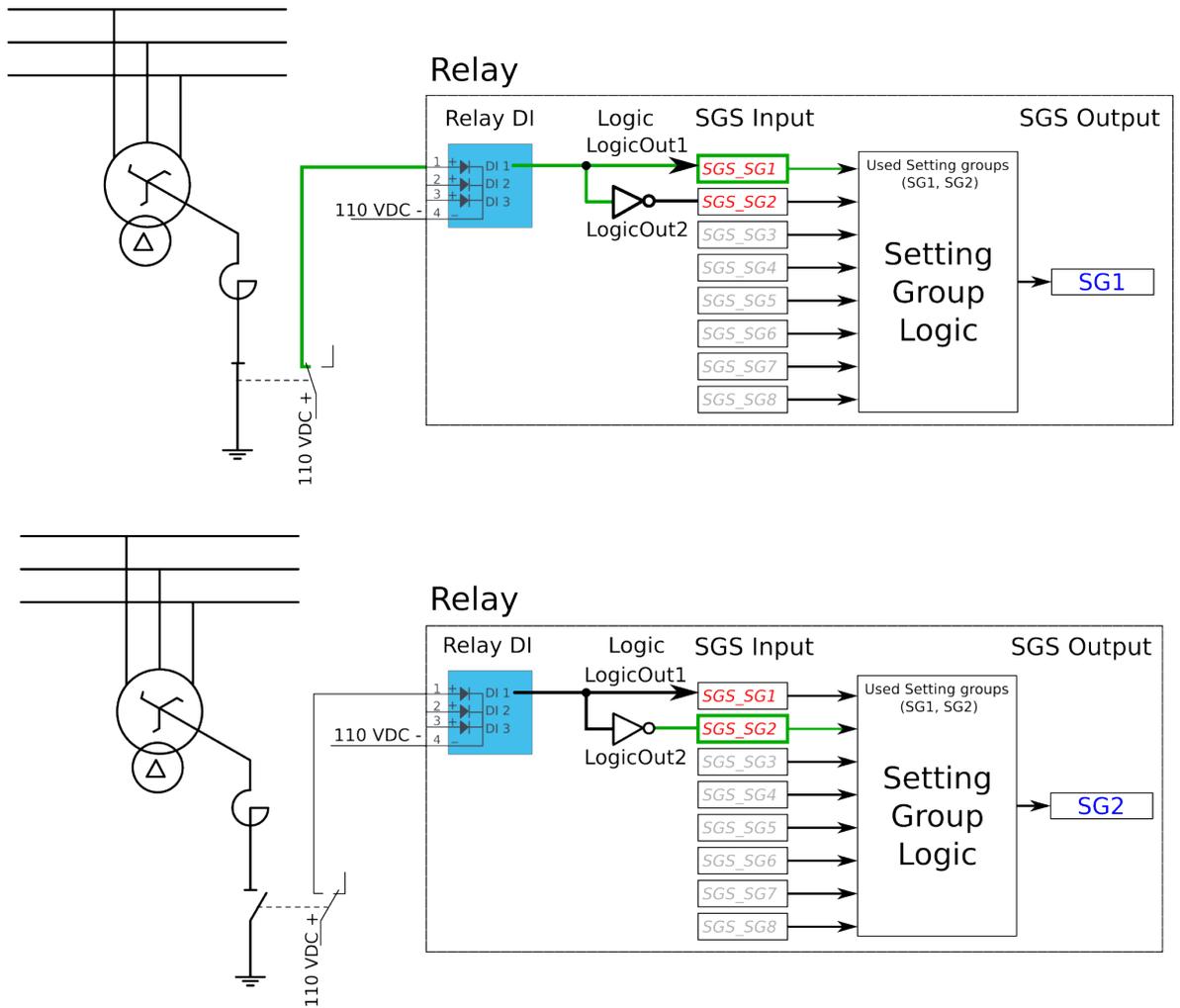
| Name | Range | Step | Default | Description |
|-----------------|----------------------------|------|---------------|--|
| Setting group 1 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 1 ("SG1"). Has the highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no other SG requests will be processed. |
| Setting group 2 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 2 ("SG2"). Has the second highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no requests with a lower priority than SG1 will be processed. |
| Setting group 3 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 3 ("SG3"). Has the third highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no requests with a lower priority than SG1 and SG2 will be processed. |
| Setting group 4 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 4 ("SG4"). Has the fourth highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no requests with a lower priority than SG1, SG2 and SG3 will be processed. |
| Setting group 5 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 5 ("SG5"). Has the fourth lowest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, SG6, SG7 and SG8 requests will not be processed. |
| Setting group 6 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 6 ("SG6"). Has the third lowest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, SG7 and SG8 requests will not be processed. |
| Setting group 7 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 7 ("SG7"). Has the second lowest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, only SG8 requests will not be processed. |
| Setting group 8 | 0: Not active 1: Active | - | 0: Not active | The selection of Setting group 8 ("SG8"). Has the lowest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, all other SG requests will be processed regardless of the signal status of this setting group. |

Example applications for setting group control

This chapter presents some of the most common applications for setting group changing requirements.

A Petersen coil compensated network usually uses directional sensitive earth fault protection. The user needs to control its characteristics between varmetric and wattmetric; the selection is based on whether the Petersen coil is connected when the network is compensated, or whether it is open when the network is unearthed.

Figure. 5.4.1 - 84. Setting group control – one-wire connection from Petersen coil status.



Depending on the application's requirements, the setting group control can be applied either with a one-wire connection or with a two-wire connection by monitoring the state of the Petersen coil connection.

When the connection is done with one wire, the setting group change logic can be applied as shown in the figure above. The status of the Petersen coil controls whether Setting group 1 is active. If the coil is disconnected, Setting group 2 is active. This way, if the wire is broken for some reason, the setting group is always controlled to SG2.

Figure. 5.4.1 - 85. Setting group control – two-wire connection from Petersen coil status.

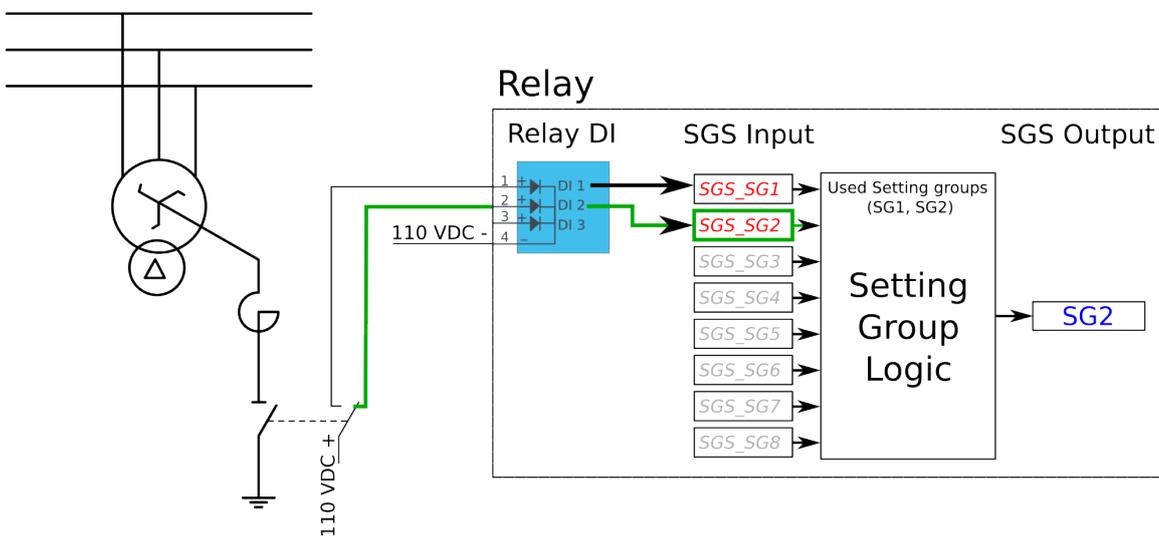
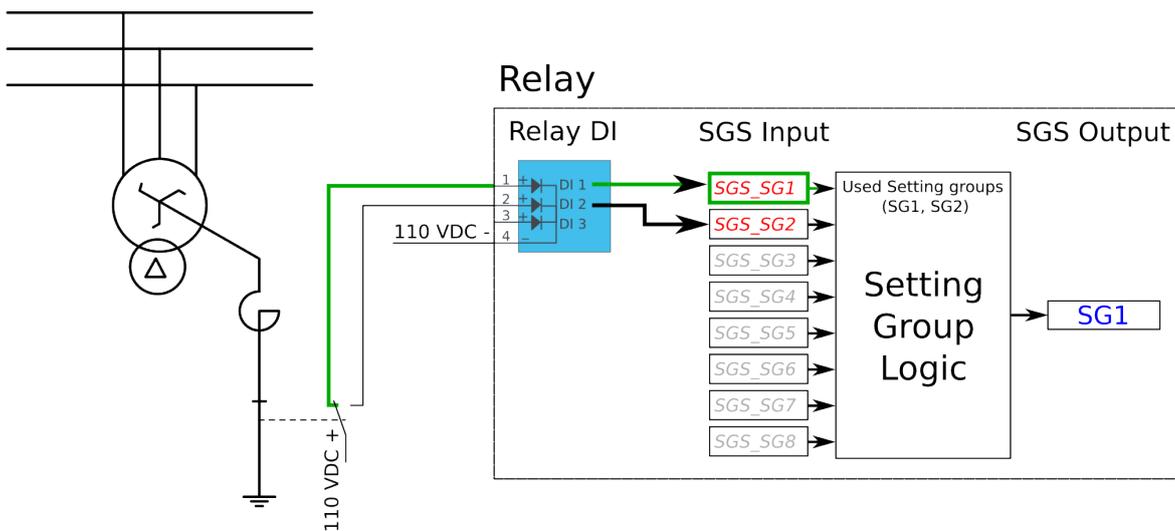
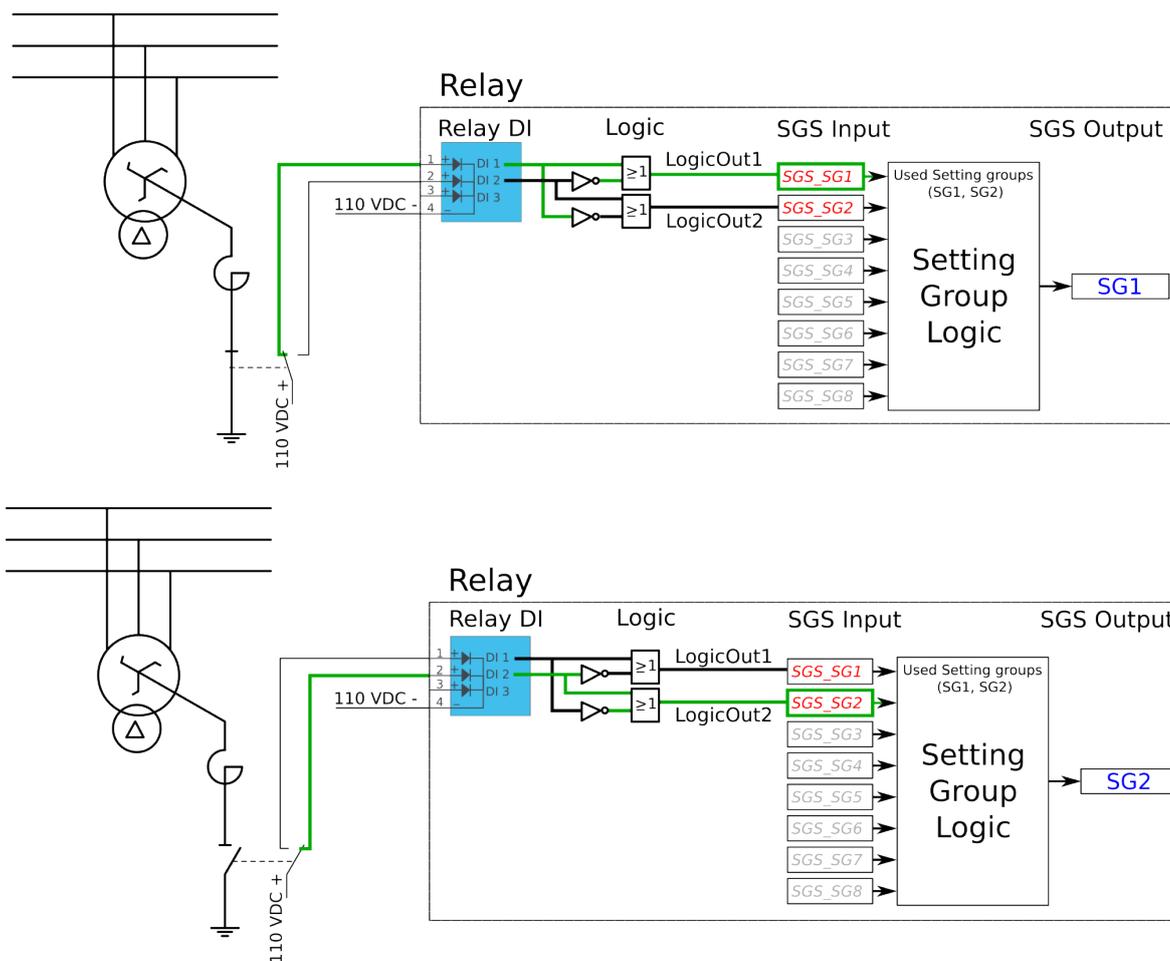


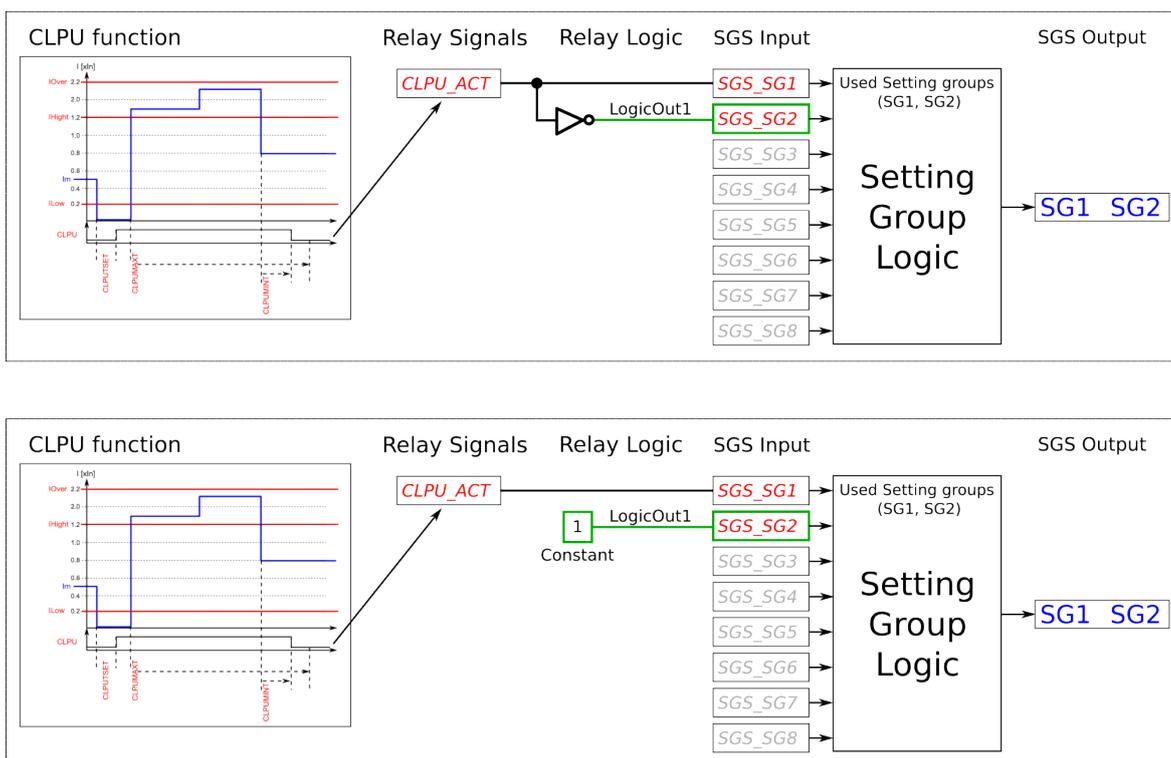
Figure. 5.4.1 - 86. Setting group control – two-wire connection from Petersen coil status with additional logic.



The images above depict a two-wire connection from the Petersen coil: the two images at the top show a direct connection, while the two images on the bottom include additional logic. With a two-wire connection the state of the Petersen coil can be monitored more securely. The additional logic ensures that a single wire loss will not affect the correct setting group selection.

The application-controlled setting group change can also be applied entirely from the relay's internal logics. For example, the setting group change can be based on the cold load pick-up function (see the image below).

Figure. 5.4.1 - 87. Entirely application-controlled setting group change with the cold load pick-up function.



In these examples the cold load pick-up function's output is used for the automatic setting group change. Similarly to this application, any combination of the signals available in the relay's database can be programmed to be used in the setting group selection logic.

As all these examples show, setting group selection with application control has to be built fully before they can be used for setting group control. The setting group does not change back to SG1 unless it is controlled back to SG1 by this application; this explains the inverted signal NOT as well as the use of logics in setting group control. One could also have SG2 be the primary SG, while the ON signal would be controlled by the higher priority SG1; this way the setting group would automatically return to SG2 after the automatic control is over.

Events

The setting group selection function block (abbreviated "SGS" in event block names) generates events from its controlling status, its applied input signals, enabling and disabling of setting groups, as well as unsuccessful control changes. The function does not have a register.

Table. 5.4.1 - 82. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|--------------|
| 4160 | 65 | SGS | 0 | SG2 Enabled |
| 4161 | 65 | SGS | 1 | SG2 Disabled |
| 4162 | 65 | SGS | 2 | SG3 Enabled |
| 4163 | 65 | SGS | 3 | SG3 Disabled |
| 4164 | 65 | SGS | 4 | SG4 Enabled |
| 4165 | 65 | SGS | 5 | SG4 Disabled |
| 4166 | 65 | SGS | 6 | SG5 Enabled |
| 4167 | 65 | SGS | 7 | SG5 Disabled |

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|---|
| 4168 | 65 | SGS | 8 | SG6 Enabled |
| 4169 | 65 | SGS | 9 | SG6 Disabled |
| 4170 | 65 | SGS | 10 | SG7 Enabled |
| 4171 | 65 | SGS | 11 | SG7 Disabled |
| 4172 | 65 | SGS | 12 | SG8 Enabled |
| 4173 | 65 | SGS | 13 | SG8 Disabled |
| 4174 | 65 | SGS | 14 | SG1 Request ON |
| 4175 | 65 | SGS | 15 | SG1 Request OFF |
| 4176 | 65 | SGS | 16 | SG2 Request ON |
| 4177 | 65 | SGS | 17 | SG2 Request OFF |
| 4178 | 65 | SGS | 18 | SG3 Request ON |
| 4179 | 65 | SGS | 19 | SG3 Request OFF |
| 4180 | 65 | SGS | 20 | SG4 Request ON |
| 4181 | 65 | SGS | 21 | SG4 Request OFF |
| 4182 | 65 | SGS | 22 | SG5 Request ON |
| 4183 | 65 | SGS | 23 | SG5 Request OFF |
| 4184 | 65 | SGS | 24 | SG6 Request ON |
| 4185 | 65 | SGS | 25 | SG6 Request OFF |
| 4186 | 65 | SGS | 26 | SG7 Request ON |
| 4187 | 65 | SGS | 27 | SG7 Request OFF |
| 4188 | 65 | SGS | 28 | SG8 Request ON |
| 4189 | 65 | SGS | 29 | SG8 Request OFF |
| 4190 | 65 | SGS | 30 | Remote Change SG Reqeuest ON |
| 4191 | 65 | SGS | 31 | Remote Change SG Request OFF |
| 4192 | 65 | SGS | 32 | Local Change SG Request ON |
| 4193 | 65 | SGS | 33 | Local Change SG Request OFF |
| 4194 | 65 | SGS | 34 | Force Change SG ON |
| 4195 | 65 | SGS | 35 | Force Change SG OFF |
| 4196 | 65 | SGS | 36 | SG Request Fail Not configured SG ON |
| 4197 | 65 | SGS | 37 | SG Request Fail Not configured SG OFF |
| 4198 | 65 | SGS | 38 | Force Request Fail Force ON |
| 4199 | 65 | SGS | 39 | Force Request Fail Force OFF |
| 4200 | 65 | SGS | 40 | SG Req. Fail Lower priority Request ON |
| 4201 | 65 | SGS | 41 | SG Req. Fail Lower priority Request OFF |
| 4202 | 65 | SGS | 42 | SG1 Active ON |
| 4203 | 65 | SGS | 43 | SG1 Active OFF |
| 4204 | 65 | SGS | 44 | SG2 Active ON |
| 4205 | 65 | SGS | 45 | SG2 Active OFF |

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|----------------|
| 4206 | 65 | SGS | 46 | SG3 Active ON |
| 4207 | 65 | SGS | 47 | SG3 Active OFF |
| 4208 | 65 | SGS | 48 | SG4 Active ON |
| 4209 | 65 | SGS | 49 | SG4 Active OFF |
| 4210 | 65 | SGS | 50 | SG5 Active ON |
| 4211 | 65 | SGS | 51 | SG5 Active OFF |
| 4212 | 65 | SGS | 52 | SG6 Active ON |
| 4213 | 65 | SGS | 53 | SG6 Active OFF |
| 4214 | 65 | SGS | 54 | SG7 Active ON |
| 4215 | 65 | SGS | 55 | SG7 Active OFF |
| 4216 | 65 | SGS | 56 | SG8 Active ON |
| 4217 | 65 | SGS | 57 | SG8 Active OFF |

5.4.2 Object control and monitoring

The object control and monitoring function takes care of both for circuit breakers and disconnectors. The monitoring and controlling are based on the statuses of the relay's configured digital inputs and outputs. The number of controllable and monitored objects in each relay depends on the device type and amount of digital inputs. One controllable object requires a minimum of two (2) output contacts. The status monitoring of one monitored object usually requires two (2) digital inputs. Alternatively, object status monitoring can be performed with a single digital input: the input's active state and its zero state (switched to 1 with a NOT gate in the Logic editor).

An object can be controlled manually or automatically. Manual control can be done by local control, or by remote control. Local manual control can be done by relays front panel (HMI) or by external push buttons connected to relays digital inputs. Manual remote control can be done through one of the various communication protocols available (Modbus, IEC101/103/104 etc.). The function supports the modes "Direct control" and "Select before execute" while controlled remotely. Automatic controlling can be done with functions like auto-reclosing function (ANSI 79).

Object control consists of the following:

- control logic
- control monitor
- output handler.

In addition to these main parts, the user can add object-related circuit breaker failure protection (CBFP; 50BF) and object wear monitoring in the object control block. These additional functions are not included in the basic version of the object control block.

The main outputs of the function are the OBJECT OPEN and OBJECT CLOSE control signals. Additionally, the function reports the monitored object's status and applied operations. The setting parameters are static inputs for the function, which can only be changed by the user in the function's setup phase.

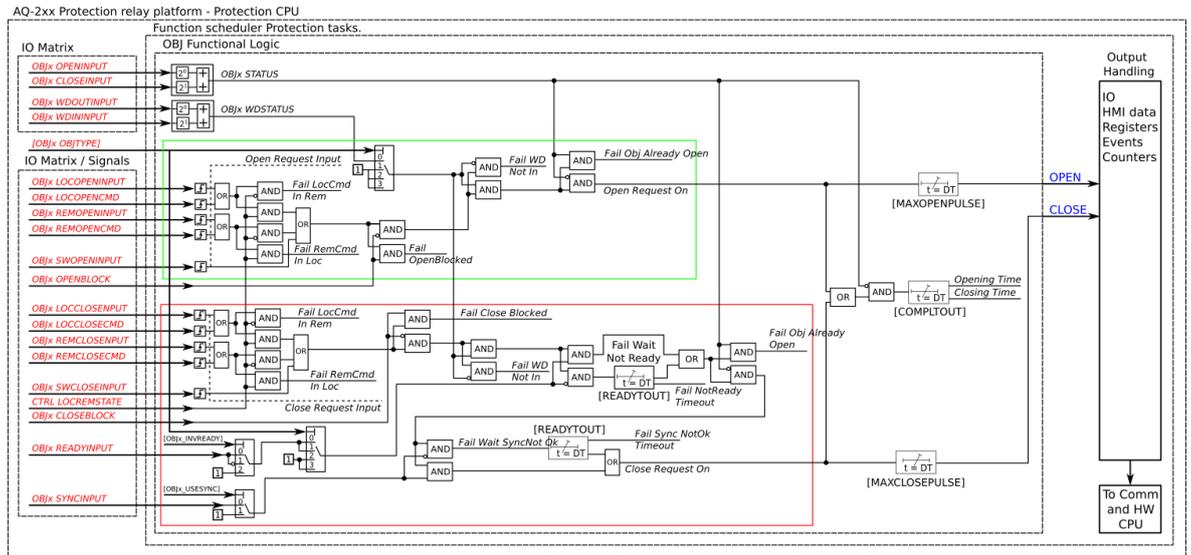
The inputs for the function are the following:

- digital input status indications (the OPEN and CLOSE status signals)
- blockings (if applicable)
- the OBJECT READY and SYNCHROCHECK monitor signals (if applicable).
- Withdrawable cart IN and OUT status signals (if applicable).

The function generates general time stamped ON/OFF events to the common event buffer from each of the two (2) output signals as well as several operational event signals. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for OPEN, CLOSE, OPEN FAILED, and CLOSE FAILED events.

The following figure presents a simplified function block diagram of the object control and monitoring function.

Figure. 5.4.2 - 88. Simplified function block diagram of the object control and monitoring function.



Settings

The following parameters help the user to define the object. The operation of the function varies based on these settings and the selected object type. The selected object type determines how much control is needed and which setting parameters are required to meet those needs.

Table. 5.4.2 - 83. Object set and status.

| Name | Range | Step | Default | Description |
|-------------------------|--|------|--------------------|--|
| Local/Remote status | 0: Local 1: Remote | - | 1: Remote | Displays the status of the relay's "local/remote" switch. Local controls cannot override the open and close commands while device is in "Remote" status. The remote controls cannot override the open and close commands while device is in "Local" status. |
| Object name | - | - | Objectx | The user-set name of the object, at maximum 32 characters long. |
| Object type | 0: Withdrawable circuit breaker 1: Circuit breaker 2: Disconnecter (MC) 3: Disconnecter (GND) | - | 1: Circuit breaker | The selection of the object type. This selection defines the number of required digital inputs for the monitored object. This affects the symbol displayed in the HMI and the monitoring of the circuit breaker. It also affects whether the withdrawable cart is in/out status is monitored. See the next table ("Object types") for a more detailed look at which functionalities each of the object types have. |
| Objectx Breaker status | 0: Intermediate 1: Open 2: Closed 3: Bad | - | - | Displays the status of breaker. Intermediate is displayed when neither of the status signals (open or close) are active. Bad status is displayed when both status signals (open and close) are active. |
| Objectx Withdraw status | 0: WDIntermediate 1: WDCartOut 2: WDCart In 3: WDBad 4: Not in use | - | - | Displays the status of circuit breaker cart. WDIntermediate is displayed when neither of the status signals (in or out) are active. WDBad status is displayed when both status signals (in and out) are active. If the selected object type is not set to "Withdrawable circuit breaker", this setting displays the "No in use" option. |

| Name | Range | Step | Default | Description |
|-------------------------------|--|------|---------------|--|
| Additional status information | 0: Open Blocked 1: Open Allowed 2: Close Blocked 3: Close Allowed 4: Object Ready 5: Object Not Ready 6: Sync Ok 7: Sync Not Ok | - | - | Displays additional information about the status of the object. |
| Use Synchrocheck | 0: Not in use 1: Synchrocheck in use | - | 0: Not in use | Selects whether the "Synchrocheck" condition is in use for the circuit breaker close command. If "In use" is selected the input chosen to "Sync.check status in" has to be active to be able to close circuit breaker. |
| Use Object ready | 0: Ready High 1: Ready Low 2: Not in use | - | 2: Not in use | Selects whether the "Object ready" condition is in use for the circuit breaker close command. If in use the signal connected to "Object ready status In" has to be high or low to be able to close the breaker (depending on "Ready High or Low" selection). |
| Open requests | 0...2 ³² -1 | 1 | - | Displays the number of successful "Open" requests. |
| Close requests | 0...2 ³² -1 | 1 | - | Displays the number of successful "Close" requests. |
| Open requests failed | 0...2 ³² -1 | 1 | - | Displays the number of failed "Open" requests. |
| Close requests failed | 0...2 ³² -1 | 1 | - | Displays the number of failed "Close" requests. |
| Clear statistics | 0: - 1: Clear | - | 0: - | Clears the request statistics, setting them back to zero (0). Automatically returns to "-" after the clearing is finished. |

Table. 5.4.2 - 84. Object types.

| Name | Functionalities | Description |
|------------------------------|---|--|
| Withdrawable circuit breaker | Breaker cart position Circuit breaker position Circuit breaker control Object ready check before closing breaker Synchrochecking before closing breaker Interlocks | The monitor and control configuration of the withdrawable circuit breaker. |
| Circuit breaker | Position indication Control Object ready check before closing breaker Synchrochecking before closing breaker Interlocks | The monitor and control configuration of the circuit breaker. |
| Disconnecter (MC) | Position indication Control | The position monitoring and control of the disconnecter. |
| Disconnecter (GND) | Position indication | The position indication of the earth switch. |

Table. 5.4.2 - 85. I/O.

| Signal | Range | Description |
|--|---|--|
| Objectx Open input ("Objectx Open Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored object's OPEN status. "1" refers to the active open state of the monitored object. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| Objectx Close input ("Objectx Close Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored object's CLOSE status. "1" refers to the active close state of the monitored object. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| WD Object In ("Withdrw.CartIn.Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored withdrawable object's position is IN. "1" means that the withdrawable object cart is in. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| WD Object Out ("Withdrw.CartOut.Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored withdrawable object's position is OUT. "1" means that the withdrawable object cart is pulled out. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| Object Ready (Objectx Ready status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. Indicates that status of the monitored object. "1" means that the object is ready and the spring is charged for a close command. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| Syncrocheck permission ("Sync.Check status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input or a synchrocheck function. "1" means that the synchrocheck conditions are met and the object can be closed. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| Objectx Open command ("Objectx Open Command") | OUT1...OUTx | The physical "Open" command pulse to the device's output relay. |
| Objectx Close command ("Objectx Close Command") | OUT1...OUTx | The physical "Close" command pulse to the device's output relay. |

Table. 5.4.2 - 86. Operation settings.

| Name | Range | Step | Default | Description |
|------------------------------------|-----------------|--------|---------|--|
| Breaker traverse time | 0.02...500.00 s | 0.02 s | 0.2 s | Determines the maximum time between open and close statuses when the breaker switches. If this set time is exceeded and both open and closed status inputs are active, the status "Bad" is activated in the "Objectx Breaker status" setting. If neither of the status inputs are active after this delay, the status "Intermediate" is activated. |
| Maximum Close command pulse length | 0.02...500.00 s | 0.02 s | 0.2 s | Determines the maximum length for a Close pulse from the output relay to the controlled object. If the object operates faster than this set time, the control pulse is reset and a status change is detected. |

| Name | Range | Step | Default | Description |
|-----------------------------------|-----------------|--------|---------|--|
| Maximum Open command pulse length | 0.02...500.00 s | 0.02 s | 0.2 s | Determines the maximum length for a Open pulse from the output relay to the controlled object. If the object operates faster than this set time, the control pulse is reset and a status change is detected. |
| Control termination timeout | 0.02...500.00 s | 0.02 s | 10 s | Determines the control pulse termination timeout. If the object has not changed its status in this given time the function will issue an error event and the control is ended. This parameter is common for both open and close commands. |
| Final trip pulse length | 0.00...500.00 s | 0.02 s | 0.2 s | Determines the length of the final trip pulse length. When the object has executed the final trip, this signal activates. If set to 0 s, the signal is continuous. If auto-recloser function controls the object, "final trip" signal is activated only when there are no automatic reclosings expected after opening the breaker. |

Table. 5.4.2 - 87. Control settings (DI and Application).

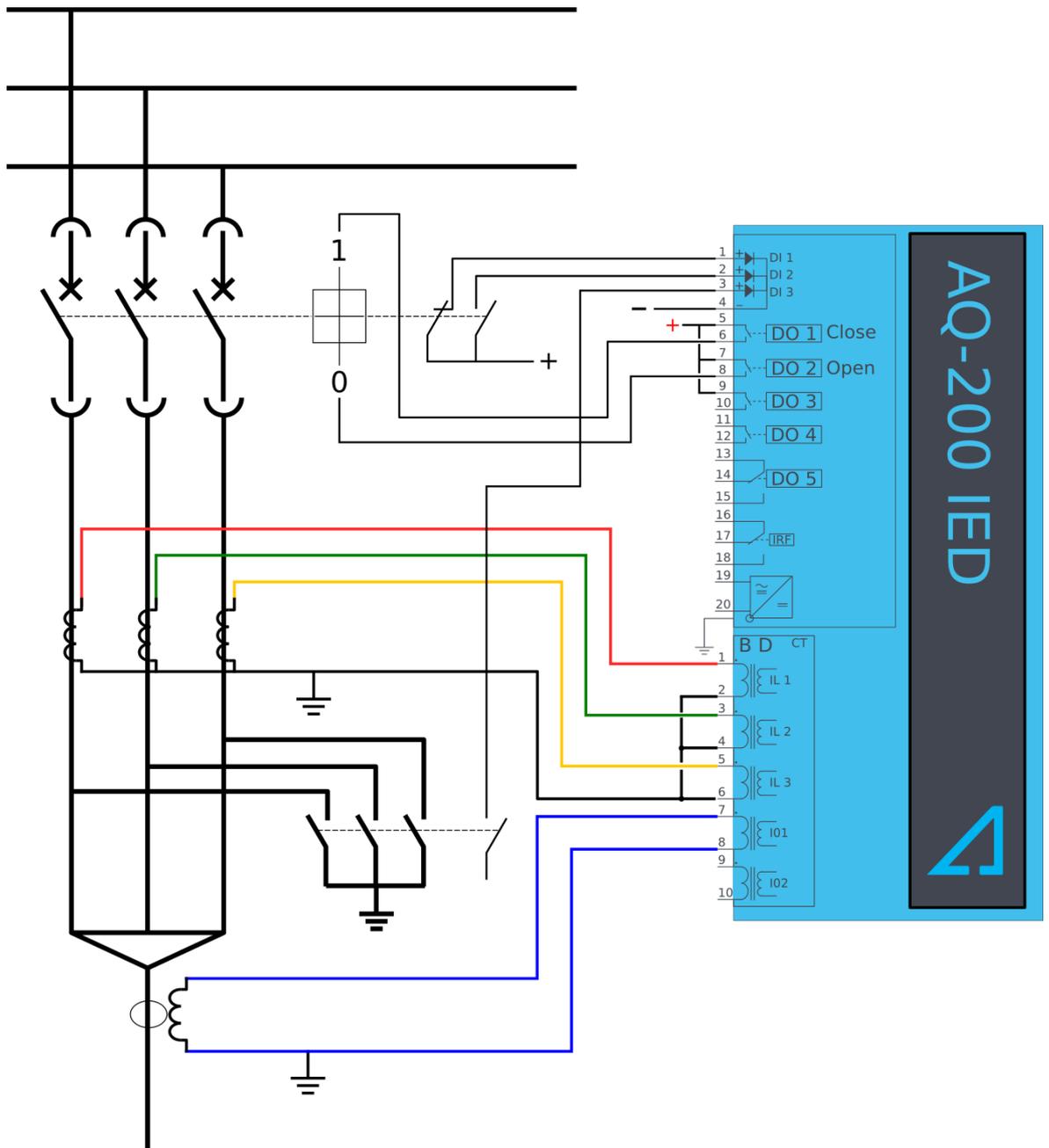
| Signal | Range | Description |
|------------------------------------|--|--|
| Access level for MIMIC control | 0: User 1: Operator 2: Configurator 3: Super user | Defines what level of access is required for MIMIC control. The default is the "Configurator" level. |
| Objectx LOCAL Close control input | Digital input or other logical signal selected by the user | The local Close command from a physical digital input (e.g. a push button). |
| Objectx LOCAL Open control input | Digital input or other logical signal selected by the user | The local Open command from a physical digital input (e.g. a push button). |
| Objectx REMOTE Close control input | Digital input or other logical signal selected by the user | The remote Close command from a physical digital input (e.g. RTU). |
| Objectx REMOTE Open control input | Digital input or other logical signal selected by the user | The remote Open command from a physical digital input (e.g. RTU). |
| Objectx Application Close | Digital input or other logical signal selected by the user | The Close command from the application. Can be any logical signal. |
| Objectx Application Open | Digital input or other logical signal selected by the user | The Open command from the application. Can be any logical signal. |

Blocking and interlocking

The interlocking and blocking conditions can be set for each controllable object, with Open and Close set separately. Blocking and interlocking can be based on any of the following: other object statuses, a software function or a digital input.

The image below presents an example of an interlock application, where the closed earthing switch interlocks the circuit breaker close command.

Figure. 5.4.2 - 89. Example of an interlock application.



In order for the blocking signal to be received on time, it has to reach the function 5 ms before the control command.

Events and registers

The object control and monitoring function (abbreviated "OBJ" in event block names) generates events and registers from the status changes in monitored signals as well as control command fails and operations. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The function registers its operation into the last twelve (12) time-stamped registers. The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.4.2 - 88. Event codes of the OBJ function instances 1 – 10.

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 2944 | 46 | OBJ1 | 0 | Object Intermediate |
| 2945 | 46 | OBJ1 | 1 | Object Open |
| 2946 | 46 | OBJ1 | 2 | Object Close |
| 2947 | 46 | OBJ1 | 3 | Object Bad |
| 2948 | 46 | OBJ1 | 4 | WD Intermediate |
| 2949 | 46 | OBJ1 | 5 | WD Out |
| 2950 | 46 | OBJ1 | 6 | WD In |
| 2951 | 46 | OBJ1 | 7 | WD Bad |
| 2952 | 46 | OBJ1 | 8 | Open Request ON |
| 2953 | 46 | OBJ1 | 9 | Open Request OFF |
| 2954 | 46 | OBJ1 | 10 | Open Command ON |
| 2955 | 46 | OBJ1 | 11 | Open Command OFF |
| 2956 | 46 | OBJ1 | 12 | Close Request ON |
| 2957 | 46 | OBJ1 | 13 | Close Request OFF |
| 2958 | 46 | OBJ1 | 14 | Close Command ON |
| 2959 | 46 | OBJ1 | 15 | Close Command OFF |
| 2960 | 46 | OBJ1 | 16 | Open Blocked ON |
| 2961 | 46 | OBJ1 | 17 | Open Blocked OFF |
| 2962 | 46 | OBJ1 | 18 | Close Blocked ON |
| 2963 | 46 | OBJ1 | 19 | Close Blocked OFF |
| 2964 | 46 | OBJ1 | 20 | Object Ready |
| 2965 | 46 | OBJ1 | 21 | Object Not Ready |
| 2966 | 46 | OBJ1 | 22 | Sync Ok |
| 2967 | 46 | OBJ1 | 23 | Sync Not Ok |
| 2968 | 46 | OBJ1 | 24 | Open Command Fail |
| 2969 | 46 | OBJ1 | 25 | Close Command Fail |
| 2970 | 46 | OBJ1 | 26 | Final trip ON |
| 2971 | 46 | OBJ1 | 27 | Final trip OFF |
| 3008 | 47 | OBJ2 | 0 | Object Intermediate |
| 3009 | 47 | OBJ2 | 1 | Object Open |
| 3010 | 47 | OBJ2 | 2 | Object Close |
| 3011 | 47 | OBJ2 | 3 | Object Bad |
| 3012 | 47 | OBJ2 | 4 | WD Intermediate |
| 3013 | 47 | OBJ2 | 5 | WD Out |
| 3014 | 47 | OBJ2 | 6 | WD In |
| 3015 | 47 | OBJ2 | 7 | WD Bad |
| 3016 | 47 | OBJ2 | 8 | Open Request ON |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 3017 | 47 | OBJ2 | 9 | Open Request OFF |
| 3018 | 47 | OBJ2 | 10 | Open Command ON |
| 3019 | 47 | OBJ2 | 11 | Open Command OFF |
| 3020 | 47 | OBJ2 | 12 | Close Request ON |
| 3021 | 47 | OBJ2 | 13 | Close Request OFF |
| 3022 | 47 | OBJ2 | 14 | Close Command ON |
| 3023 | 47 | OBJ2 | 15 | Close Command OFF |
| 3024 | 47 | OBJ2 | 16 | Open Blocked ON |
| 3025 | 47 | OBJ2 | 17 | Open Blocked OFF |
| 3026 | 47 | OBJ2 | 18 | Close Blocked ON |
| 3027 | 47 | OBJ2 | 19 | Close Blocked OFF |
| 3028 | 47 | OBJ2 | 20 | Object Ready |
| 3029 | 47 | OBJ2 | 21 | Object Not Ready |
| 3030 | 47 | OBJ2 | 22 | Sync Ok |
| 3031 | 47 | OBJ2 | 23 | Sync Not Ok |
| 3032 | 47 | OBJ2 | 24 | Open Command Fail |
| 3033 | 47 | OBJ2 | 25 | Close Command Fail |
| 3034 | 47 | OBJ2 | 26 | Final trip ON |
| 3035 | 47 | OBJ2 | 27 | Final trip OFF |
| 3072 | 48 | OBJ3 | 0 | Object Intermediate |
| 3073 | 48 | OBJ3 | 1 | Object Open |
| 3074 | 48 | OBJ3 | 2 | Object Close |
| 3075 | 48 | OBJ3 | 3 | Object Bad |
| 3076 | 48 | OBJ3 | 4 | WD Intermediate |
| 3077 | 48 | OBJ3 | 5 | WD Out |
| 3078 | 48 | OBJ3 | 6 | WD In |
| 3079 | 48 | OBJ3 | 7 | WD Bad |
| 3080 | 48 | OBJ3 | 8 | Open Request ON |
| 3081 | 48 | OBJ3 | 9 | Open Request OFF |
| 3082 | 48 | OBJ3 | 10 | Open Command ON |
| 3083 | 48 | OBJ3 | 11 | Open Command OFF |
| 3084 | 48 | OBJ3 | 12 | Close Request ON |
| 3085 | 48 | OBJ3 | 13 | Close Request OFF |
| 3086 | 48 | OBJ3 | 14 | Close Command ON |
| 3087 | 48 | OBJ3 | 15 | Close Command OFF |
| 3088 | 48 | OBJ3 | 16 | Open Blocked ON |
| 3089 | 48 | OBJ3 | 17 | Open Blocked OFF |
| 3090 | 48 | OBJ3 | 18 | Close Blocked ON |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 3091 | 48 | OBJ3 | 19 | Close Blocked OFF |
| 3092 | 48 | OBJ3 | 20 | Object Ready |
| 3093 | 48 | OBJ3 | 21 | Object Not Ready |
| 3094 | 48 | OBJ3 | 22 | Sync Ok |
| 3095 | 48 | OBJ3 | 23 | Sync Not Ok |
| 3096 | 48 | OBJ3 | 24 | Open Command Fail |
| 3097 | 48 | OBJ3 | 25 | Close Command Fail |
| 3098 | 48 | OBJ3 | 26 | Final trip ON |
| 3099 | 48 | OBJ3 | 27 | Final trip OFF |
| 3136 | 49 | OBJ4 | 0 | Object Intermediate |
| 3137 | 49 | OBJ4 | 1 | Object Open |
| 3138 | 49 | OBJ4 | 2 | Object Close |
| 3139 | 49 | OBJ4 | 3 | Object Bad |
| 3140 | 49 | OBJ4 | 4 | WD Intermediate |
| 3141 | 49 | OBJ4 | 5 | WD Out |
| 3142 | 49 | OBJ4 | 6 | WD In |
| 3143 | 49 | OBJ4 | 7 | WD Bad |
| 3144 | 49 | OBJ4 | 8 | Open Request ON |
| 3145 | 49 | OBJ4 | 9 | Open Request OFF |
| 3146 | 49 | OBJ4 | 10 | Open Command ON |
| 3147 | 49 | OBJ4 | 11 | Open Command OFF |
| 3148 | 49 | OBJ4 | 12 | Close Request ON |
| 3149 | 49 | OBJ4 | 13 | Close Request OFF |
| 3150 | 49 | OBJ4 | 14 | Close Command ON |
| 3151 | 49 | OBJ4 | 15 | Close Command OFF |
| 3152 | 49 | OBJ4 | 16 | Open Blocked ON |
| 3153 | 49 | OBJ4 | 17 | Open Blocked OFF |
| 3154 | 49 | OBJ4 | 18 | Close Blocked ON |
| 3155 | 49 | OBJ4 | 19 | Close Blocked OFF |
| 3156 | 49 | OBJ4 | 20 | Object Ready |
| 3157 | 49 | OBJ4 | 21 | Object Not Ready |
| 3158 | 49 | OBJ4 | 22 | Sync Ok |
| 3159 | 49 | OBJ4 | 23 | Sync Not Ok |
| 3160 | 49 | OBJ4 | 24 | Open Command Fail |
| 3161 | 49 | OBJ4 | 25 | Close Command Fail |
| 3162 | 49 | OBJ4 | 26 | Final trip ON |
| 3163 | 49 | OBJ4 | 27 | Final trip OFF |
| 3200 | 50 | OBJ5 | 0 | Object Intermediate |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 3201 | 50 | OBJ5 | 1 | Object Open |
| 3202 | 50 | OBJ5 | 2 | Object Close |
| 3203 | 50 | OBJ5 | 3 | Object Bad |
| 3204 | 50 | OBJ5 | 4 | WD Intermediate |
| 3205 | 50 | OBJ5 | 5 | WD Out |
| 3206 | 50 | OBJ5 | 6 | WD In |
| 3207 | 50 | OBJ5 | 7 | WD Bad |
| 3208 | 50 | OBJ5 | 8 | Open Request ON |
| 3209 | 50 | OBJ5 | 9 | Open Request OFF |
| 3210 | 50 | OBJ5 | 10 | Open Command ON |
| 3211 | 50 | OBJ5 | 11 | Open Command OFF |
| 3212 | 50 | OBJ5 | 12 | Close Request ON |
| 3213 | 50 | OBJ5 | 13 | Close Request OFF |
| 3214 | 50 | OBJ5 | 14 | Close Command ON |
| 3215 | 50 | OBJ5 | 15 | Close Command OFF |
| 3216 | 50 | OBJ5 | 16 | Open Blocked ON |
| 3217 | 50 | OBJ5 | 17 | Open Blocked OFF |
| 3218 | 50 | OBJ5 | 18 | Close Blocked ON |
| 3219 | 50 | OBJ5 | 19 | Close Blocked OFF |
| 3220 | 50 | OBJ5 | 20 | Object Ready |
| 3221 | 50 | OBJ5 | 21 | Object Not Ready |
| 3222 | 50 | OBJ5 | 22 | Sync Ok |
| 3223 | 50 | OBJ5 | 23 | Sync Not Ok |
| 3224 | 50 | OBJ5 | 24 | Open Command Fail |
| 3225 | 50 | OBJ5 | 25 | Close Command Fail |
| 3226 | 50 | OBJ5 | 26 | Final trip ON |
| 3227 | 50 | OBJ5 | 27 | Final trip OFF |
| 9600 | 150 | OBJ6 | 0 | Object Intermediate |
| 9601 | 150 | OBJ6 | 1 | Object Open |
| 9602 | 150 | OBJ6 | 2 | Object Close |
| 9603 | 150 | OBJ6 | 3 | Object Bad |
| 9604 | 150 | OBJ6 | 4 | WD Intermediate |
| 9605 | 150 | OBJ6 | 5 | WD Out |
| 9606 | 150 | OBJ6 | 6 | WD In |
| 9607 | 150 | OBJ6 | 7 | WD Bad |
| 9608 | 150 | OBJ6 | 8 | Open Request ON |
| 9609 | 150 | OBJ6 | 9 | Open Request OFF |
| 9610 | 150 | OBJ6 | 10 | Open Command ON |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 9611 | 150 | OBJ6 | 11 | Open Command OFF |
| 9612 | 150 | OBJ6 | 12 | Close Request ON |
| 9613 | 150 | OBJ6 | 13 | Close Request OFF |
| 9614 | 150 | OBJ6 | 14 | Close Command ON |
| 9615 | 150 | OBJ6 | 15 | Close Command OFF |
| 9616 | 150 | OBJ6 | 16 | Open Blocked ON |
| 9617 | 150 | OBJ6 | 17 | Open Blocked OFF |
| 9618 | 150 | OBJ6 | 18 | Close Blocked ON |
| 9619 | 150 | OBJ6 | 19 | Close Blocked OFF |
| 9620 | 150 | OBJ6 | 20 | Object Ready |
| 9621 | 150 | OBJ6 | 21 | Object Not Ready |
| 9622 | 150 | OBJ6 | 22 | Sync Ok |
| 9623 | 150 | OBJ6 | 23 | Sync Not Ok |
| 9624 | 150 | OBJ6 | 24 | Open Command Fail |
| 9625 | 150 | OBJ6 | 25 | Close Command Fail |
| 9626 | 150 | OBJ6 | 26 | Final trip ON |
| 9627 | 150 | OBJ6 | 27 | Final trip OFF |
| 9664 | 151 | OBJ7 | 0 | Object Intermediate |
| 9665 | 151 | OBJ7 | 1 | Object Open |
| 9666 | 151 | OBJ7 | 2 | Object Close |
| 9667 | 151 | OBJ7 | 3 | Object Bad |
| 9668 | 151 | OBJ7 | 4 | WD Intermediate |
| 9669 | 151 | OBJ7 | 5 | WD Out |
| 9670 | 151 | OBJ7 | 6 | WD In |
| 9671 | 151 | OBJ7 | 7 | WD Bad |
| 9672 | 151 | OBJ7 | 8 | Open Request ON |
| 9673 | 151 | OBJ7 | 9 | Open Request OFF |
| 9674 | 151 | OBJ7 | 10 | Open Command ON |
| 9675 | 151 | OBJ7 | 11 | Open Command OFF |
| 9676 | 151 | OBJ7 | 12 | Close Request ON |
| 9677 | 151 | OBJ7 | 13 | Close Request OFF |
| 9678 | 151 | OBJ7 | 14 | Close Command ON |
| 9679 | 151 | OBJ7 | 15 | Close Command OFF |
| 9680 | 151 | OBJ7 | 16 | Open Blocked ON |
| 9681 | 151 | OBJ7 | 17 | Open Blocked OFF |
| 9682 | 151 | OBJ7 | 18 | Close Blocked ON |
| 9683 | 151 | OBJ7 | 19 | Close Blocked OFF |
| 9684 | 151 | OBJ7 | 20 | Object Ready |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 9685 | 151 | OBJ7 | 21 | Object Not Ready |
| 9686 | 151 | OBJ7 | 22 | Sync Ok |
| 9687 | 151 | OBJ7 | 23 | Sync Not Ok |
| 9688 | 151 | OBJ7 | 24 | Open Command Fail |
| 9689 | 151 | OBJ7 | 25 | Close Command Fail |
| 9690 | 151 | OBJ7 | 26 | Final trip ON |
| 9691 | 151 | OBJ7 | 27 | Final trip OFF |
| 9728 | 152 | OBJ8 | 0 | Object Intermediate |
| 9729 | 152 | OBJ8 | 1 | Object Open |
| 9730 | 152 | OBJ8 | 2 | Object Close |
| 9731 | 152 | OBJ8 | 3 | Object Bad |
| 9732 | 152 | OBJ8 | 4 | WD Intermediate |
| 9733 | 152 | OBJ8 | 5 | WD Out |
| 9734 | 152 | OBJ8 | 6 | WD In |
| 9735 | 152 | OBJ8 | 7 | WD Bad |
| 9736 | 152 | OBJ8 | 8 | Open Request ON |
| 9737 | 152 | OBJ8 | 9 | Open Request OFF |
| 9738 | 152 | OBJ8 | 10 | Open Command ON |
| 9739 | 152 | OBJ8 | 11 | Open Command OFF |
| 9740 | 152 | OBJ8 | 12 | Close Request ON |
| 9741 | 152 | OBJ8 | 13 | Close Request OFF |
| 9742 | 152 | OBJ8 | 14 | Close Command ON |
| 9743 | 152 | OBJ8 | 15 | Close Command OFF |
| 9744 | 152 | OBJ8 | 16 | Open Blocked ON |
| 9745 | 152 | OBJ8 | 17 | Open Blocked OFF |
| 9746 | 152 | OBJ8 | 18 | Close Blocked ON |
| 9747 | 152 | OBJ8 | 19 | Close Blocked OFF |
| 9748 | 152 | OBJ8 | 20 | Object Ready |
| 9749 | 152 | OBJ8 | 21 | Object Not Ready |
| 9750 | 152 | OBJ8 | 22 | Sync Ok |
| 9751 | 152 | OBJ8 | 23 | Sync Not Ok |
| 9752 | 152 | OBJ8 | 24 | Open Command Fail |
| 9753 | 152 | OBJ8 | 25 | Close Command Fail |
| 9754 | 152 | OBJ8 | 26 | Final trip ON |
| 9755 | 152 | OBJ8 | 27 | Final trip OFF |
| 9792 | 153 | OBJ9 | 0 | Object Intermediate |
| 9793 | 153 | OBJ9 | 1 | Object Open |
| 9794 | 153 | OBJ9 | 2 | Object Close |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 9795 | 153 | OBJ9 | 3 | Object Bad |
| 9796 | 153 | OBJ9 | 4 | WD Intermediate |
| 9797 | 153 | OBJ9 | 5 | WD Out |
| 9798 | 153 | OBJ9 | 6 | WD In |
| 9799 | 153 | OBJ9 | 7 | WD Bad |
| 9800 | 153 | OBJ9 | 8 | Open Request ON |
| 9801 | 153 | OBJ9 | 9 | Open Request OFF |
| 9802 | 153 | OBJ9 | 10 | Open Command ON |
| 9803 | 153 | OBJ9 | 11 | Open Command OFF |
| 9804 | 153 | OBJ9 | 12 | Close Request ON |
| 9805 | 153 | OBJ9 | 13 | Close Request OFF |
| 9806 | 153 | OBJ9 | 14 | Close Command ON |
| 9807 | 153 | OBJ9 | 15 | Close Command OFF |
| 9808 | 153 | OBJ9 | 16 | Open Blocked ON |
| 9809 | 153 | OBJ9 | 17 | Open Blocked OFF |
| 9810 | 153 | OBJ9 | 18 | Close Blocked ON |
| 9811 | 153 | OBJ9 | 19 | Close Blocked OFF |
| 9812 | 153 | OBJ9 | 20 | Object Ready |
| 9813 | 153 | OBJ9 | 21 | Object Not Ready |
| 9814 | 153 | OBJ9 | 22 | Sync Ok |
| 9815 | 153 | OBJ9 | 23 | Sync Not Ok |
| 9816 | 153 | OBJ9 | 24 | Open Command Fail |
| 9817 | 153 | OBJ9 | 25 | Close Command Fail |
| 9818 | 153 | OBJ9 | 26 | Final trip ON |
| 9819 | 153 | OBJ9 | 27 | Final trip OFF |
| 9856 | 154 | OBJ10 | 0 | Object Intermediate |
| 9857 | 154 | OBJ10 | 1 | Object Open |
| 9858 | 154 | OBJ10 | 2 | Object Close |
| 9859 | 154 | OBJ10 | 3 | Object Bad |
| 9860 | 154 | OBJ10 | 4 | WD Intermediate |
| 9861 | 154 | OBJ10 | 5 | WD Out |
| 9862 | 154 | OBJ10 | 6 | WD In |
| 9863 | 154 | OBJ10 | 7 | WD Bad |
| 9864 | 154 | OBJ10 | 8 | Open Request ON |
| 9865 | 154 | OBJ10 | 9 | Open Request OFF |
| 9866 | 154 | OBJ10 | 10 | Open Command ON |
| 9867 | 154 | OBJ10 | 11 | Open Command OFF |
| 9868 | 154 | OBJ10 | 12 | Close Request ON |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|--------------------|
| 9869 | 154 | OBJ10 | 13 | Close Request OFF |
| 9870 | 154 | OBJ10 | 14 | Close Command ON |
| 9871 | 154 | OBJ10 | 15 | Close Command OFF |
| 9872 | 154 | OBJ10 | 16 | Open Blocked ON |
| 9873 | 154 | OBJ10 | 17 | Open Blocked OFF |
| 9874 | 154 | OBJ10 | 18 | Close Blocked ON |
| 9875 | 154 | OBJ10 | 19 | Close Blocked OFF |
| 9876 | 154 | OBJ10 | 20 | Object Ready |
| 9877 | 154 | OBJ10 | 21 | Object Not Ready |
| 9878 | 154 | OBJ10 | 22 | Sync Ok |
| 9879 | 154 | OBJ10 | 23 | Sync Not Ok |
| 9880 | 154 | OBJ10 | 24 | Open Command Fail |
| 9881 | 154 | OBJ10 | 25 | Close Command Fail |
| 9882 | 154 | OBJ10 | 26 | Final trip ON |
| 9883 | 154 | OBJ10 | 27 | Final trip OFF |

Table. 5.4.2 - 89. Register content.

| Name | Description |
|------------------------------|--|
| Date and time | dd.mm.yyyy hh:mm:ss.mss |
| Event code | 2944-9883 Descr. |
| Recorded Object opening time | Time difference between the object receiving an "Open" command and the object receiving the "Open" status. |
| Recorded Object closing time | Time difference between the object receiving a "Close" command and object receiving the "Closed" status. |
| Object status | The status of the object. |
| WD status | The status of the withdrawable circuit breaker. |
| Open fail | The cause of an "Open" command's failure. |
| Close fail | The cause of a "Close" command's failure. |
| Open command | The source of an "Open" command. |
| Close command | The source of an "Open" command. |
| General status | The general status of the function. |

5.4.3 Indicator object monitoring

The indicator object monitoring function takes care of the status monitoring of disconnectors. The function's sole purpose is indication and does not therefore have any control functionality. To control circuit breakers and/or disconnectors, please use the Object control and monitoring function. The monitoring is based on the statuses of the configured relay's digital inputs. The number of monitored indicators in a relay depends on the device type and available inputs. The status monitoring of one monitored object usually requires two (2) digital inputs. Alternatively, object status monitoring can be performed with a single digital input: the input's active state and its zero state (switched to 1 with a NOT gate in the Logic editor).

The outputs of the function are the monitored indicator statuses (Open, Close, Intermediate and Bad). The setting parameters are static inputs for the function, which can only be changed by the use in the function's setup phase.

The inputs of the function are the binary status indications. The function generates general time stamped ON/OFF events to the common event buffer from each of the following signals: OPEN, CLOSE, BAD and INTERMEDIATE event signals. The time stamp resolution is 1 ms.

Settings

Function uses available hardware and software digital signal statuses. These input signals are also setting parameters for the function.

Table. 5.4.3 - 90. Indicator status.

| Name | Range | Default | Description |
|--|---|---------|---|
| Indicator name ("Ind. Name") | - | IndX | The user-set name of the object, at maximum 32 characters long. |
| IndicatorX Object status ("Ind.X Object Status") | 0: Intermediate 1: Open 2: Closed 3: Bad | - | Displays the status of the indicator object. Intermediate status is displayed when neither of the status conditions (open or close) are active. Bad status is displayed when both of the status conditions (open and close) are active. |

Table. 5.4.3 - 91. Indicator I/O.

| Signal | Range | Description |
|--|---|--|
| IndicatorX Open input ("Ind.X Open Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored indicator's OPEN status. "1" refers to the active "Open" state of the monitored indicator. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |
| IndicatorX Close input ("Ind.X Close Status In") | Digital input or other logical signal selected by the user (SWx) | A link to a physical digital input. The monitored indicator's CLOSE status. "1" refers to the active "Close" state of the monitored indicator. If IEC 61850 is enabled, GOOSE signals can be used for status indication. |

Events

The indicator object monitoring function (abbreviated "CIN" in event block names) generates events from the status changes in the monitored signals, including the continuous status indications. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

Table. 5.4.3 - 92. Event codes (instances 1 – 5).

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|--------------|
| 6656 | 104 | CIN1 | 0 | Intermediate |
| 6657 | 104 | CIN1 | 1 | Open |
| 6658 | 104 | CIN1 | 2 | Close |
| 6659 | 104 | CIN1 | 3 | Bad |
| 6720 | 105 | CIN2 | 0 | Intermediate |

| Event Number | Event channel | Event block name | Event Code | Description |
|--------------|---------------|------------------|------------|--------------|
| 6721 | 105 | CIN2 | 1 | Open |
| 6722 | 105 | CIN2 | 2 | Close |
| 6723 | 105 | CIN2 | 3 | Bad |
| 6784 | 106 | CIN3 | 0 | Intermediate |
| 6785 | 106 | CIN3 | 1 | Open |
| 6786 | 106 | CIN3 | 2 | Close |
| 6787 | 106 | CIN3 | 3 | Bad |
| 6848 | 107 | CIN4 | 0 | Intermediate |
| 6849 | 107 | CIN4 | 1 | Open |
| 6850 | 107 | CIN4 | 2 | Close |
| 6851 | 107 | CIN4 | 3 | Bad |
| 6912 | 108 | CIN5 | 0 | Intermediate |
| 6913 | 108 | CIN5 | 1 | Open |
| 6914 | 108 | CIN5 | 2 | Close |
| 6915 | 108 | CIN5 | 3 | Bad |

5.4.4 Milliampere output control

The milliamp current loop is the prevailing process control signal in many industries. It is an ideal method of transferring process information because a current does not change as it travels from a transmitter to a receiver. It is also much more simple and cost-effective.

The benefits of 4...20 mA loops:

- the dominant standard in many industries
- the simplest option to connect and configure
- uses less wiring and connections than other signals, thus greatly reducing initial setup costs
- good for travelling long distances, as current does not degrade over long connections like voltage does
- less sensitive to background electrical noise
- detects a fault in the system incredibly easily since 4 mA is equal to 0 % output.

Milliampere (mA) outputs

AQ-200 series supports up to two (2) independent mA option cards. Each card has four (4) mA output channels and one (1) mA input channel. If the device has an mA option card, enable mA outputs at *Control* → *Device IO* → *mA outputs*. The outputs are activated in groups of two: channels 1 and 2 are activated together, as are channels 3 and 4 (see the image below).

Figure. 5.4.4 - 90. Activating mA output channels.

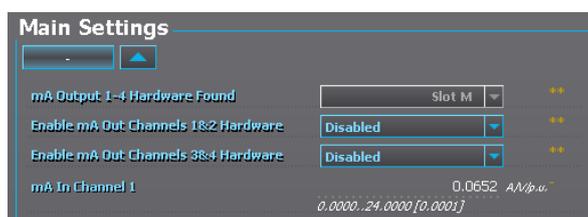


Table. 5.4.4 - 93. Main settings (output channels).

| Name | | Range | Default | Description |
|------------------|-----------------------------------|---------------------------|-------------|---|
| mA option card 1 | Enable mA output channels 1 and 2 | 0: Disabled 1: Enabled | 0: Disabled | Enables and disables the outputs of the mA output card 1. |
| | Enable mA output channels 3 and 4 | | | |
| mA option card 2 | Enable mA output channels 5 and 6 | 0: Disabled 1: Enabled | 0: Disabled | Enables and disables the outputs of the mA output card 2. |
| | Enable mA output channels 7 and 8 | | | |

Table. 5.4.4 - 94. Settings for mA output channels.

| Name | Range | Step | Default | Description |
|---|--|----------|---|--|
| Enable mA output channel | 0: Disabled 1: Enabled | - | 0: Disabled | Enables and disables the selected mA output channel. If the channel is disabled, the channel settings are hidden. |
| Magnitude selection for mA output channel | 0: Currents 1: Voltages 2: Powers 3: Impedance and admittance 4: Other | - | 0: Currents | Defines the measurement category that is used for mA output control. |
| Magnitude of mA output channel | (dependent on the measurement category selection) | - | (dependent on the measurement category selection) | Defines the measurement magnitude used for mA output control. The available measurements depend on the selection of the "Magnitude selection for mA output channel" parameter. |
| Input value 1 | $-10^7 \dots 10^7$ | 0.001 | 0 | The first input point in the mA output control curve. |
| Scaled mA output value 1 | 0.0000...24.0000mA | 0.0001mA | 0mA | The mA output value when the measured value is equal to or less than Input value 1. |
| Input value 2 | $-10^7 \dots 10^7$ | 0.001 | 1 | The second input point in the mA output control curve. |
| Scaled mA output value 2 | 0.0000...24.0000mA | 0.0001mA | 0mA | The mA output value when the measured value is equal to or greater than Input value 2. |

Figure. 5.4.4 - 91. Example of the effects of mA output channel settings.

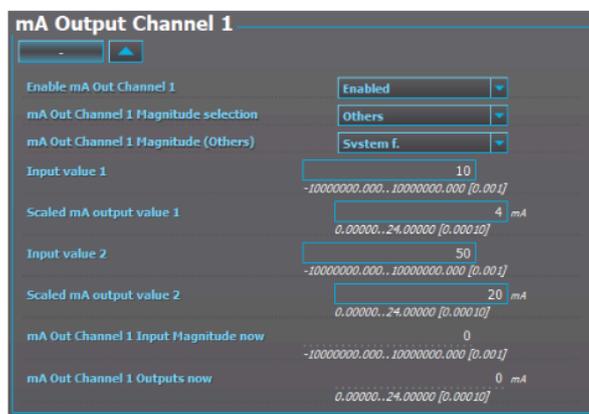
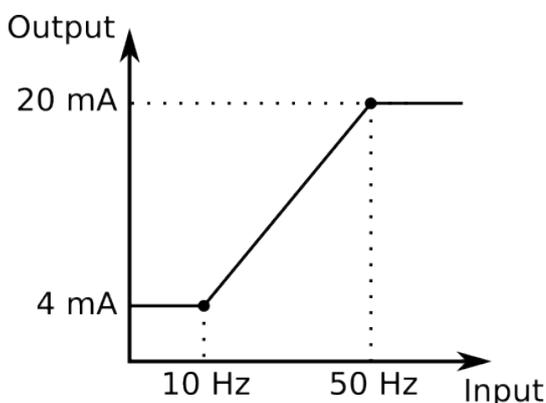


Table. 5.4.4 - 95. Hardware indications.

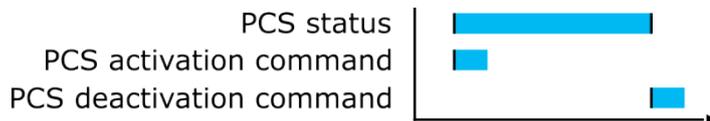
| Name | Range | Step | Description |
|--------------------------------------|---|------|---|
| Hardware in mA output channels 1...4 | 0: None 1: Slot A 2: Slot B 3: Slot C 4: Slot D 5: Slot E 6: Slot F | - | Indicates the option card slot where the mA output card is located. |
| Hardware in mA output channels 5...8 | | | |

Table. 5.4.4 - 96. Measurement values reported by mA output cards.

| Name | Range | Step | Description |
|------------------------------------|--------------------|----------|---|
| mA in Channel 1 | 0.0000...24.0000mA | 0.0001mA | Displays the measured mA value of the selected input channel. |
| mA in Channel 2 | | | |
| mA Out Channel Input Magnitude now | $-10^7 \dots 10^7$ | 0.001 | Displays the input value of the selected mA output channel at that moment. |
| mA Out Channel Outputs now | 0.0000...24.0000mA | 0.0001mA | Displays the output value of the selected mA output channel at that moment. |

5.4.5 Programmable control switch

The programmable control switch is a control function that controls its binary output signal. This output signal can be controlled locally from the relay's mimic (displayed as a box in the mimic) or remotely from the RTU. The main purpose of programmable control switches is to block or enable function and to change function properties by changing the setting group. However, this binary signal can also be used for any number of other purposes, just like all other binary signals. Once a programmable control switch has been activated or disabled, it remains in that state until given a new command to switch to the opposite state (see the image below). The switch cannot be controlled by an auxiliary input, such as digital inputs or logic signals; it can only be controlled locally (mimic) or remotely (RTU).



Settings.

These settings can be accessed at *Control* → *Device I/O* → *Programmable control switch*.

Table. 5.4.5 - 97. Settings.

| Name | Range | Default | Description |
|--------------------------------|--|-----------------|--|
| Switch name | - | Switchx | The user-settable name of the selected switch. The name can be up to 32 characters long. |
| Access level for Mimic control | 0: User 1: Operator 2: Configurator 3: Super user | 2: Configurator | Determines which access level is required to be able to control the programmable control switch via the Mimic. |

Events

The programmable control switch function (abbreviated "PCS" in event block names) generates events from status changes. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers five (5) independent switches.

Table. 5.4.5 - 98. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|--------------|
| 384 | 6 | PCS | 0 | Switch 1 ON |
| 385 | 6 | PCS | 1 | Switch 1 OFF |
| 386 | 6 | PCS | 2 | Switch 2 ON |
| 387 | 6 | PCS | 3 | Switch 2 OFF |
| 388 | 6 | PCS | 4 | Switch 3 ON |
| 389 | 6 | PCS | 5 | Switch 3 OFF |
| 390 | 6 | PCS | 6 | Switch 4 ON |
| 391 | 6 | PCS | 7 | Switch 4 OFF |
| 392 | 6 | PCS | 8 | Switch 5 ON |
| 393 | 6 | PCS | 9 | Switch 5 OFF |

5.4.6 Analog input scaling curves

Sometimes when measuring with RTD inputs, milliampere inputs and digital inputs the measurement might be inaccurate because the signal coming from the source is inaccurate. One common example of this is tap changer location indication signal not changing linearly from step to step. If the output difference between the steps are not equal to each other, measuring the incoming signal accurately is not enough. "Analog input scaling curves" menu can be used to take these inaccuracies into account.

Analog input scaling curve settings can be found at *Measurement* → *AI(mA, DI volt) scaling* menu.

Currently following measurements can be scaled with analog input scaling curves:

- RTD inputs and mA inputs in "RTD & mA input" option cards
- mA inputs in "mA output & mA input" option cards
- Digital input voltages

Table. 5.4.6 - 99. Main settings (input channel).

| Name | Range | Step | Default | Description |
|----------------------|-----------------------------|------|----------------|---|
| Analog input scaling | 0: Disabled 1: Activated | - | 0: Disabled | Enables and disables the input. |
| Scaling curve 1...4 | 0: Disabled 1: Activated | - | 0: Disabled | Enables and disables the scaling curve and the input measurement. |

| Name | Range | Step | Default | Description |
|---|---|---------|----------------|---|
| Curve 1...4 input signal select | 0: S7 mA Input 1: S8 mA Input 2: S15 mA Input 3: S16 mA Input 4: DI1 Voltage ... 23: DI20 Voltage 24: RTD S1 Resistance ... 39: RTD S16 Resistance 40: mA In 1 (I card 1) 41: mA In 2 (I card 2) | - | 0: S7 mA Input | Defines the measurement used by scaling curve. |
| Curve 1...4 input signal filtering | 0: No 1: Yes | - | 0: No | Enables calculation of the average of received signal. |
| Curve 1...4 input signal filter time constant | 0.005...3800.000 s | 0.005 s | 1 s | Time constant for input signal filtering. This parameter is visible when "Curve 1...4 input signal filtering" has been set to "Yes". |
| Curve 1...4 input signal out of range set | 0: No 1: Yes | - | 0: No | Enables out of range signals. If input signal is out of minimum and maximum limits, "ASC1...4 input out of range" signal is activated. |
| Curve1...4 input minimum | -1 000 000.00...1 000 000.00 | 0.00001 | 0 | Defines the minimum input of the curve. If input is below the set limit, "ASC1...4 input out of range" is activated. |
| Curve 1...4 input | -1 000 000.00...1 000 000.00 | 0.00001 | - | Displays the input measurement received by the curve. |
| Curve1...4 input maximum | -1 000 000.00...1 000 000.00 | 0.00001 | 0 | Defines the maximum input of the curve. If input is above the set limit, "ASC1...4 input out of range" is activated. |
| Curve1...4 output | -1 000 000.00...1 000 000.00 | 0.00001 | - | Displays the output of the curve. |

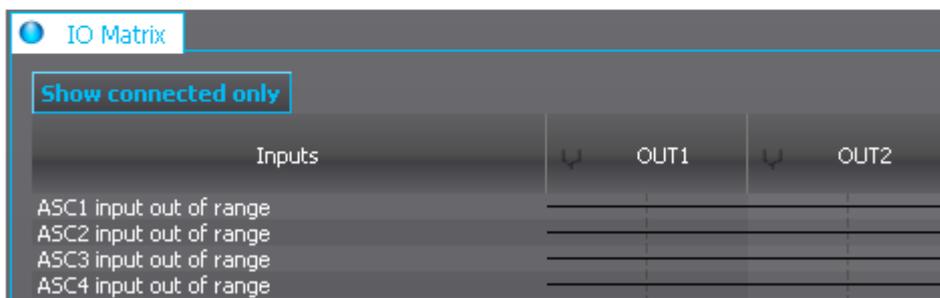
The input signal filter (see the image below) calculates the average of received signals according to the set time constant. This is why rapid changes and disturbances (such as fast spikes) are smothered.



The Nyquist rate states that the filter time constant must be at least double the period time of the disturbance process signal. For example, the value for the filter time constant is 2 seconds for a 1 second period time of a disturbance oscillation.

$$H(s) = \frac{Wc}{s+Wc} = \frac{1}{1+s/Wc}$$

When the curve signal is out of range, it activates the "ASC1...4 input out of range" signal, which can be used inside logic or with other relay functions. The signal can be assigned directly to an output relay or to an LED in the I/O matrix. The "Out of range" signal is activated, when the measured signal falls below the set input minimum limit, or when it exceeds the input maximum limit. The "Out of range" signal is very useful when e.g. a 4...20 mA input signal is used (see the image below).



If for some reason the input signal is lost, the value is fixed to the last actual measured cycle value. The value does not go down to the minimum if it has been something else at the time of the signal breaking.

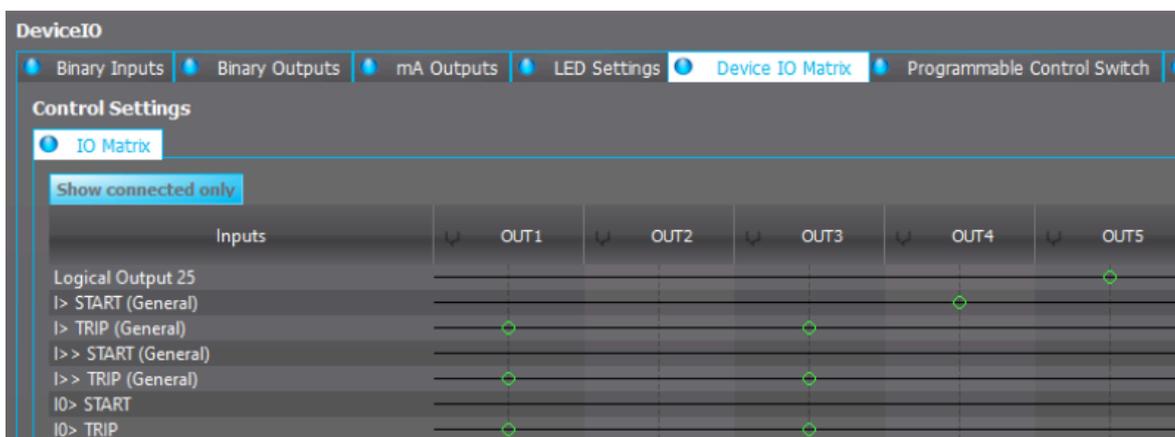
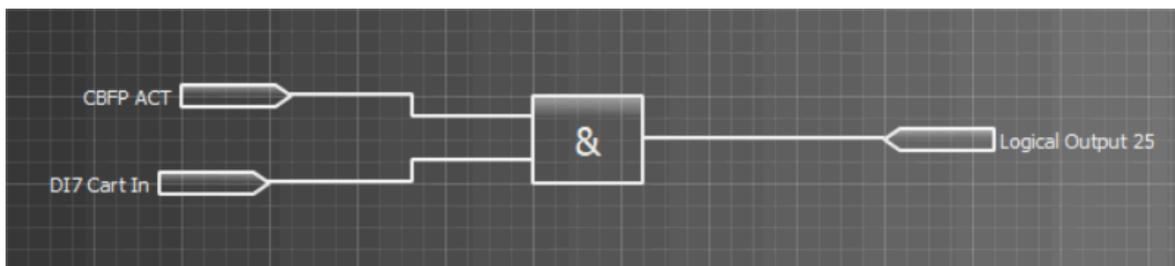
Table. 5.4.6 - 100. Output settings and indications.

| Name | Range | Step | Default | Description |
|--------------------------|---|----------|-------------------|--|
| Curve 1...4 update cycle | 5...10 000ms | 5ms | 150ms | Defines the length of the input measurement update cycle. If the user wants a fast operation, this setting should be fairly low. |
| Scaled value handling | 0: Floating point 1: Integer out (Floor) 2: Integer (Ceiling) 3: Integer (Nearest) | - | 0: Floating point | Rounds the milliampere signal output as selected. |
| Input value 1 | 0...4000 | 0.000 01 | 0 | The measured input value at Curve Point 1. |
| Scaled output value 1 | -10 ⁷ ...10 ⁷ | 0.000 01 | 0 | Scales the measured milliampere signal at Point 1. |
| Input value 2 | 0...4000 | 0.000 01 | 1 | The measured input value at Curve Point 2. |
| Scaled output value 1 | -10 ⁷ ...10 ⁷ | 0.000 01 | 0 | Scales the measured milliampere signal at Point 2. |
| Add curvepoint 3...20 | 0: Not used 1: Used | - | 0: Not used | Allows the user to create their own curve with up to twenty (20) curve points, instead of using a linear curve between two points. |

5.4.7 Logical outputs

Logical outputs are used for sending binary signals out from a logic that has been built in the logic editor. Logical signals can be used for blocking functions, changing setting groups, controlling digital outputs, activating LEDs, etc. The status of logical outputs can also be reported to a SCADA system. The figure below presents a logic output example where a signal from the circuit breaker failure protection function controls the digital output relay number 5 ("OUT5") when the circuit breaker's cart status is "In". The image above is from the logic editor and the image below from AQtivate 200.

Figure. 5.4.7 - 92. Logic output example.



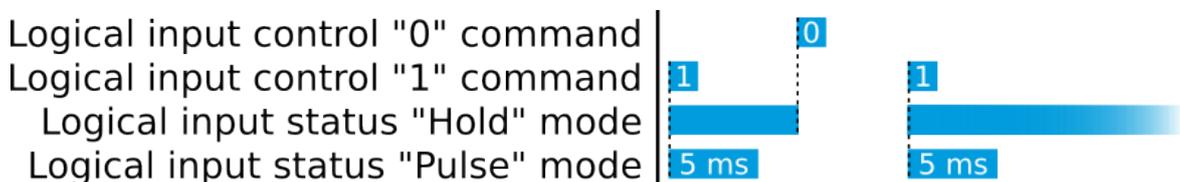
5.4.8 Logical inputs

Logical inputs are binary signals that a user can control manually to change the behavior of the AQ-200 unit or to give direct control commands. Logical inputs can be controlled with a virtual switch built in the mimic and from a SCADA system (IEC 61850, Modbus, IEC 101, etc.). Logical inputs are volatile signals: their status will always return to "0" when the AQ-200 device is rebooted.

Logical inputs have two modes available: Hold and Pulse. When a logical input which has been set to "Hold" mode is controlled to "1", the input will switch to status "1" and it stays in that status until it is given a control command to go to status "0" or until the device is rebooted. When a logical input which has been set to "Pulse" mode is controlled to "1", the input will switch to status "1" and return back to "0" after 5 ms.

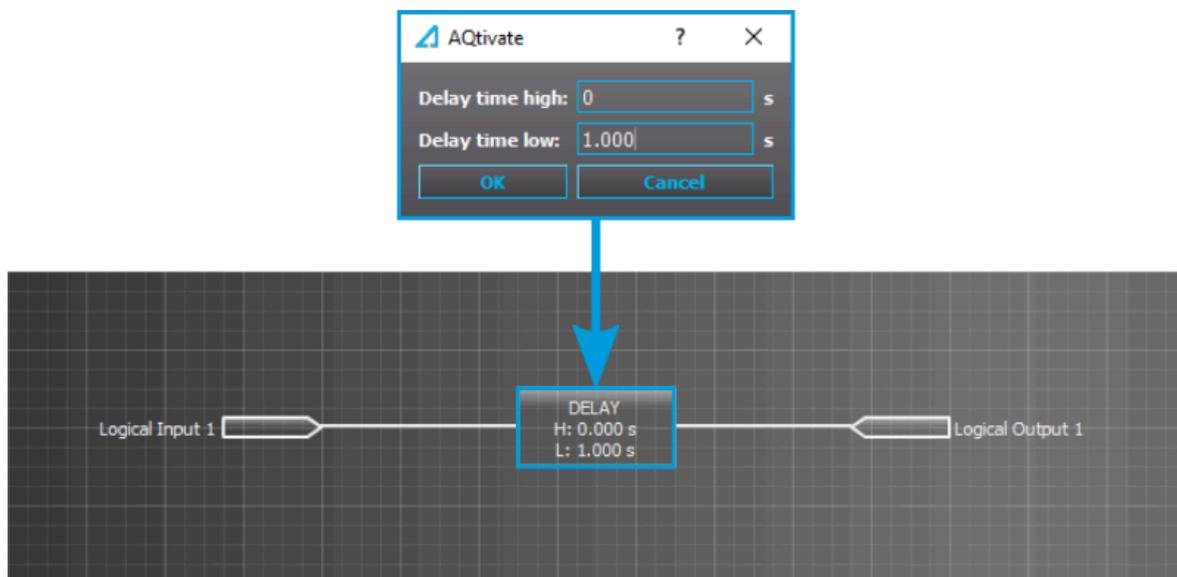
The figure below presents the operation of a logical input in Hold mode and in Pulse mode.

Figure. 5.4.8 - 93. Operation of logical input in "Hold" and "Pulse" modes.



A logical input pulse can also be extended by connecting a DELAY-low gate to a logical output, as has been done in the example figure below.

Figure. 5.4.8 - 94. Extending a logical input pulse.



Logical input control "1" command
 Logical input status "Pulse" mode
 Logical output status

| |
|-------------------|
| 1 |
| 5 ms |
| Delay low setting |

5.5 Monitoring functions

5.5.1 Total harmonic distortion (THD)

The total harmonic distortion (THD) function is used for monitoring the content of the current harmonic. The THD is a measurement of the harmonic distortion present, and it is defined as the ratio between the sum of all harmonic components' powers and the power of the fundamental frequency (RMS).

Harmonics can be caused by different sources in electric networks such as electric machine drives, thyristor controls, etc. The function's monitoring of the currents can be used to alarm of the harmonic content rising too high; this can occur when there is an electric quality requirement in the protected unit, or when the harmonics generated by the process need to be monitored.

The function constantly measures the phase and residual current magnitudes as well as the harmonic content of the monitored signals up to the 31st harmonic component. When the function is activated, the measurements are also available for the mimic and the measurement views in the HMI carousel. The user can also set the alarming limits for each measured channel if the application so requires.

The monitoring of the measured signals can be selected to be based either on an amplitude ratio or on the above-mentioned power ratio. The difference is in the calculation formula (as shown below):

Figure. 5.5.1 - 95. THD calculation formulas.

$$THD_P = \frac{I_{x2}^2 + I_{x3}^2 + I_{x4}^2 \dots I_{x31}^2}{I_{x1}^2}$$

, where
 I = measured current,
 x = measurement input,
 n = harmonic number

$$THD_A = \sqrt{\frac{I_{x2}^2 + I_{x3}^2 + I_{x4}^2 \dots I_{x31}^2}{I_{x1}^2}}$$

, where
 I = measured current,
 x = measurement input,
 n = harmonic number

While both of these formulas exist, the power ratio (THD_P) is recognized by the IEEE, and the amplitude ratio (THD_A) is recognized by the IEC.

The blocking signal and the setting group selection control the operating characteristics of the function during normal operation, i.e. the user or user-defined logic can change function parameters while the function is running. This only applies if the alarming is activated.

The outputs of the function are the START and ALARM ACT signals for the phase current ("THDPH") and the residual currents ("THDI01" and "THDI02") as well as BLOCKED signals. The function uses a total of eight (8) separate setting groups which can be selected from one common source.

The operational logic consists of the following:

- input magnitude processing
- threshold comparator
- block signal chec
- time delay characteristics
- output processing.

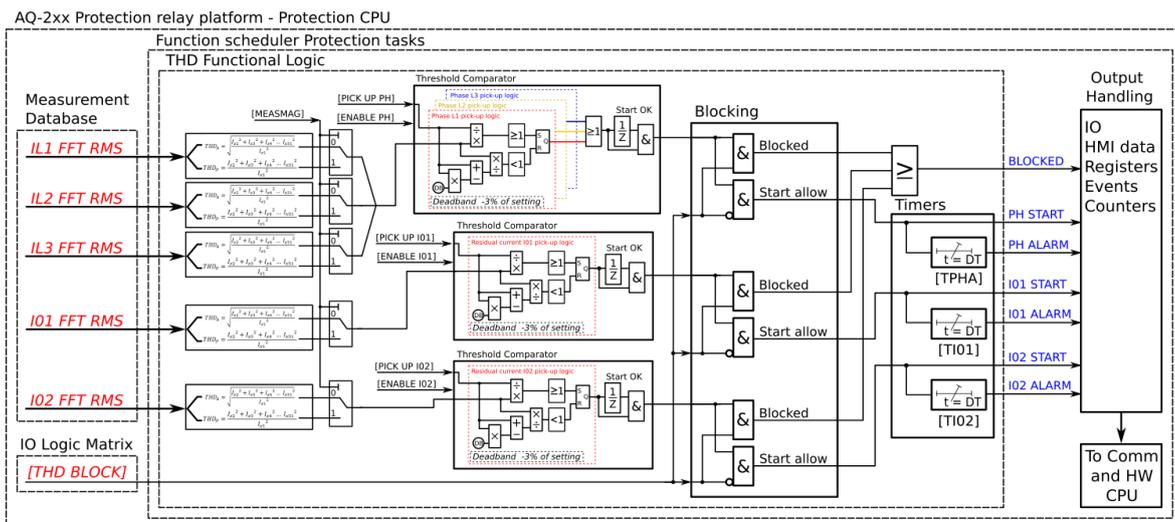
The inputs of the function are the following:

- setting parameters
- digital inputs and logic signals
- measured and pre-processed current magnitudes

The function outputs can be used for direct I/O controlling and user logic programming. The function generates general time-stamped ON/OFF events to the common event buffer from each of the seven (7) output signals. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, ALARM ACT and BLOCKED events.

The following figure presents a simplified function block diagram of the total harmonic distortion monitor function.

Figure. 5.5.1 - 96. Simplified function block diagram of the total harmonic distortion monitor function.



Measured input

The function block uses analog current measurement values. The function always uses FFT measurement of the whole harmonic specter of 32 components from each measured current channel. From these measurements the function calculates either the amplitude ratio or the power ratio. A -20 ms averaged value of the selected magnitude is used for pre-fault data registering.

Table. 5.5.1 - 101. Measurement inputs of the total harmonic distortion monitor function.

| Signal | Description | Time base |
|--------|---|-----------|
| IL1FFT | FFT measurement of phase L1 (A) current | 5ms |
| IL2FFT | FFT measurement of phase L2 (B) current | 5ms |
| IL3FFT | FFT measurement of phase L3 (C) current | 5ms |
| I01FFT | FFT measurement of residual I01 current | 5ms |
| I02FFT | FFT measurement of residual I02 current | 5ms |

The selection of the calculation method is made with a setting parameter (common for all measurement channels).

General settings

The following general settings define the general behavior of the function. These settings are static i.e. it is not possible to change them by editing the setting group.

Table. 5.5.1 - 102. General settings.

| Name | Range | Step | Default | Description |
|-----------------------|--------------------------|------|--------------|---|
| Measurement magnitude | 1: Amplitude 2: Power | - | 1: Amplitude | Defines which available measured magnitude the function uses. |

Pick-up

The $Phase_{THD}$, $I01_{THD}$ and $I02_{THD}$ setting parameters control the the pick-up and activation of the function. They define the maximum allowed measured current before action from the function. Before the function activates alarm signals, their corresponding pick-up elements need to be activated with the setting parameters *Enable phase THD alarm*, *Enable I01 THD alarm* and *Enable I02 THD alarm*. The function constantly calculates the ratio between the setting values and the measured magnitude for each of the three phases. The reset ratio of 97 % is built into the function and is always relative to the setting value. The setting value is common for all measured phases. When the I_m exceeds the I_{set} value (in single, dual or all phases), it triggers the pick-up operation of the function.

Table. 5.5.1 - 103. Pick-up settings.

| Name | Range | Step | Default | Description |
|------------------------|---------------------------|-------|---------------|---|
| Enable phase THD alarm | 0: Enabled 1: Disabled | - | 0: Enabled | Enables and disables the THD alarm function from phase currents. |
| Enable I01 THD alarm | 0: Enabled 1: Disabled | - | 0: Enabled | Enables and disables the THD alarm function from residual current input I01. |
| Enable I02 THD alarm | 0: Enabled 1: Disabled | - | 0: Enabled | Enables and disables the THD alarm function from residual current input I02. |
| Phase THD pick-up | 0.10...100.00% | 0.01% | 10.00% | The pick-up setting for the THD alarm element from the phase currents. At least one of the phases' measured THD value has to exceed this setting in order for the alarm signal to activate. |
| I01 THD pick-up | 0.10...100.00% | 0.01% | 10.00% | The pick-up setting for the THD alarm element from the residual current I01. The measured THD value has to exceed this setting in order for the alarm signal to activate. |
| I02 THD pick-up | 0.10...100.00% | 0.01% | 10.00% | The pick-up setting for the THD alarm element from the residual current I02. The measured THD value has to exceed this setting in order for the alarm signal to activate. |

The pick-up activation of the function is not directly equal to the START signal generation of the function. The START signal is allowed if the blocking condition is not active.

Read-only parameters

The relay's *Info* page displays useful, real-time information on the state of the protection function. It is accessed either through the relay's HMI display, or through the setting tool software when it is connected to the relay and its Live Edit mode is active.

Table. 5.5.1 - 104. Information displayed by the function.

| Name | Range | Step | Description |
|---------------|---|------|---|
| THD condition | 0: Normal 1: Start 2: Alarm 3: Blocked | - | Displays status of the monitoring function. |

Function blocking

The block signal is checked in the beginning of each program cycle. The blocking signal is received from the blocking matrix in the function's dedicated input. If the blocking signal is not activated when the pick-up element activates, a START signal is generated and the function proceeds to the time characteristics calculation.

If the blocking signal is active when the pick-up element activates, a BLOCKED signal is generated and the function does not process the situation further. If the START function has been activated before the blocking signal, it resets and the release time characteristics are processed similarly to when the pick-up signal is reset.

The blocking of the function causes an HMI display event and a time-stamped blocking event with information of the startup current values and its fault type to be issued.

The blocking signal can also be tested in the commissioning phase by a software switch signal when the relay's testing mode "Enable stage forcing" is activated (*General* → *Device*).

The variables the user can set are binary signals from the system. The blocking signal needs to reach the device minimum of 5 ms before the set operating delay has passed in order for the blocking to activate in time.

Operating time characteristics for activation and reset

This function supports definite time delay (DT). The following table presents the setting parameters for the function's time characteristics.

Table. 5.5.1 - 105. Settings for operating time characteristics.

| Name | Range | Step | Default | Description |
|-----------------------|-------------------|--------|---------|---|
| Phase THD alarm delay | 0.000...1800.000s | 0.005s | 10.000s | Defines the delay for the alarm timer from the phase currents' measured THD. |
| I01 THD alarm delay | 0.000...1800.000s | 0.005s | 10.000s | Defines the delay for the alarm timer from the residual current I01's measured THD. |
| I02 THD alarm delay | 0.000...1800.000s | 0.005s | 10.000s | Defines the delay for the alarm timer from the residual current I02's measured THD. |

Events and registers

The total harmonic distortion monitor function (abbreviated "THD" in event block names) generates events and registers from the status changes in the alarm function when it is activated. The recorded signals are START and ALARM signals for the monitoring elements as well as common BLOCKED signals. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

The events triggered by the function are recorded with a time stamp and with process data values.

Table. 5.5.1 - 106. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|---------------------|
| 3520 | 55 | THD1 | 0 | THD Start Phase ON |
| 3521 | 55 | THD1 | 1 | THD Start Phase OFF |
| 3522 | 55 | THD1 | 2 | THD Start I01 ON |
| 3523 | 55 | THD1 | 3 | THD Start I01 OFF |
| 3524 | 55 | THD1 | 4 | THD Start I02 ON |
| 3525 | 55 | THD1 | 5 | THD Start I02 OFF |
| 3526 | 55 | THD1 | 6 | THD Alarm Phase ON |
| 3527 | 55 | THD1 | 7 | THD Alarm Phase OFF |
| 3528 | 55 | THD1 | 8 | THD Alarm I01 ON |

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|-------------------|
| 3529 | 55 | THD1 | 9 | THD Alarm I01 OFF |
| 3530 | 55 | THD1 | 10 | THD Alarm I02 ON |
| 3531 | 55 | THD1 | 11 | THD Alarm I02 OFF |
| 3532 | 55 | THD1 | 12 | Blocked ON |
| 3533 | 55 | THD1 | 13 | Blocked OFF |

The function registers its operation into the last twelve (12) time-stamped registers. The register of the function records the ON event process data for ACTIVATED, BLOCKED, etc. The table below presents the structure of the function's register content.

Table. 5.5.1 - 107. Register content.

| Date and time | Event code | L1h, L2h, L3h pretriggering current | L1h, L2h, L3h Fault current | L1h, L2h, L3h Prefault current | Used SG |
|----------------------------|------------------|--|---|--------------------------------------|-----------------------------|
| dd.mm.yyyy hh:mm:ss.mss | 3520-3533 Descr. | Start -200ms THD averages of each phase. | Trip -20 ms THD averages of each phase. | Trip -200 ms averages of each phase. | Setting group 1...8 active. |

5.5.2 Disturbance recorder (DR)

The disturbance recorder is a high-capacity (64 MB) and fully digital recorder integrated to the protection relay. The maximum sample rate of the recorder's analog channels is 64 samples per cycle. The recorder also supports 95 digital channels simultaneously with the twenty (20) measured analog channels.

The recorder provides a great tool to analyze the performance of the power system during network disturbance situations. The recorder's output is in general COMTRADE format and it is compatible with most viewers and injection devices. The files are based on the IEEE standard C37.111-1999. Captured recordings can be injected as playback with secondary testing tools that support the COMTRADE file format. Playback of files might help to analyze the fault, or can be simply used for educational purposes.

Analog and digital recording channels

Up to 20 analog recording channels and 95 digital channels are supported. The available analog channels vary according to the device type.

Table. 5.5.2 - 108. Analog recording channels.

| Signal | Description |
|--------|------------------------------------|
| IL1 | Phase current I_{L1} |
| IL2 | Phase current I_{L2} |
| IL3 | Phase current I_{L3} |
| I01c | Residual current I_{01} coarse* |
| I01f | Residual current I_{01} fine* |
| I02c | Residual current I_{02} coarse* |
| I02f | Residual current I_{02} fine* |
| IL1" | Phase current I_{L1} (CT card 2) |

| Signal | Description |
|-------------|--|
| IL2" | Phase current I_{L2} (CT card 2) |
| IL3" | Phase current I_{L3} (CT card 2) |
| I01"c | Residual current I_{01} coarse* (CT card 2) |
| I01"f | Residual current I_{01} fine* (CT card 2) |
| I02"c | Residual current I_{02} coarse* (CT card 2) |
| I02"f | Residual current I_{02} fine* (CT card 2) |
| U1(2)VT1 | Line-to-neutral U_{L1} or line-to-line voltage U_{12} (VT card 1) |
| U2(3)VT1 | Line-to-neutral U_{L2} or line-to-line voltage U_{23} (VT card 1) |
| U3(1)VT1 | Line-to-neutral U_{L3} or line-to-line voltage U_{31} (VT card 1) |
| U0(ss)VT1 | Zero sequence voltage U_0 or synchrocheck voltage U_{SS} (VT card 1) |
| F tracked 1 | Tracked frequency of reference 1 |
| F tracked 2 | Tracked frequency of reference 2 |
| F tracked 3 | Tracked frequency of reference 3 |
| ISup | Current measurement module voltage supply supervision (CT card 1) |
| ISup" | Current measurement module voltage supply supervision (CT card 2) |
| USup | Voltage measurement module voltage supply supervision (VT card 2) |
| IL1"" | Phase current I_{L1} (CT card 3) |
| IL2"" | Phase current I_{L2} (CT card 3) |
| IL3"" | Phase current I_{L3} (CT card 3) |
| I01""c | Residual current I_{01} coarse* (CT card 3) |
| I01""f | Residual current I_{01} fine* (CT card 3) |
| I02""c | Residual current I_{02} coarse* (CT card 3) |
| I02""f | Residual current I_{02} fine* (CT card 3) |
| ISup_3 | Current measurement module voltage supply supervision (CT card 3) |
| UL1(2)VT2 | Line-to-neutral U_{L1} or line-to-line voltage U_{12} (VT card 2) |
| UL2(3)VT2 | Line-to-neutral U_{L2} or line-to-line voltage U_{23} (VT card 2) |
| UL3(1)VT2 | Line-to-neutral U_{L3} or line-to-line voltage U_{31} (VT card 2) |
| U0(SS)VT2 | Zero sequence voltage U_0 or synchrocheck voltage U_{SS} (VT card 2) |
| USup_2 | Voltage measurement module voltage supply supervision (VT card 2) |

***NOTE:** There are two signals for each residual current channel in the disturbance recorder: coarse and fine. A coarse signal is capable of sampling in the full range of the current channel but suffers a loss of accuracy at very low currents. A fine signal is capable of sampling at very low currents and with high accuracy but cuts off at higher currents. Table below lists performance of both channels with fine and coarse gain.

Table. 5.5.2 - 109. Residual current channel performance with coarse or residual gain.

| Channel | Coarse gain range | Fine gain range | Fine gain peak |
|---------|-------------------|-----------------|----------------|
| I01 | 0...150 A | 0...10 A | 15 A |
| I02 | 0...75 A | 0...5 A | 8 A |

Table. 5.5.2 - 110. Digital recording channels – Measurements.

| Signal | Description | Signal | Description |
|------------------------------|--|-------------------------------|--|
| Currents | | | |
| Pri.Pha.curr.ILx | Primary phase current ILx (IL1, IL2, IL3) | Pha.curr.ILx TRMS Pri | Primary phase current TRMS (IL1, IL2, IL3) |
| Pha.angle ILx | Phase angle ILx (IL1, IL2, IL3) | Pos./Neg./Zero seq.curr. | Positive/Negative/Zero sequence current |
| Pha.curr.ILx | Phase current ILx (IL1, IL2, IL3) | Sec.Pos./Neg./Zero seq.curr. | Secondary positive/negative/zero sequence current |
| Sec.Pha.curr.ILx | Secondary phase current ILx (IL1, IL2, IL3) | Pri.Pos./Neg./Zero seq.curr. | Primary positive/negative/zero sequence current |
| Pri.Res.curr.I0x | Primary residual current I0x (I01, I02) | Pos./Neg./Zero seq.curr.angle | Positive/Negative/Zero sequence current angle |
| Res.curr.angle I0x | Residual current angle I0x (I01, I02) | Res.curr.I0x TRMS | Residual current TRMS I0x (I01, I02) |
| Res.curr.I0x | Residual current I0x (I01, I02) | Res.curr.I0x TRMS Sec | Secondary residual current TRMS I0x (I01, I02) |
| Sec.Res.curr.I0x | Secondary residual current I0x (I01, I02) | Res.curr.I0x TRMS Pri | Primary residual current TRMS I0x (I01, I02) |
| Pri.cal.I0 | Primary calculated I0 | Pha.Lx ampl. THD | Phase Lx amplitude THD (L1, L2, L3) |
| Sec.calc.I0 | Secondary calculated I0 | Pha.Lx pow. THD | Phase Lx power THD (L1, L2, L3) |
| calc.I0 | Calculated I0 | Res.I0x ampl. THD | Residual I0x amplitude THD (I01, I02) |
| calc.I0 Pha.angle | Calculated I0 phase angle | Res.I0x pow. THD | Residual I0x power THD (I01, I02) |
| Pha.curr.ILx TRMS | Phase current TRMS ILx (IL1, IL2, IL3) | P-P curr.ILx | Phase-to-phase current ILx (IL1, IL2, IL3) |
| Pha.curr.ILx TRMS Sec | Secondary phase current TRMS (IL1, IL2, IL3) | P-P curr.I0x | Phase-to-phase current I0x (I01, I02) |
| Voltages | | | |
| Ux Volt p.u. | Ux voltage in per-unit values (U1, U2, U3, U4) | System volt ULxx mag | Magnitude of the system voltage ULxx (UL12, UL23, UL31) |
| Ux Volt pri | Primary Ux voltage (U1, U2, U3, U4) | System volt ULxx mag(kV) | Magnitude of the system voltage ULxx in kilovolts (UL12, UL23, UL31) |
| Ux Volt sec | Secondary Ux voltage (U1, U2, U3, U4) | System volt ULxx ang | Angle of the system voltage ULxx (UL12, UL23, UL31) |
| Ux Volt TRMS p.u. | Ux voltage TRMS in per-unit values (U1, U2, U3, U4) | System volt ULx mag | Magnitude of the system voltage ULx (U1, U2, U3, U4) |
| Ux Volt TRMS pri | Primary Ux voltage TRMS (U1, U2, U3, U4) | System volt ULx mag(kV) | Magnitude of the system voltage ULx in kilovolts (U1, U2, U3, U4) |
| Ux Volt TRMS sec | Secondary Ux voltage TRMS (U1, U2, U3, U4) | System volt ULx ang | Angle of the system voltage ULx (U1, U2, U3, U4) |
| Pos./Neg./Zero seq.Volt.p.u. | Positive/Negative/Zero sequence voltage in per-unit values | System volt U0 mag | Magnitude of the system voltage U0 |
| Pos./Neg./Zero seq.Volt.pri | Primary positive/negative/zero sequence voltage | System volt U0 mag(kV) | Magnitude of the system voltage U0 in kilovolts |
| Pos./Neg./Zero seq.Volt.sec | Secondary positive/negative/zero sequence voltage | System volt U0 mag(%) | Magnitude of the system voltage U0 in percentages |
| Ux Angle | Ux angle (U1, U2, U3, U4) | System volt U0 ang | Angle of the system voltage U0 |

| Signal | Description | Signal | Description |
|--|--|---|---|
| Pos./Neg./Zero Seq volt.Angle | Positive/Negative/Zero sequence voltage angle | Ux Angle difference | Ux angle difference (U1, U2, U3) |
| Resistive and reactive currents | | | |
| ILx Resistive Current p.u. | ILx resistive current in per-unit values (IL1, IL2, IL3) | Pos.seq. Resistive Current Pri. | Primary positive sequence resistive current |
| ILx Reactive Current p.u. | ILx reactive current in per-unit values (IL1, IL2, IL3) | Pos.seq. Reactive Current Pri. | Primary positive sequence reactive current |
| Pos.Seq. Resistive Current p.u. | Positive sequence resistive current in per-unit values | I0x Residual Resistive Current Pri. | Primary residual resistive current I0x (I01, I02) |
| Pos.Seq. Reactive Current p.u. | Positive sequence reactive current in per-unit values | I0x Residual Reactive Current Pri. | Primary residual reactive current I0x (I01, I02) |
| I0x Residual Resistive Current p.u. | I0x residual resistive current in per-unit values (I01, I02) | ILx Resistive Current Sec. | Secondary resistive current ILx (IL1, IL2, IL3) |
| I0x Residual Reactive Current p.u. | I0x residual ractive current in per-unit values (I01, I02) | ILx Reactive Current Sec. | Secondary reactive current ILx (IL1, IL2, IL3) |
| ILx Resistive Current Pri. | Primary resistive current ILx (IL1, IL2, IL3) | I0x Residual Resistive Current Sec. | Secondary residual resistive current I0x (I01, I02) |
| ILx Reactive Current Pri. | Primary reactive current ILx (IL1, IL2, IL3) | I0x Residual Reactive Current Sec. | Secondary residual reactive current I0x (I01, I02) |
| Power, GYB, frequency | | | |
| Lx PF | Lx power factor (L1, L2, L3) | Curve x Input | Input of Curve x (1, 2, 3, 4) |
| POW1 3PH Apparent power (S) | Three-phase apparent power | Curve x Output | Output of Curve x (1, 2, 3, 4) |
| POW1 3PH Apparent power (S MVA) | Three-phase apparent power in megavolt-amperes | Enablefbasedfunctions(VT1) | Enable frequency-based functions |
| POW1 3PH Active power (P) | Three-phase active power | Track.sys.f. | Tracked system frequency |
| POW1 3PH Active power (P MW) | Three-phase active power in megawatts | Sampl.f. used | Used sample frequency |
| POW1 3PH Reactive power (Q) | Three-phase reactive power | Tr f CH x | Tracked frequency (channels A, B, C) |
| POW1 3PH Reactive power (Q MVar) | Three-phase reactive power in megavars | Alg f Fast | Fast frequency algorithm |
| POW1 3PH Tan(phi) | Three-phase tangent phi | Alg f avg | Average frequency algorithm |
| POW1 3PH Cos(phi) | Three-phase cosine phi | Frequency based protections blocked | When true ("1"), all frequency-based protections are blocked. |
| 3PH PF | Three-phase power factor | f atm. Protections (when not measurable returns to nominal) | Frequency at the moment. If the system nominal is set to 50 Hz, this will show "50 Hz". |
| Neutral conductance G (Pri) | Primary neutral conductance | f atm. Display (when not measurable is 0 Hz) | Frequency at the moment. If the frequency is not measurable, this will show "0 Hz". |

| Signal | Description | Signal | Description |
|--------------------------------|----------------------------------|--------------------------|---|
| Neutral susceptance B (Pri) | Primary neutral susceptance | f meas qlty | Quality of tracked frequency |
| Neutral admittance Y (Pri) | Primary neutral admittance | f meas from | Indicates which of the three voltage or current channel frequencies is used by the relay. |
| Neutral admittance Y (Ang) | Neutral admittance angle | SS1.meas.frqs | Synchrocheck – the measured frequency from voltage channel 1 |
| I01 Resistive component (Pri) | Primary resistive component I01 | SS2.meas.frqs | Synchrocheck – the measured frequency from voltage channel 2 |
| I01 Capacitive component (Pri) | Primary capacitive component I01 | Enable f based functions | Status of this signal is active when frequency-based protection functions are enabled. |

Table. 5.5.2 - 111. Digital recording channels – Binary signals.

| Signal | Description | Signal | Description |
|----------------------------|---|--|--|
| Dlx | Digital input 1...11 | Timer x Output | Output of Timer 1...10 |
| Open/close control buttons | Active if buttons 1 or 0 in the unit's front panel are pressed. | Internal Relay Fault active | If the unit has an internal fault, this signal is active. |
| Status PushButton x On | Status of Push Button 1...12 is ON | (Protection, control and monitoring event signals) | (see the individual function description for the specific outputs) |
| Status PushButton x Off | Status of Push Button 1...12 is OFF | Always True/False | "Always false" is always "0". Always true is always "1". |
| Forced SG in use | Stage forcing in use | OUTx | Output contact statuses |
| SGx Active | Setting group 1...8 active | GOOSE INx | GOOSE input 1...64 |
| Double Ethernet LinkA down | Double ethernet communication card link A connection is down. | GOOSE INx quality | Quality of GOOSE input 1...64 |
| Double Ethernet LinkB down | Double ethernet communication card link B connection is down. | Logical Input x | Logical input 1...32 |
| MBIO ModA Ch x Invalid | Channel 1...8 of MBIO Mod A is invalid | Logical Output x | Logical output 1...64 |
| MBIO ModB Ch x Invalid | Channel 1...8 of MBIO Mod B is invalid | NTP sync alarm | If NTP time synchronization is lost, this signal will be active. |
| MBIO ModC Ch x Invalid | Channel 1...8 of MBIO Mod C is invalid | Ph.Rotating Logic control 0=A-B-C, 1=A-C-B | Phase rotating order at the moment. If true ("1") the phase order is reversed. |



NOTE!

Digital channels are measured every 5 ms.

Recording settings and triggering

Disturbance recorder can be triggered manually or automatically by using the dedicated triggers. Every signal listed in "Digital recording channels" can be selected to trigger the recorder.

The device has a maximum limit of 100 for the number of recordings. Even when the recordings are very small, their number cannot exceed 100. The number of analog and digital channels together with the sample rate and the time setting affect the recording size. See calculation examples below in the section titled "Estimating the maximum length of total recording time".

Table. 5.5.2 - 112. Recorder control settings.

| Name | Range | Step | Default | Description |
|----------------------------------|--|--------|------------|--|
| Recorder enabled | 0: Enabled 1: Disabled | - | 0: Enabled | Enables and disables the disturbance recorder function. |
| Recorder status | 0: Recorder ready 1: Recording triggered 2: Recording and storing 3: Storing recording 4: Recorder full 5: Wrong config | - | - | Indicates the status of recorder. |
| Clear record+ | 0...2 ³² -1 | 1 | - | Clears selected recording. If "1" is inserted, first recording will be cleared from memory. If "10" is inserted, tenth (10th) recording will be cleared from memory. |
| Manual trigger | 0: - 1: Trig | - | 0: - | Triggers disturbance recording manually. This parameter will return back to "-" automatically. |
| Clear all records | 0: - 1: Clear | - | 0: - | Clears all disturbance recordings. |
| Clear newest record | 0: - 1: Clear | - | 0: - | Clears the newest stored disturbance recording. |
| Clear oldest record | 0: - 1: Clear | - | 0: - | Clears the oldest stored disturbance recording. |
| Max. number of recordings | 0...100 | 1 | - | Displays the maximum number of recordings that can be stored in the device's memory with settings currently in use. The maximum number of recordings can go up to 100. |
| Max. length of a recording | 0.000...1800.000s | 0.001s | - | Displays the maximum length of a single recording. |
| Max. location of the pre-trigger | 0.000...1800.000s | 0.001s | - | Displays the highest pre-triggering time that can be set with the settings currently in use. |
| Recordings in memory | 0...100 | 1 | - | Displays how many recordings are stored in the memory. |

Table. 5.5.2 - 113. Recorder trigger setting.

| Name | Description |
|------------------|--|
| Recorder trigger | Selects the trigger input(s). Clicking the "Edit" button brings up a pop-up window, and checking the boxes enable the selected triggers. |

Table. 5.5.2 - 114. Recorder settings.

| Name | Range | Step | Default | Description |
|------------------|-------------------|-------|---------|---------------------------------|
| Recording length | 0.100...1800.000s | 0.01s | 1s | Sets the length of a recording. |

| Name | Range | Step | Default | Description |
|------------------------------|---|------|-------------|--|
| Recording mode | 0: FIFO 1: Keep olds | - | 0: FIFO | Selects what happens when the memory is full. "FIFO" (= first in, first out) replaces the oldest stored recording with the latest one. "Keep olds" does not accept new recordings. |
| Analog channel samples | 0: 64s/c 1: 32s/c 2: 16s/c 3: 8s/c | - | 0: 64s/c | Selects the sample rate of the disturbance recorder in samples per cycle. The samples are saved from the measured wave according to this setting. |
| Digital channel samples | 5ms (fixed) | - | 5 ms(fixed) | The fixed sample rate of the recorded digital channels. |
| Pretriggering time | 0.2...15.0s | 0.1s | 0.2s | Sets the recording length before the trigger. |
| Analog recording CH1...CH20 | 0...8 freely selectable channels | - | - | Selects the analog channel for recording. Please see the list of all available analog channels in the section titled "Analog and digital recording channels". |
| Automatically get recordings | 0: Disabled 1: Enabled | - | 0: Disabled | Enables and disables the automatic transfer of recordings. The recordings are taken from the relay's protection CPU and transferred to the relay's FTP directory in the communication CPU; the FTP client then automatically loads the recordings from the relay and transfers them further to the SCADA system. Please note that when this setting is enabled, all new disturbance recordings will be pushed to the FTP server of the relay. Up to six (6) recordings can be stored in the FTP at once. Once those six recordings have been retrieved and removed, more recordings will then be pushed to the FTP. When a recording has been sent to the FTP server of the relay, it is no longer accessible through setting tools <i>Disturbance recorder</i> → <i>Get DR files</i> command. |
| Recorder digital channels | 0...95 freely selectable channels | - | - | Selects the digital channel for recording. Please see the list of all available digital channels in the section titled "Analog and digital recording channels". |

NOTE!



The disturbance recorder is not ready unless the "Max. length of a recording" parameter is showing some value other than zero. At least one trigger input has to be selected in the "Recorder Trigger" setting to fulfill this term.

Estimating the maximum length of total recording time

Once the disturbance recorder's settings have been made and loaded to the relay, the device automatically calculates and displays the total length of recordings. However, if the user wishes to confirm this calculation, they can do so with the following formula. Please note that the formula assumes there are no other files in the FTP that share the 64 MB space.

$$\frac{\text{Total sample reserve}}{(f_n * (Ch_{an} + 1) * SR) + (200 \text{ Hz} * Ch_{dig})}$$

Where:

- total sample reserve = the number of samples available in the FTP when no other files are saved; calculated by dividing the total number of available bytes by 4 bytes (=the size of one sample); e.g. 64 306 588 bytes/4 bytes = 16 076 647 samples.
- f_n = the nominal frequency (Hz).

- Ch_{an} = the number of analog channels recorded; "+ 1" stands for the time stamp for each recorded sample.
- SR = the selected sample rate (s/c).
- 200 Hz = the rate at which digital channels are always recorded, i.e. 5 ms.
- Ch_{dig} = the number of digital channels recorded.

For example, let us say the nominal frequency is 50 Hz, the selected sample rate is 64 s/c, nine (9) analog channels and two (2) digital channels record. The calculation is as follows:

$$\frac{16\,076\,647 \text{ samples}}{(50 \text{ Hz} * (9 + 1) * 64) + (200 \text{ Hz} * 2)} \approx 496 \text{ s}$$

Therefore, the maximum recording length in our example is approximately 496 seconds.

Application example

This chapter presents an application example of how to set the disturbance recorder and analyze its output. The recorder is configured by using the setting tool software or relay HMI, and the results are analyzed with the AQviewer software (is automatically downloaded and installed with AQtivate). Registered users can download the latest tools from the Arcteq website (arcteq.fi/downloads/).

In this example, we want the recordings to be made according to the following specifications:

- the recording length is 6.0 s
- the sample rate is 64 s/c (therefore, with a 50 Hz system frequency a sample is taken every 312.5 μ s)
- the analog channels 1...8 are used
- digital channels are tracked every 5 ms
- the first activation of the overcurrent stage trip ($I > TRIP$) triggers the recorder
- the pre-triggering time is 5 (ie. how long is recorded before the $I > TRIP$ signal) and the post-triggering time is 1 s

The image below shows how these settings are placed in the setting tool.

Figure. 5.5.2 - 97. Disturbance recorder settings.

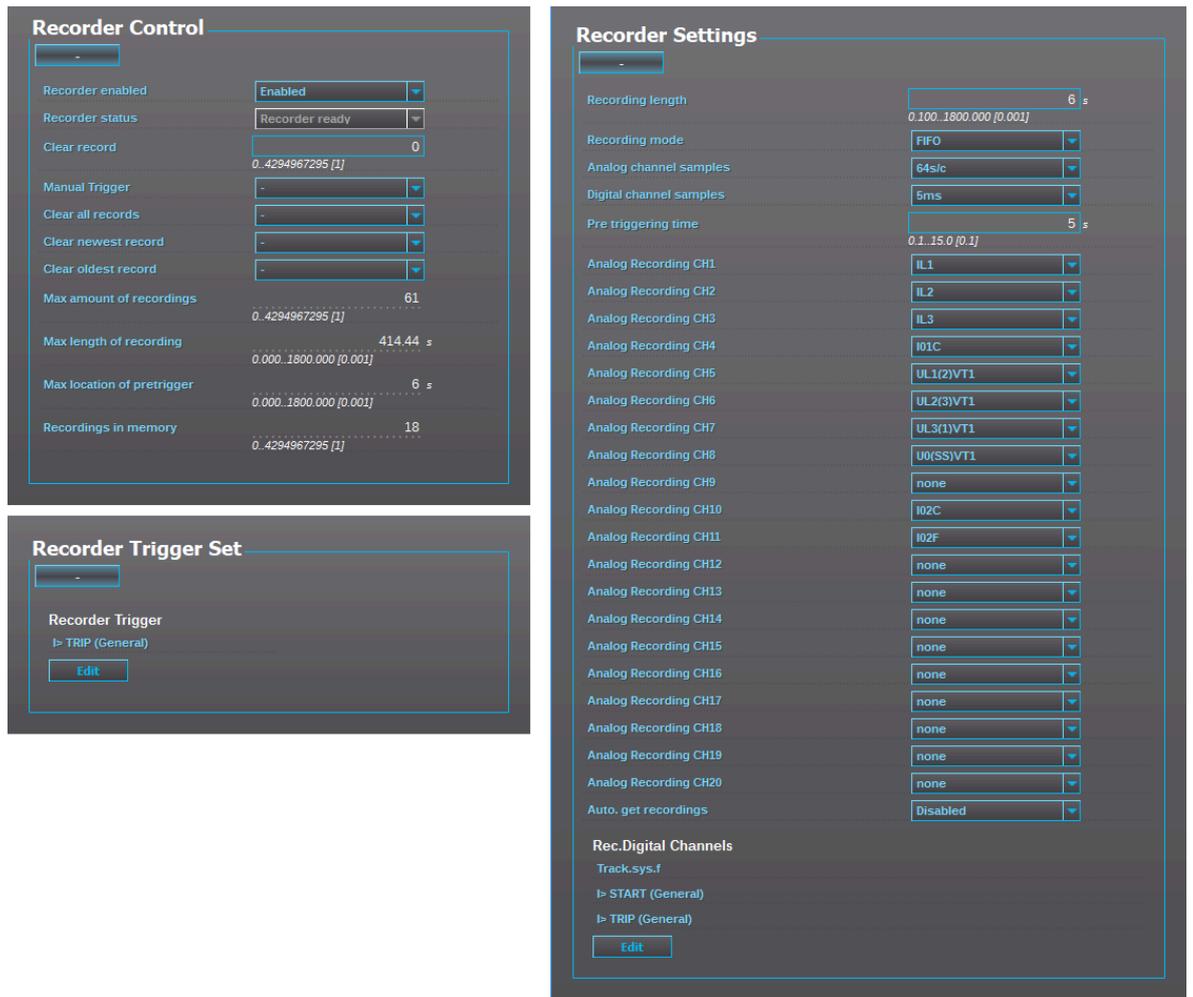
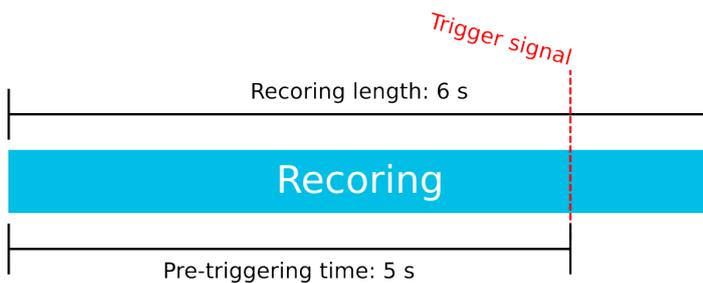
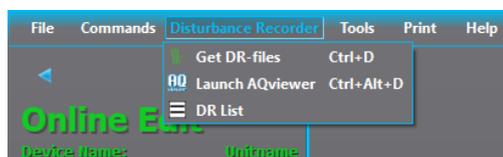


Figure. 5.5.2 - 98. Effects of recording length and pre-triggering time signals. This example is based on the settings shown above.



When there is at least one recording in the device's memory, that recording can be analyzed by using the AQviewer software (see the image below). However, the recording must first be made accessible to AQviewer. The user can read it from the device's memory (*Disturbance recorder* → *Get DR-files*). Alternatively, the user can load the recordings individually (*Disturbance recorder* → *DR List*) from a folder in the PC's hard disk drive; the exact location of the folder is described in *Tools* → *Settings* → *DR path*.



The user can also launch the AQviewer software from the *Disturbance recorder* menu.

AQviewer

Opening folders

Disturbance recordings can be opened by clicking on the "Open folder" icon or by going to *File* → *Open* (see the image below). The recordings are packed COMTRADE files; a -zip file includes *.cfg and *.dat files. AQviewer can open both original packed .zip files and COMTRADE files directly as they are located in same directory.



Adding signals to plotters

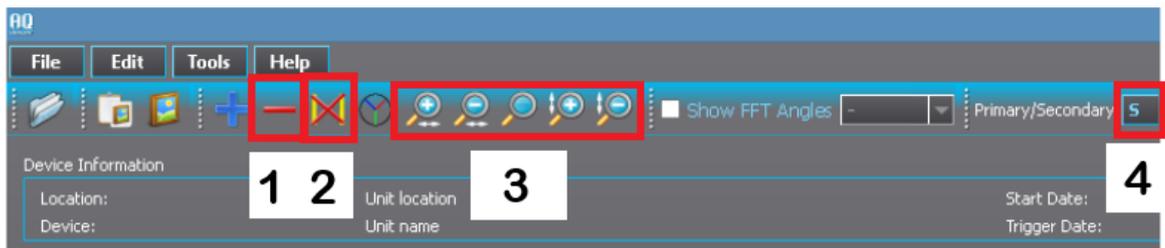
By default, the default plotter is empty. Choose the measured signals ("Analog channels") on the left to move them to the plotter. In the image below (on the left) the phase currents IL1, IL2 and IL3 are selected; AQViewer color-codes them automatically. If you want to add another plotter, choose the blue "+" icon (in the main toolbar on the top). Please note that the "Add plotter" text appears when you move the cursor on top of the icon. Once clicked, the "Add graph" pop-up window appears (see the image below on the right). In the example the line-to-neutral voltages UL1, UL2 and UL3 are selected and moved to the window on the right. Confirm the selection by clicking the "OK" button.

Figure. 5.5.2 - 99. Adding another plotter



General use and zooming

1. You can remove plotters individually by using the red "—" icon (numbered "1" in the image below). Please note that the "Remove plotters" text appears when you move the cursor on top of the icon.
2. You can add cursors to measure time by staying on top of any plotter and double-clicking the left mouse button. You can add up to five (5) cursors simultaneously. You can remove cursors by clicking on the icon (numbered "2" in the image below). Please note that the "Remove all cursors" text appears when you move the cursor on top of the icon.
3. You can zoom in manually by placing the cursor on top of a plotter, holding down the left mouse button and moving the cursor to create the area you want to zoom in. You can also zoom in (and out) by using the horizontal and vertical magnifying glass "+" and "—" icons (numbered "3" in the image below). If you want to reset the zooming, click on the middle magnifying glass icon. You can also zoom in and out the amplitude of individual plotters by holding down **Shift** and scrolling the mouse wheel up and down, respectively.
4. You can toggle between primary (P) and secondary (S) signals (numbered "4" in the image below).



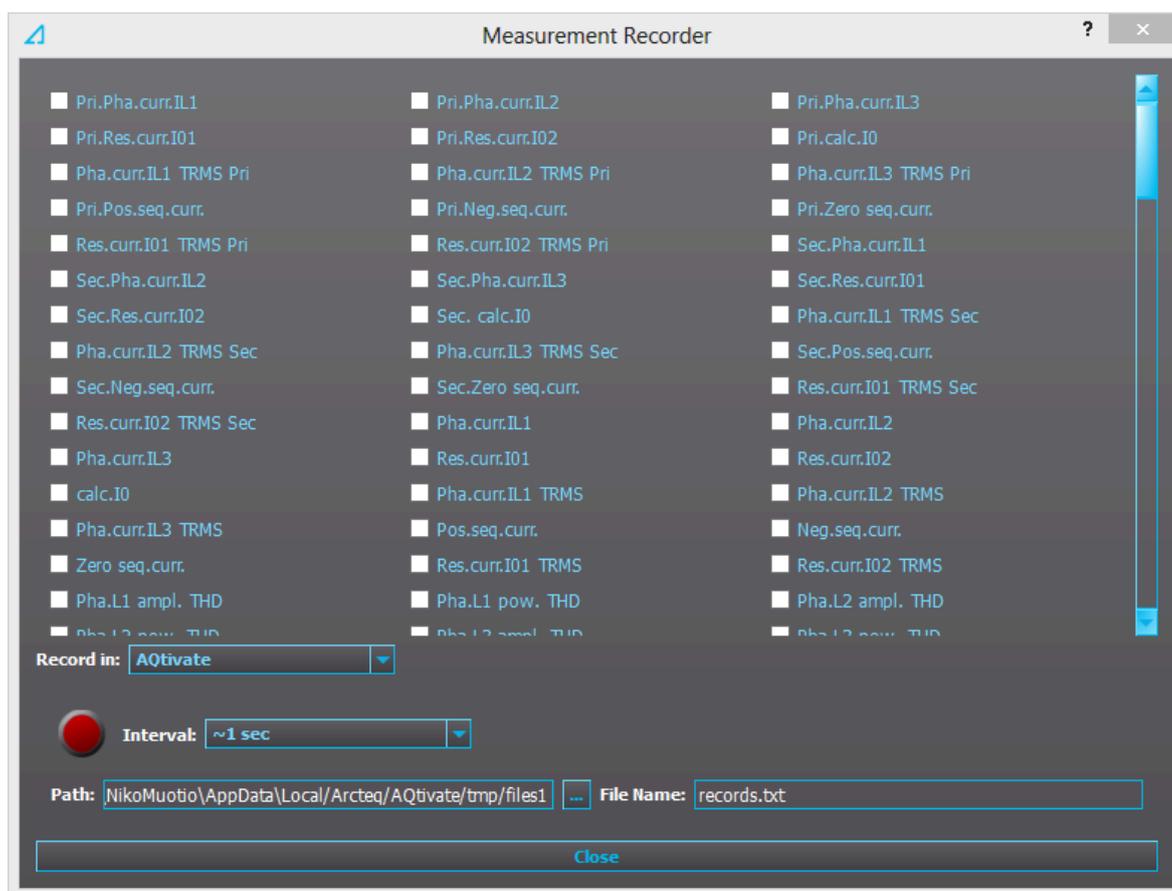
Events

The disturbance recorder function (abbreviated "DR" in event block names) generates events and registers from the status changes of the function: the recorder generates an event each time it is triggered (manually or by dedicated signals). Events cannot be masked off. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

Table. 5.5.2 - 115. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|--------------------------|
| 4096 | 64 | DR1 | 0 | Recorder triggered ON |
| 4097 | 64 | DR1 | 1 | Recorder triggered OFF |
| 4098 | 64 | DR1 | 2 | Recorder memory cleared |
| 4099 | 64 | DR1 | 3 | Oldest record cleared |
| 4100 | 64 | DR1 | 4 | Recorder memory full ON |
| 4101 | 64 | DR1 | 5 | Recorder memory full OFF |
| 4102 | 64 | DR1 | 6 | Recording ON |
| 4103 | 64 | DR1 | 7 | Recording OFF |
| 4104 | 64 | DR1 | 8 | Storing recording ON |
| 4105 | 64 | DR1 | 9 | Storing recording OFF |
| 4106 | 64 | DR1 | 10 | Newest record cleared |

5.5.3 Measurement recorder



Measurements can be recorded to a file with the measurement recorder. The chosen measurements are recorded at selected intervals. In the "Measurement recorder" window, the measurements the user wants to be recorded can be selected by checking their respective check boxes. In order for the measurement recorder to activate, a connection to a relay must be established via the setting tool software and its Live Edit mode must be enabled (see the AQtivate 200 manual for more information). Navigate to the measurement recorder through *Tools* → *Miscellaneous tools* → *Measurement recorder*. The recording interval can be changed from the "Interval" drop-down menu. From the "Record in" drop-down menu the user can also choose whether the measurements are recorded in the setting tool or in the relay.

If the recording is done in the setting tool, both the setting tool software and its Live Edit mode have to be activated. The user can change the recording file location by editing the "Path" field. File names can also be changed with the "File name" field. Hitting the "Record" button (the big red circle) starts the recorder. Please note that closing the "Measurement recorder" window does not stop the recording; that can only be done by hitting the "Stop" button (the big blue circle).

If the recording is done in the relay, only the recording interval needs to be set before recording can be started. The setting tool estimates the maximum recording time, which depends on the recording interval. When the measurement recorder is running, the measurements can be viewed in graph form with the AQtivate PRO software (see the image below).

Figure. 5.5.3 - 100. Measurement recorder values viewed with AQtivate PRO.



Table. 5.5.3 - 116. Available analog signals.

| | | |
|-----------------------|-----------------------------|----------------------------------|
| Current measurements | P-P Curr.I"L3 | L1 Imp.React.Ind.E.Mvarh |
| Pri.Pha.Curr.IL1 | P-P Curr.I"01 | L1 Imp.React.Ind.E.kvarh |
| Pri.Pha.Curr.IL2 | P-P Curr.I"02 | L1 Exp/Imp React.Ind.E.bal.Mvarh |
| Pri.Pha.Curr.IL3 | Pha.angle I"L1 | L1 Exp/Imp React.Ind.E.bal.kvarh |
| Pri.Res.Curr.I01 | Pha.angle I"L2 | L2 Exp.Active Energy MWh |
| Pri.Res.Curr.I02 | Pha.angle I"L3 | L2 Exp.Active Energy kWh |
| Pri.Calc.I0 | Res.Curr.angle I"01 | L2 Imp.Active Energy MWh |
| Pha.Curr.IL1 TRMS Pri | Res.Curr.angle I"02 | L2 Imp.Active Energy kWh |
| Pha.Curr.IL2 TRMS Pri | Calc.I"0.angle | L2 Exp/Imp Act. E balance MWh |
| Pha.Curr.IL3 TRMS Pri | I" Pos.Seq.Curr.angle | L2 Exp/Imp Act. E balance kWh |
| Pri.Pos.Seq.Curr. | I" Neg.Seq.Curr.angle | L2 Exp.React.Cap.E.Mvarh |
| Pri.Neg.Seq.Curr. | I" Zero.Seq.Curr.angle | L2 Exp.React.Cap.E.kvarh |
| Pri.Zero.Seq.Curr. | Voltage measurements | L2 Imp.React.Cap.E.Mvarh |
| Res.Curr.I01 TRMS Pri | U1Volt Pri | L2 Imp.React.Cap.E.kvarh |
| Res.Curr.I02 TRMS Pri | U2Volt Pri | L2 Exp/Imp React.Cap.E.bal.Mvarh |
| Sec.Pha.Curr.IL1 | U3Volt Pri | L2 Exp/Imp React.Cap.E.bal.kvarh |
| Sec.Pha.Curr.IL2 | U4Volt Pri | L2 Exp.React.Ind.E.Mvarh |
| Sec.Pha.Curr.IL3 | U1Volt Pri TRMS | L2 Exp.React.Ind.E.kvarh |
| Sec.Res.Curr.I01 | U2Volt Pri TRMS | L2 Imp.React.Ind.E.Mvarh |
| Sec.Res.Curr.I02 | U3Volt Pri TRMS | L2 Imp.React.Ind.E.kvarh |
| Sec.Calc.I0 | U4Volt Pri TRMS | L2 Exp/Imp React.Ind.E.bal.Mvarh |
| Pha.Curr.IL1 TRMS Sec | Pos.Seq.Volt.Pri | L2 Exp/Imp React.Ind.E.bal.kvarh |

| | | |
|-----------------------|---------------------------|----------------------------------|
| Pha.Curr.IL2 TRMS Sec | Neg.Seq.Volt.Pri | L3 Exp.Active Energy MWh |
| Pha.Curr.IL3 TRMS Sec | Zero.Seq.Volt.Pri | L3 Exp.Active Energy kWh |
| Sec.Pos.Seq.Curr. | U1Volt Sec | L3 Imp.Active Energy MWh |
| Sec.Neg.Seq.Curr. | U2Volt Sec | L3 Imp.Active Energy kWh |
| Sec.Zero.Seq.Curr. | U3Volt Sec | L3 Exp/Imp Act. E balance MWh |
| Res.Curr.I01 TRMS Sec | U4Volt Sec | L3 Exp/Imp Act. E balance kWh |
| Res.Curr.I02 TRMS Sec | U1Volt Sec TRMS | L3 Exp.React.Cap.E.Mvarh |
| Pha.Curr.IL1 | U2Volt Sec TRMS | L3 Exp.React.Cap.E.kvarh |
| Pha.Curr.IL2 | U3Volt Sec TRMS | L3 Imp.React.Cap.E.Mvarh |
| Pha.Curr.IL3 | U4Volt Sec TRMS | L3 Imp.React.Cap.E.kvarh |
| Res.Curr.I01 | Pos.Seq.Volt.Sec | L3 Exp/Imp React.Cap.E.bal.Mvarh |
| Res.Curr.I02 | Neg.Seq.Volt.Sec | L3 Exp/Imp React.Cap.E.bal.kvarh |
| Calc.I0 | Zero.Seq.Volt.Sec | L3 Exp.React.Ind.E.Mvarh |
| Pha.Curr.IL1 TRMS | U1Volt p.u. | L3 Exp.React.Ind.E.kvarh |
| Pha.Curr.IL2 TRMS | U2Volt p.u. | L3 Imp.React.Ind.E.Mvarh |
| Pha.Curr.IL3 TRMS | U3Volt p.u. | L3 Imp.React.Ind.E.kvarh |
| Pos.Seq.Curr. | U4Volt p.u. | L3 Exp/Imp React.Ind.E.bal.Mvarh |
| Neg.Seq.Curr. | U1Volt TRMS p.u. | L3 Exp/Imp React.Ind.E.bal.kvarh |
| Zero.Seq.Curr. | U2Volt TRMS p.u. | Exp.Active Energy MWh |
| Res.Curr.I01 TRMS | U3Volt p.u. | Exp.Active Energy kWh |
| Res.Curr.I02 TRMS | U4Volt p.u. | Imp.Active Energy MWh |
| Pha.L1 ampl. THD | Pos.Seq.Volt. p.u. | Imp.Active Energy kWh |
| Pha.L2 ampl. THD | Neg.Seq.Volt. p.u. | Exp/Imp Act. E balance MWh |
| Pha.L3 ampl. THD | Zero.Seq.Volt. p.u. | Exp/Imp Act. E balance kWh |
| Pha.L1 pow. THD | U1Volt Angle | Exp.React.Cap.E.Mvarh |
| Pha.L2 pow. THD | U2Volt Angle | Exp.React.Cap.E.kvarh |
| Pha.L3 pow. THD | U3Volt Angle | Imp.React.Cap.E.Mvarh |
| Res.I01 ampl. THD | U4Volt Angle | Imp.React.Cap.E.kvarh |
| Res.I01 pow. THD | Pos.Seq.Volt. Angle | Exp/Imp React.Cap.E.bal.Mvarh |
| Res.I02 ampl. THD | Neg.Seq.Volt. Angle | Exp/Imp React.Cap.E.bal.kvarh |
| Res.I02 pow. THD | Zero.Seq.Volt. Angle | Exp.React.Ind.E.Mvarh |
| P-P Curr.IL1 | System Volt UL12 mag | Exp.React.Ind.E.kvarh |
| P-P Curr.IL2 | System Volt UL12 mag (kV) | Imp.React.Ind.E.Mvarh |
| P-P Curr.IL3 | System Volt UL23 mag | Imp.React.Ind.E.kvarh |
| P-P Curr.I01 | System Volt UL23 mag (kV) | Exp/Imp React.Ind.E.bal.Mvarh |
| P-P Curr.I02 | System Volt UL31 mag | Exp/Imp React.Ind.E.bal.kvarh |
| Pha.angle IL1 | System Volt UL31 mag (kV) | Other measurements |
| Pha.angle IL2 | System Volt UL1 mag | TM> Trip expect mode |
| Pha.angle IL3 | System Volt UL1 mag (kV) | TM> Time to 100% T |

| | | |
|------------------------|---------------------------|---------------------------|
| Res.Curr.angle I01 | System Volt UL2 mag | TM> Reference T curr. |
| Res.Curr.angle I02 | System Volt UL2 mag (kV) | TM> Active meas curr. |
| Calc.I0.angle | System Volt UL3 mag | TM> T est.with act. curr. |
| Pos.Seq.Curr.angle | System Volt UL3 mag (kV) | TM> T at the moment |
| Neg.Seq.Curr.angle | System Volt U0 mag | TM> Max.Temp.Rise All. |
| Zero.Seq.Curr.angle | System Volt U0 mag (kV) | TM> Temp.Rise atm. |
| Pri.Pha.Curr.I"L1 | System Volt U1 mag | TM> Hot Spot estimate |
| Pri.Pha.Curr.I"L2 | System Volt U1 mag (kV) | TM> Hot Spot Max. All |
| Pri.Pha.Curr.I"L3 | System Volt U2 mag | TM> Used k for amb.temp |
| Pri.Res.Curr.I"01 | System Volt U2 mag (kV) | TM> Trip delay remaining |
| Pri.Res.Curr.I"02 | System Volt U3 mag | TM> Alarm 1 time to rel. |
| Pri.Calc.I"0 | System Volt U3 mag (kV) | TM> Alarm 2 time to rel. |
| Pha.Curr.I"L1 TRMS Pri | System Volt U4 mag | TM> Inhibit time to rel. |
| Pha.Curr.I"L2 TRMS Pri | System Volt U4 mag (kV) | TM> Trip time to rel. |
| Pha.Curr.I"L3 TRMS Pri | System Volt UL12 ang | S1 Measurement |
| I" Pri.Pos.Seq.Curr. | System Volt UL23 ang | S2 Measurement |
| I" Pri.Neg.Seq.Curr. | System Volt UL31 ang | S3 Measurement |
| I" Pri.Zero.Seq.Curr. | System Volt UL1 ang | S4 Measurement |
| Res.Curr.I"01 TRMS Pri | System Volt UL2 ang | S5 Measurement |
| Res.Curr.I"02 TRMS Pri | System Volt UL3 ang | S6 Measurement |
| Sec.Pha.Curr.I"L1 | System Volt U0 ang | S7 Measurement |
| Sec.Pha.Curr.I"L2 | System Volt U1 ang | S8 Measurement |
| Sec.Pha.Curr.I"L3 | System Volt U2 ang | S9 Measurement |
| Sec.Res.Curr.I"01 | System Volt U3 ang | S10 Measurement |
| Sec.Res.Curr.I"02 | System Volt U4 ang | S11 Measurement |
| Sec.Calc.I"0 | Power measurements | S12 Measurement |
| Pha.Curr.I"L1 TRMS Sec | L1 Apparent Power (S) | Sys.meas.frqs |
| Pha.Curr.I"L2 TRMS Sec | L1 Active Power (P) | f atm. |
| Pha.Curr.I"L3 TRMS Sec | L1 Reactive Power (Q) | f meas from |
| I" Sec.Pos.Seq.Curr. | L1 Tan(phi) | SS1.meas.frqs |
| I" Sec.Neg.Seq.Curr. | L1 Cos(phi) | SS1f meas from |
| I" Sec.Zero.Seq.Curr. | L2 Apparent Power (S) | SS2 meas.frqs |
| Res.Curr.I"01 TRMS Sec | L2 Active Power (P) | SS2f meas from |
| Res.Curr.I"02 TRMS Sec | L2 Reactive Power (Q) | L1 Bias current |
| Pha.Curr.I"L1 | L2 Tan(phi) | L1 Diff current |
| Pha.Curr.I"L2 | L2 Cos(phi) | L1 Char current |
| Pha.Curr.I"L3 | L3 Apparent Power (S) | L2 Bias current |
| Res.Curr.I"01 | L3 Active Power (P) | L2 Diff current |
| Res.Curr.I"02 | L3 Reactive Power (Q) | L2 Char current |

| | | |
|--------------------|----------------------------------|----------------------|
| Calc.I"0 | L3 Tan(phi) | L3 Bias current |
| Pha.Curr.I"L1 TRMS | L3 Cos(phi) | L3 Diff current |
| Pha.Curr.I"L2 TRMS | 3PH Apparent Power (S) | L3 Char current |
| Pha.Curr.I"L3 TRMS | 3PH Active Power (P) | HV I0d> Bias current |
| I" Pos.Seq.Curr. | 3PH Reactive Power (Q) | HV I0d> Diff current |
| I" Neg.Seq.Curr. | 3PH Tan(phi) | HV I0d> Char current |
| I" Zero.Seq.Curr. | 3PH Cos(phi) | LV I0d> Bias current |
| Res.Curr.I"01 TRMS | Energy measurements | LV I0d> Diff current |
| Res.Curr.I"02 TRMS | L1 Exp.Active Energy MWh | LV I0d> Char current |
| Pha.IL"1 ampl. THD | L1 Exp.Active Energy kWh | Curve1 Input |
| Pha.IL"2 ampl. THD | L1 Imp.Active Energy MWh | Curve1 Output |
| Pha.IL"3 ampl. THD | L1 Imp.Active Energy kWh | Curve2 Input |
| Pha.IL"1 pow. THD | L1 Exp/Imp Act. E balance MWh | Curve2 Output |
| Pha.IL"2 pow. THD | L1 Exp/Imp Act. E balance kWh | Curve3 Input |
| Pha.IL"3 pow. THD | L1 Exp.React.Cap.E.Mvarh | Curve3 Output |
| Res.I"01 ampl. THD | L1 Exp.React.Cap.E.kvarh | Curve4 Input |
| Res.I"01 pow. THD | L1 Imp.React.Cap.E.Mvarh | Curve4 Output |
| Res.I"02 ampl. THD | L1 Imp.React.Cap.E.kvarh | Control mode |
| Res.I"02 pow. THD | L1 Exp/Imp React.Cap.E.bal.Mvarh | Motor status |
| P-P Curr.I"L1 | L1 Exp/Imp React.Cap.E.bal.kvarh | Active setting group |
| P-P Curr.I"L2 | L1 Exp.React.Ind.E.Mvarh | |
| | L1 Exp.React.Ind.E.kvarh | |

5.5.4 Measurement value recorder

The measurement value recorder function records the value of the selected magnitudes at the time of a pre-defined trigger signal. An typical application is the recording of fault currents or voltages at the time of the breaker trips; it can also be used to record the values from any trigger signal set by the user. The user can select whether the function records per-unit values or primary values. Additionally, the user can set the function to record overcurrent fault types or voltage fault types. The function operates instantly from the trigger signal.

The measurement value recorder function has an integrated fault display which shows the current fault values when the tripped by one of the following functions: I> (non-directional overcurrent), Idir> (directional overcurrent), I0> (non-directional earth fault), I0dir> (directional earth fault), f< (underfrequency), f> (overfrequency), U< (undervoltage), U> (overvoltage), U1/U2 >/< (sequence voltage) or U0> (residual voltage). When any of these functions trip, the fault values and the fault type are displayed in the Mimic view. The view can be enabled by activating the "VREC Trigger on" setting (*Tools* → *Events and logs* → *Set alarm events*). The resetting of the fault values is done by the input selected in the *General* menu.

Measured input

The function block uses analog current and voltage measurement values. Based on these values, the relay calculates the primary and secondary values of currents, voltages, powers, and impedances as well as other values.

The user can set up to eight (8) magnitudes to be recorded when the function is triggered. An overcurrent fault type, a voltage fault type, and a tripped stage can be recorded and reported straight to SCADA.

NOTE!



The available measurement values depend on the relay type. If only current analog measurements are available, the recorder can solely use signals which only use current. The same applies, if only voltage analog measurements are available.

| Currents | Description |
|---|---|
| IL1 (ff), IL2 (ff), IL3 (ff), I01 (ff), I02 (ff) | The fundamental frequency current measurement values (RMS) of phase currents and of residual currents. |
| IL1TRMS, IL2TRMS, IL3TRMS, I01TRMS, I02TRMS | The TRMS current measurement values of phase currents and of residual currents. |
| IL1,2,3 & I01/I02 2 nd h., 3 rd h., 4 th h., 5 th h., 7 th h., 9 th h., 11 th h., 13 th h., 15 th h., 17 th h., 19 th h. | The magnitudes of phase current components: Fundamental, 2 nd harmonic, 3 rd harmonic, 4 th harmonic, 5 th harmonic, 7 th harmonic, 9 th harmonic, 11 th harmonic, 13 th harmonic, 15 th harmonic, 17 th harmonic, 19 th harmonic current. |
| I1, I2, I0Z | The positive sequence current, the negative sequence current and the zero sequence current. |
| I0CalcMag | The residual current calculated from phase currents. |
| IL1Ang, IL2Ang, IL3Ang, I01Ang, I02Ang, I0CalcAng, I1Ang, I2Ang | The angles of each measured current. |
| Voltages | Description |
| UL1Mag, UL2Mag, UL3Mag, UL12Mag, UL23Mag, UL31Mag U0Mag, U0CalcMag | The magnitudes of phase voltages, of phase-to-phase voltages, and of residual voltages. |
| U1 Pos.seq V mag, U2 Neg.seq V mag | The positive sequence voltage and the negative sequence voltage. |
| UL1Ang, UL2Ang, UL3Ang, UL12Ang, UL23Ang, UL31Ang U0Ang, U0CalcAng | The angles of phase voltages, of phase-to-phase voltages, and of residual voltages. |
| U1 Pos.seq V Ang, U2 Neg.seq V Ang | The positive sequence angle and the negative sequence angle. |
| Powers | Description |
| S3PH, P3PH, Q3PH | The three-phase apparent, active and reactive powers. |
| SL1, SL2, SL3, PL1, PL2, PL3, QL1, QL2, QL3 | The phase apparent, active and reactive powers. |
| tanfi3PH, tanfiL1, tanfiL2, tanfiL3 | The tan (φ) of three-phase powers and phase powers. |
| cosfi3PH, cosfiL1, cosfiL2, cosfiL3 | The cos (φ) of three-phase powers and phase powers. |
| Impedances and admittances | Description |
| RL12, RL23, RL31 XL12, XL23, XL31, RL1, RL2, RL3 XL1, XL2, XL3 Z12, Z23, Z31 ZL1, ZL2, ZL3 | The phase-to-phase and phase-to-neutral resistances, reactances and impedances. |
| Z12Ang, Z23Ang, Z31Ang, ZL1Ang, ZL2Ang, ZL3Ang | The phase-to-phase and phase-to-neutral impedance angles. |

| Currents | Description |
|---|--|
| Rseq, Xseq, Zseq RseqAng, XseqAng, ZseqAng | The positive sequence resistance, reactance and impedance values and angles. |
| GL1, GL2, GL3, G0 BL1, BL2, BL3, B0 YL1, YL2, YL3, Y0 | The conductances, susceptances and admittances. |
| YL1angle, YL2angle, YL3angle Y0angle | The admittance angles. |
| Others | Description |
| System f. | The tracking frequency in use at that moment. |
| Ref f1 | The reference frequency 1. |
| Ref f2 | The reference frequency 2. |
| M thermal T | The motor thermal temperature. |
| F thermal T | The feeder thermal temperature. |
| T thermal T | The transformer thermal temperature. |
| RTD meas 1...16 | The RTD measurement channels 1...16. |
| Ext RTD meas 1...8 | The external RTD measurement channels 1...8 (ADAM module). |

Reported values

When triggered, the function holds the recorded values of up to eight channels, as set. In addition to this tripped stage, the overcurrent fault type and the voltage fault types are reported to SCADA.

Table. 5.5.4 - 117. Reported values.

| Name | Range | Step | Description |
|------------------------|--|------|-----------------------------|
| Tripped stage | 0: - 1: I> Trip 2: I>> Trip 3: I>>> Trip 4: I>>>> Trip 5: IDir> Trip 6: IDir>> Trip 7: IDir>>> Trip 8: IDir>>>> Trip 9: U> Trip 10: U>> Trip 11: U>>> Trip 12: U>>>> Trip 13: U< Trip 14: U<< Trip 15: U<<< Trip 16: U<<<< Trip 17: IO> TRIP 18: IO>> Trip 19: IO>>> Trip 20: IO>>>> Trip 21: IODir> Trip 22: IODir>> Trip 23: IODir>>> Trip 24: IODir>>>> Trip 25: f> Trip 26: f>> Trip 27: f>>> Trip 28: f>>>> Trip 29: f< Trip 30: f<< Trip 31: f<<< Trip 32: f<<<< Trip 33: P> Trip 34: P< Trip 35: Prev> Trip 36: T> Trip 37: I2> Trip 38: I2>> Trip 39: I2>>> Trip 40: I2>>>> Trip 41: U1/2 > Trip 42: U1/2 >> Trip 43: U1/2 >>> Trip 44: U1/2 >>>> Trip 45: U0> Trip 46: U0>> Trip 47: U0>>> Trip 48: U0>>>> Trip | - | The tripped stage. |
| Overcurrent fault type | 0: - 1: A-G 2: B-G 3: A-B 4: C-G 5: A-C 6: B-C 7: A-B-C | - | The overcurrent fault type. |

| Name | Range | Step | Description |
|--------------------|---|----------------|--|
| Voltage fault type | 0: - 1: A(AB) 2: B(BC) 3: A-B(AB-BC) 4: C(CA) 5: A-C(AB-CA) 6: B-C(BC-CA) 7: A-B-C 8: - 9: Overfrequency 10: Underfrequency 11: Overpower 12: Underpower 13: Reversepower 14: Thermal overload 15: Unbalance 16: Harmonic overcurrent 17: Residual overvoltage | - | The voltage fault type. |
| Magnitude 1...8 | 0.000...1800.000 A/V/p.u. | 0.001 A/V/p.u. | The recorded value in one of the eight channels. |

Events

The measurement value recorder function (abbreviated "VREC" in event block names) generates events from the function triggers. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

Table. 5.5.4 - 118. Event codes.

| Event number | Event channel | Event block name | Event code | Description |
|--------------|---------------|------------------|------------|------------------------|
| 9984 | 156 | VREC1 | 0 | Recorder triggered ON |
| 9985 | 156 | VREC1 | 1 | Recorder triggered OFF |

6 System integration

6.1 Communication protocols

6.1.1 NTP

When enabled, the NTP (Network Time Protocol) service can use external time sources to synchronize the device's system time. The NTP client service uses an Ethernet connection to connect to the NTP time server. NTP can be enabled by setting the primary time server and the secondary time server parameters to the address of the system's NTP time source(s).

Table. 6.1.1 - 119. Server settings.

| Name | Range | Description |
|-------------------------------|---------------------------|---|
| Primary time server address | 0.0.0.0...255.255.255.255 | Defines the address of the primary NTP server. Setting this parameter at "0.0.0.0" means that the server is not in use. |
| Secondary time server address | 0.0.0.0...255.255.255.255 | Defines the address of the secondary (or backup) NTP server. Setting this parameter at "0.0.0.0" means that the server is not in use. |

Table. 6.1.1 - 120. Client settings.

| Name | Range | Description |
|----------------|---|--|
| IP address | 0.0.0.0...255.255.255.255 | Defines the address of the NTP client. NOTE: This address must be different than the relay's IP address. |
| Netmask | 0.0.0.0...255.255.255.255 | Defines the client's netmask. |
| Gateway | 0.0.0.0...255.255.255.255 | Defines the client's gateway. |
| MAC address | - | Displays the MAC address of the client. |
| Network status | 0: Running 1: IP error 2: NM error 3: GW error | Displays the status or possible errors of the NTP (client) settings. |

Table. 6.1.1 - 121. Status.

| Name | Range | Description |
|-----------------------------|-------------------------------|---|
| NTP quality for events | 0: No sync 1: Synchronized | Displays the status of the NTP time synchronization at the moment. NOTE: This indication is not valid if another time synchronization method is used (external serial). |
| NTP-processed message count | 0...2 ³² -1 | Displays the number of messages processed by the NTP protocol. |

NOTE!



A unique IP address must be reserved for the NTP client. The relay's IP address cannot be used.

Additionally, the time zone of the relay can be set by connecting to the relay and the selecting the time zone at *Commands* → *Set time zone* (AQtivate).

6.1.2 Modbus/TCP and Modbus/RTU

The device supports both Modbus/TCP and Modbus/RTU communication. Modbus/TCP uses the Ethernet connection to communicate with Modbus/TCP clients. Modbus/RTU is a serial protocol that can be selected for the available serial ports.

The following Modbus function types are supported:

- Read multiple holding registers (function code 3)
- Write single holding register (function code 6)
- Write multiple holding registers (function code 16)
- Read/Write multiple registers (function code 23)

The following data can be accessed using both Modbus/TCP and Modbus/RTU:

- Device measurements
- Device I/O
- Commands
- Events
- Time

Once the configuration file has been loaded, the user can access the Modbus map of the relay via the AQtivate software (*Tools* → *Communication* → *Modbusmap*). Please note that holding registers start from 1. Some masters might begin numbering holding register from 0 instead of 1; this will cause an offset of 1 between the relay and the master.

Table. 6.1.2 - 122. Modbus/TCP settings.

| Parameter | Range | Description |
|-------------------|--|---|
| Enable Modbus/TCP | 0: Disabled 1: Enabled | Enables and disables the Modbus/TCP on the Ethernet port. |
| IP port | 0...65 535 | Defines the IP port used by Modbus/TCP. The standard port (and the default setting) is 502. |
| Event read mode | 0: Get oldest available 1: Continue previous connection 2: New events only | 0: Get oldest event possible (Default and current implementation) 1: Continue with the event idx from previous connection 2: Get only new events from connection time and forward |

Table. 6.1.2 - 123. Modbus/RTU settings.

| Parameter | Range | Description |
|---------------|---------|--|
| Slave address | 1...247 | Defines the Modbus/RTU slave address for the unit. |

Additionally, the user can adjust the measurement update interval with the following parameters (found at *Measurement* → *Measurement update*). These parameters do not affect the operating times of protection functions, only the frequency of measurement reporting to Modbus.

Table. 6.1.2 - 124. Settings for measurement update interval.

| Name | Range | Step | Default | Description |
|-------------------------------------|----------------|------|---------|--|
| Current measurement update interval | 500...10 000ms | 5ms | 2 000ms | Defines the measurement update interval of all current-related measurements. |
| Voltage measurement update interval | 500...10 000ms | 5ms | 2 000ms | Defines the measurement update interval of all voltage-related measurements. |

| Name | Range | Step | Default | Description |
|---------------------------------------|----------------|------|---------|--|
| Power measurement update interval | 500...10 000ms | 5ms | 2 000ms | Defines the measurement update interval of all power-related measurements. |
| Impedance measurement update interval | 500...10 000ms | 5ms | 2 000ms | Defines the measurement update interval of all impedance-related measurements. |

6.1.3 Modbus I/O

The Modbus I/O protocol can be selected to communicate on the available serial ports. The Modbus I/O is actually a Modbus/RTU master implementation that is dedicated to communicating with serial Modbus/RTU slaves such as RTD input modules. Up to three (3) Modbus/RTU slaves can be connected to the same bus polled by the Modbus I/O implementation. These are named I/O Module A, I/O Module B and I/O Module C. Each of the modules can be configured using parameters in the following two tables.

Table. 6.1.3 - 125. Module settings.

| Name | Range | Description |
|----------------------|------------------------------------|---|
| I/O module X address | 0...247 | Defines the Modbus unit address for the selected I/O Module (A, B, or C). If this setting is set to "0", the selected module is not in use. |
| Module x type | 0: ADAM-4018+ 1: ADAM-4015 | Selects the module type. |
| Channels in use | Channel 0...Channel 7 (or None) | Selects the number of channels to be used by the module. |

Table. 6.1.3 - 126. Channel settings.

| Name | Range | Step | Default | Description |
|--------------|--|------|----------------|--|
| T.C. type | 0: +/- 20mA 1: 4...20mA 2: Type J 3: Type K 4: Type T 5: Type E 6: Type R 7: Type S | - | 1: 4...20mA | Selects the thermocouple or the mA input connected to the I/O module. Types J, K, T and E are nickel-alloy thermocouples, while Types R and S are platinum/rhodium-alloy thermocouples. |
| Input value | -101.0...2 000.0 | 0.1 | - | Displays the input value of the selected channel. |
| Input status | 0: Invalid 1: OK | - | - | Displays the input status of the selected channel. |

6.1.4 IEC 61850

The user can enable the IEC 61850 protocol in device models that support this protocol at *Communication* → *Protocols* → *IEC61850*. AQ-21x frame units support Edition 1 of IEC 61850. AQ-25x frame units support both Edition 1 and 2 of IEC61850. The following services are supported by IEC 61850 in Arcteq devices:

- Up to six data sets (predefined data sets can be edited with the IEC 61850 tool in AQtivate)
- Report Control Blocks (both buffered and unbuffered reporting)
- Control ('Direct operate with normal security', 'Select before operate with normal security', 'Direct with enhanced security' and 'Select before operate with enhanced security' control sequences)
- Disturbance recording file transfer
- GOOSE

- Time synchronization

The device's current IEC 61850 setup can be viewed and edited with the IEC61850 tool (*Tools* → *Communication* → *IEC 61850*). By browsing the 61850 tree one can see the full list of available logical nodes in the Arcteq implementation.

Settings.

The general setting parameters for the IEC 61850 protocol are visible both in AQtivate and in the local HMI. The settings are described in the table below.

Table. 6.1.4 - 127. General settings.

| Name | Range | Step | Default | Description |
|----------------------------|---------------------------|---------|----------------|--|
| Enable IEC 61850 | 0: Disabled 1: Enabled | - | 0: Disabled | Enables and disables the IEC 61850 communication protocol. |
| IP port | 0...65 535 | 1 | 102 | Defines the IP port used by the IEC 61850 protocol. The standard (and default) port is 102. |
| General deadband | 0.1...10.0% | 0.1% | 2% | Determines the general data reporting deadband settings. |
| Active energy deadband | 0.1...1000.0kWh | 0.1kWh | 2kWh | Determines the data reporting deadband settings for this measurement. |
| Reactive energy deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Active power deadband | 0.1...1000.0kW | 0.1kW | 2kW | Determines the data reporting deadband settings for this measurement. |
| Reactive power deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Apparent power deadband | 0.1...1000.0kVA | 0.1kVA | 2kVA | Determines the data reporting deadband settings for this measurement. |
| Power factor deadband | 0.01...0.99 | 0.01 | 0.05 | Determines the data reporting deadband settings for this measurement. |
| Frequency deadband | 0.01...1.00Hz | 0.01Hz | 0.1Hz | Determines the data reporting deadband settings for this measurement. |
| Current deadband | 0.01...50.00A | 0.01A | 5A | Determines the data reporting deadband settings for this measurement. |
| Residual current deadband | 0.01...50.00A | 0.01A | 0.2A | Determines the data reporting deadband settings for this measurement. |
| Voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Residual voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Angle measurement deadband | 0.1...5.0deg | 0.1deg | 1deg | Determines the data reporting deadband settings for this measurement. |
| Integration time | 0...10 000ms | 1ms | 0ms | Defines the integration time of the protocol. If this parameter is set to "0 ms", no integration time is in use. |
| Reconfigure GOOSE | 0: - 1: Reconfigure | - | 0: - | Reconfigures the GOOSE. |
| Enable GOOSE subscriber | 0: Disabled 1: Enabled | - | 0: Disabled | Enabled and disables the GOOSE subscriber. |

For more information on the IEC 61850 communication protocol support, please refer to the conformance statement documents (www.arcteq.fi/downloads/ → AQ-200 series → Resources).

6.1.5 GOOSE

Arcteq relays support both GOOSE publisher and GOOSE subscriber. GOOSE subscriber is enabled with the "GOOSE subscriber enable" parameter at *Communication* → *Protocols* → *IEC 61850/GOOSE*. The GOOSE inputs are configured using either the local HMI or the AQtivate software.

There are up to 64 GOOSE inputs available for use. Each of the GOOSE inputs also has a corresponding input quality signal which can also be used in internal logic. The quality is good, when the input quality is low (that is, when the quality is marked as "0"). The value of the input quality can increase as a result of a GOOSE time-out or a configuration error, for example. The status and quality of the various logical input signals can be viewed at the *GOOSE IN status* and *GOOSE IN quality* tabs at *Control* → *Device I/O* → *Logical signals*.

GOOSE input settings

The table below presents the different settings available for all 64 GOOSE inputs.

Table. 6.1.5 - 128. GOOSE input settings.

| Name | Range | Step | Default | Description |
|------------------------------------|--|------|------------|--|
| In use | 0: No 1: Yes | - | 0: No | Enables and disables the GOOSE input in question. |
| Application ID ("AppID") | 0x0...0x3FFF | 0x1 | 0x0 | Defines the application ID that will be matched with the publisher's GOOSE control block. |
| Configuration revision ("ConfRev") | 1...2 ³² -1 | 1 | 1 | Defines the configuration revision that will be matched with the publisher's GOOSE control block. |
| Data index ("DataIdx") | 0...99 | 1 | - | Defines the data index of the value in the matched published frame. It is the status of the GOOSE input. |
| NextIdx is quality | 0: No 1: Yes | - | 0: No | Selects whether or not the next received input is the quality bit of the GOOSE input. |
| Data type | 0: Boolean 1: Integer 2: Unsigned 3: Floating point | - | 0: Boolean | Selects the data type of the GOOSE input. |

Setting the publisher

The configuration of the GOOSE publisher is done using the IEC 61850 tool in AQtivate (*Tools* → *Communication* → *IEC 61850*). Refer to *AQtivate-200 Instruction manual* for more information on how to set up GOOSE publisher.

6.1.6 IEC 103

IEC 103 is the shortened form of the international standard IEC 60870-5-103. The AQ-200 series units are able to run as a secondary (slave) station. The IEC 103 protocol can be selected for the serial ports that are available in the device. A primary (master) station can then communicate with the Arcteq device and receive information by polling from the slave device. The transfer of disturbance recordings is not supported.

NOTE: Once the configuration file has been loaded, the IEC 103 map of the relay can be found in the AQtivate software (*Tools* → *IEC 103 map*).

The following table presents the setting parameters for the IEC 103 protocol.

| Name | Range | Step | Default | Description |
|----------------------|--------------|------|---------|---|
| Slave address | 1...254 | 1 | 1 | Defines the IEC 103 slave address for the unit. |
| Measurement interval | 0...60 000ms | 1ms | 2000ms | Defines the interval for the measurements update. |

6.1.7 DNP3

DNP3 is a protocol standard which is controlled by the DNP Users Group (www.dnp.org). The implementation of a DNP3 slave is compliant with the DNP3 subset (level) 2, but it also contains some functionalities of the higher levels. For detailed information please refer to the DNP3 Device Profile document (www.arcteq.fi/downloads/ → AQ-200 series → Resources).

Settings

The following table describes the DNP3 setting parameters.

Table. 6.1.7 - 129. Settings.

| Name | Range | Step | Default | Description |
|-----------------------------------|---------------------------|------|-------------|--|
| Enable DNP3 TCP | 0: Disabled 1: Enabled | - | 0: Disabled | Enables and disables the DNP3 TCP communication protocol when the Ethernet port is used for DNP3. If a serial port is used, the DNP3 protocol can be enabled from <i>Communication</i> → <i>DNP3</i> . |
| IP port | 0...65 535 | 1 | 20 000 | Defines the IP port used by the protocol. |
| Slave address | 1...65 519 | 1 | 1 | Defines the DNP3 slave address of the unit. |
| Master address | 1...65 534 | 1 | 2 | Defines the address for the allowed master. |
| Link layer time-out | 0...60 000ms | 1ms | 0ms | Defines the length of the time-out for the link layer. |
| Link layer retries | 1...20 | 1 | 1 | Defines the number of retries for the link layer. |
| Diagnostic - Error counter | 0...2 ³² -1 | 1 | - | Counts the total number of errors in received and sent messages. |
| Diagnostic - Transmitted messages | 0...2 ³² -1 | 1 | - | Counts the total number of transmitted messages. |
| Diagnostic - Received messages | 0...2 ³² -1 | 1 | - | Counts the total number of received messages. |

Default variations

Table. 6.1.7 - 130. Default variations.

| Name | Range | Default | Description |
|-------------------------------|----------------------|----------|--|
| Group 1 variation (BI) | 0: Var 1 1: Var 2 | 0: Var 1 | Selects the variation of the binary signal. |
| Group 2 variation (BI change) | 0: Var 1 1: Var 2 | 1: Var 2 | Selects the variation of the binary signal change. |
| Group 3 variation (DBI) | 0: Var 1 1: Var 2 | 0: Var 1 | Selects the variation of the double point signal. |

| Name | Range | Default | Description |
|----------------------------------|--|----------|---|
| Group 4 variation (DBI change) | 0: Var 1 1: Var 2 | 1: Var 2 | Selects the variation of the double point signal. |
| Group 20 variation (CNTR) | 0: Var 1 1: Var 2 2: Var 5 3: Var 6 | 0: Var 1 | Selects the variation of the control signal. |
| Group 22 variation (CNTR change) | 0: Var 1 1: Var 2 2: Var 5 3: Var 6 | 2: Var 5 | Selects the variation of the control signal change. |
| Group 30 variation (AI) | 0: Var 1 1: Var 2 2: Var 3 3: Var 4 4: Var 5 | 4: Var 5 | Selects the variation of the analog signal. |
| Group 32 variation (AI change) | 0: Var 1 1: Var 2 2: Var 3 3: Var 4 4: Var 5 5: Var 7 | 4: Var 5 | Selects the variation of the analog signal change. |

Setting the analog change deadbands

Table. 6.1.7 - 131. Analog change deadband settings.

| Name | Range | Step | Default | Description |
|----------------------------|------------------|---------|---------|---|
| General deadband | 0.1...10.0% | 0.1% | 2% | Determines the general data reporting deadband settings. |
| Active energy deadband | 0.1...1000.0kWh | 0.1kWh | 2kWh | Determines the data reporting deadband settings for this measurement. |
| Reactive energy deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Active power deadband | 0.1...1000.0kW | 0.1kW | 2kW | Determines the data reporting deadband settings for this measurement. |
| Reactive power deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Apparent power deadband | 0.1...1000.0kVA | 0.1kVA | 2kVA | Determines the data reporting deadband settings for this measurement. |
| Power factor deadband | 0.01...0.99 | 0.01 | 0.05 | Determines the data reporting deadband settings for this measurement. |
| Frequency deadband | 0.01...1.00Hz | 0.01Hz | 0.1Hz | Determines the data reporting deadband settings for this measurement. |
| Current deadband | 0.01...50.00A | 0.01A | 5A | Determines the data reporting deadband settings for this measurement. |
| Residual current deadband | 0.01...50.00A | 0.01A | 0.2A | Determines the data reporting deadband settings for this measurement. |
| Voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Residual voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Angle measurement deadband | 0.1...5.0deg | 0.1deg | 1deg | Determines the data reporting deadband settings for this measurement. |
| Integration time | 0...10 000ms | 1ms | - | Displays the integration time of the protocol. |

6.1.8 IEC 101/104

The standards IEC 60870-5-101 and IEC 60870-5-104 are closely related. Both are derived from the IEC 60870-5 standard. On the physical layer the IEC 101 protocol uses serial communication whereas the IEC 104 protocol uses Ethernet communication. The IEC 101/104 implementation works as a slave in the unbalanced mode.

For detailed information please refer to the IEC 101/104 interoperability document (www.arcteq.fi/downloads/ → AQ-200 series → Resources → "AQ-200 IEC101 & IEC104 interoperability").

IEC 101 settings

Table. 6.1.8 - 132. IEC 101 settings.

| Name | Range | Step | Default | Description |
|---------------------------------|---------------|------|---------|--|
| Common address of ASDU | 0...65 534 | 1 | 1 | Defines the common address of the application service data unit (ASDU) for the IEC 101 communication protocol. |
| Common address of ASDU size | 1...2 | 1 | 2 | Defines the size of the common address of ASDU. |
| Link layer address | 0...65 534 | 1 | 1 | Defines the address for the link layer. |
| Link layer address size | 1...2 | 1 | 2 | Defines the address size of the link layer. |
| Information object address size | 2...3 | 1 | 3 | Defines the address size of the information object. |
| Cause of transmission size | 1...2 | 1 | 2 | Defines the cause of transmission size |

IEC 104 settings

Table. 6.1.8 - 133. IEC 104 settings.

| Name | Range | Step | Default | Description |
|------------------------|---------------------------------|------|----------------|--|
| IEC 104 enable | 0: Disabled 1: Enabled | - | 0: Disabled | Enables and disables the IEC 104 communication protocol. |
| IP port | 0...65 535 | 1 | 2404 | Defines the IP port used by the protocol. |
| Common address of ASDU | 0...65 534 | 1 | 1 | Defines the common address of the application service data unit (ASDU) for the IEC 104 communication protocol. |

Measurement scaling coefficients

The measurement scaling coefficients are available for the following measurements, in addition to the general measurement scaling coefficient:

- Active energy
- Reactive energy
- Active power
- Reactive power
- Apparent power
- Power factor
- Frequency

- Current
- Residual current
- Voltage
- Residual voltage
- Angle

The range is the same for all of the scaling coefficients. By default, there is no scaling.

- No scaling
- 1/10
- 1/100
- 1/1000
- 1/10 000
- 1/100 000
- 1/1 000 000
- 10
- 100
- 1000
- 10 000
- 100 000
- 1 000 000

Deadband settings.

Table. 6.1.8 - 134. Analog change deadband settings.

| Name | Range | Step | Default | Description |
|----------------------------|------------------|---------|---------|---|
| General deadband | 0.1...10.0% | 0.1% | 2% | Determines the general data reporting deadband settings. |
| Active energy deadband | 0.1...1000.0kWh | 0.1kWh | 2kWh | Determines the data reporting deadband settings for this measurement. |
| Reactive energy deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Active power deadband | 0.1...1000.0kW | 0.1kW | 2kW | Determines the data reporting deadband settings for this measurement. |
| Reactive power deadband | 0.1...1000.0kVar | 0.1kVar | 2kVar | Determines the data reporting deadband settings for this measurement. |
| Apparent power deadband | 0.1...1000.0kVA | 0.1kVA | 2kVA | Determines the data reporting deadband settings for this measurement. |
| Power factor deadband | 0.01...0.99 | 0.01 | 0.05 | Determines the data reporting deadband settings for this measurement. |
| Frequency deadband | 0.01...1.00Hz | 0.01Hz | 0.1Hz | Determines the data reporting deadband settings for this measurement. |
| Current deadband | 0.01...50.00A | 0.01A | 5A | Determines the data reporting deadband settings for this measurement. |
| Residual current deadband | 0.01...50.00A | 0.01A | 0.2A | Determines the data reporting deadband settings for this measurement. |
| Voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Residual voltage deadband | 0.01...5000.00V | 0.01V | 200V | Determines the data reporting deadband settings for this measurement. |
| Angle measurement deadband | 0.1...5.0deg | 0.1deg | 1deg | Determines the data reporting deadband settings for this measurement. |
| Integration time | 0...10 000ms | 1ms | - | Displays the integration time of the protocol. |

6.1.9 SPA

The device can act as a SPA slave. SPA can be selected as the communication protocol for the COM B port (RS-485 port in the CPU module). When the device includes a serial RS-232 card connector, the SPA protocol can also be selected as the communication protocol for the COM E and COM F ports. Please refer to the chapter "Construction and installation" in the device manual to see the connections for these modules.

The data transfer rate of SPA is 9600 bps, but it can also be set to 19 200 bps or 38 400 bps. As a slave the device sends data on demand or by sequenced polling. The available data can be measurements, circuit breaker states, function starts, function trips, etc. The full SPA signal map can be found in AQtivate (*Tools* → *SPA map*).

The SPA event addresses can be found at *Tools* → *Events and logs* → *Event list*.

NOTE!



To access SPA map and event list, an .aqc configuration file should be downloaded from the relay.

6.2 Analog fault registers

At *Communication* → *General I/O* → *Analog fault registers* the user can set up to twelve (12) channels to record the measured value when a protection function starts or trips. These values can be read in two ways: locally from this same menu, or through a communication protocol if one is in use.

The following table presents the setting parameters available for the 12 channels.

Table. 6.2 - 135. Fault register settings.

| Name | Range | Step | Default | Description |
|-----------------------|--|------|----------------|--|
| Select record source | 0: Not in use 1...12: l>, l>>, l>>>, l>>>> (IL1, IL2, IL3) 13...24: ld>, ld>>, ld>>>, ld>>>> (IL1, IL2, IL3) 25...28: l0>, l0>>, l0>>>, l0>>>> (l0) 29...32: l0d>, l0d>>, l0d>>>, l0d>>>> (l0) 33: FLX | - | 0: Not in use | Selects the protection function and its stage to be used as the source for the fault register recording. The user can choose between non-directional overcurrent, directional overcurrent, non-directional earth fault, directional earth fault, and fault locator functions. |
| Select record trigger | 0: TRIP signal 1: START signal 2: START and TRIP signals | - | 0: TRIP signal | Selects what triggers the fault register recording: the selected function's TRIP signal, its START signal, or either one. |
| Recorded fault value | - 1000 000.00...1 000 000.00 | 0.01 | - | Displays the recorded measurement value at the time of the selected fault register trigger. |

6.3 Real-time measurements to communication

With the *Real-time signals to communication* menu the user can report to SCADA measurements that are not normally available in the communication protocols mapping. Up to eight (8) magnitudes can be selected. The recorded value can be either a per-unit value or a primary value (set by the user).

Measurable values

Function block uses analog current and voltage measurement values. The relay uses these values as the basis when it calculates the primary and secondary values of currents, voltages, powers, impedances and other values.

Table. 6.3 - 136. Available measured values.

| Signals | Description |
|---|--|
| Currents | |
| IL1 (ff), IL2 (ff), IL3 (ff), I01 (ff), I02 (ff) | Fundamental frequency (RMS) current measurement values of phase currents and residual currents. |
| IL1 (TRMS), IL2 (TRMS), IL3 (TRMS), I01 (TRMS), I02 (TRMS) | TRMS current measurement values of phase currents and residual currents. |
| IL1, IL2, IL3, I01, I02 & 2 nd h., 3 rd h., 4 th h., 5 th h., 7 th h., 9 th h., 11 th h., 13 th h., 15 th h., 17 th h., 19 th h. | Magnitudes of the phase current components: 2 nd harmonic, 3 rd harmonic, 4 th harmonic, 5 th harmonic, 7 th harmonic, 9 th harmonic, 11 th harmonic, 13 th harmonic, 15 th harmonic, 17 th harmonic, 19 th harmonic current. |
| I1, I2, I0Z | Positive sequence current, negative sequence current and zero sequence current. |
| I0CalcMag | Residual current calculated from phase currents. |
| IL1Ang, IL2Ang, IL3Ang, I01Ang, I02Ang, I0CalcAng, I1Ang, I2Ang | Angles of each measured current. |
| Voltages | |
| UL1Mag, UL2Mag, UL3Mag, UL12Mag, UL23Mag, UL31Mag, U0Mag, U0CalcMag | Magnitudes of phase voltages, phase-to-phase voltages and residual voltages. |
| U1 Pos.seq V mag, U2 Neg.seq V mag | Positive and negative sequence voltages. |
| UL1Ang, UL2Ang, UL3Ang, UL12Ang, UL23Ang, UL31Ang, U0Ang, U0CalcAng | Angles of phase voltages, phase-to-phase voltages and residual voltages. |
| U1 Pos.seq V Ang, U2 Neg.seq V Ang | Positive and negative sequence angles. |
| Powers | |
| S3PH, P3PH, Q3PH | Three-phase apparent, active and reactive power. |
| SL1, SL2, SL3, PL1, PL2, PL3, QL1, QL2, QL3 | Phase apparent, active and reactive powers. |
| tanfi3PH, tanfiL1, tanfiL2, tanfiL3 | Tan (ϕ) of three-phase powers and phase powers. |
| cosfi3PH, cosfiL1, cosfiL2, cosfiL3 | Cos (ϕ) of three-phase powers and phase powers. |
| Impedances and admittances | |
| RL12, RL23, RL31, XL12, XL23, XL31, RL1, RL2, RL3, XL1, XL2, XL3, Z12, Z23, Z31, ZL1, ZL2, ZL3 | Phase-to-phase and phase-to-neutral resistances, reactances and impedances. |

| Signals | Description |
|---|--|
| Z12Ang, Z23Ang, Z31Ang, ZL1Ang, ZL2Ang, ZL3Ang | Phase-to-phase and phase-to-neutral impedance angles. |
| Rseq, Xseq, Zseq RseqAng, XseqAng, ZseqAng | Positive sequence resistance, reactance and impedance values and angles. |
| GL1, GL2, GL3, G0 BL1, BL2, BL3, B0 YL1, YL2, YL3, Y0 | Conductances, susceptances and admittances. |
| YL1angle, YL2angle, YL3angle, Y0angle | Admittance angles. |
| Others | |
| System f. | Used tracking frequency at the moment. |
| Ref f1 | Reference frequency 1. |
| Ref f2 | Reference frequency 2. |
| M thermal T | Motor thermal temperature. |
| F thermal T | Feeder thermal temperature. |
| T thermal T | Transformer thermal temperature. |
| RTD meas 1...16 | RTD measurement channels 1...16. |
| Ext RTD meas 1...8 | External RTD measurement channels 1...8 (ADAM module). |

Settings

Table. 6.3 - 137. Settings.

| Name | Range | Step | Default | Description |
|---------------------------------|---|-------|-------------|--|
| Measurement value recorder mode | 0: Disabled 1: Activated | - | 0: Disabled | Activates and disables the real-time signals to communication. |
| Scale current values to primary | 0: No 1: Yes | - | 0: No | Selects whether or not values are scaled to primary. |
| Slot X magnitude selection | 0: Currents 1: Voltages 2: Powers 3: Impedance (ZRX) and admittance (YGB) 4: Others | - | 0: Currents | Selects the measured magnitude category of the chosen slot. |
| Slot X magnitude | Described in table above ("Available measured values") | - | - | Selects the magnitude in the previously selected category. |
| Magnitude X | -10 000 000.000...10 000 000.000 | 0.001 | - | Displays the measured value of the selected magnitude of the selected slot. The unit depends on the selected magnitude (either amperes, volts, or per-unit values). |

7 Connections and application examples

7.1 Connections of AQ-E215

Figure. 7.1 - 101. The AQ-E215 variant without add-on modules.

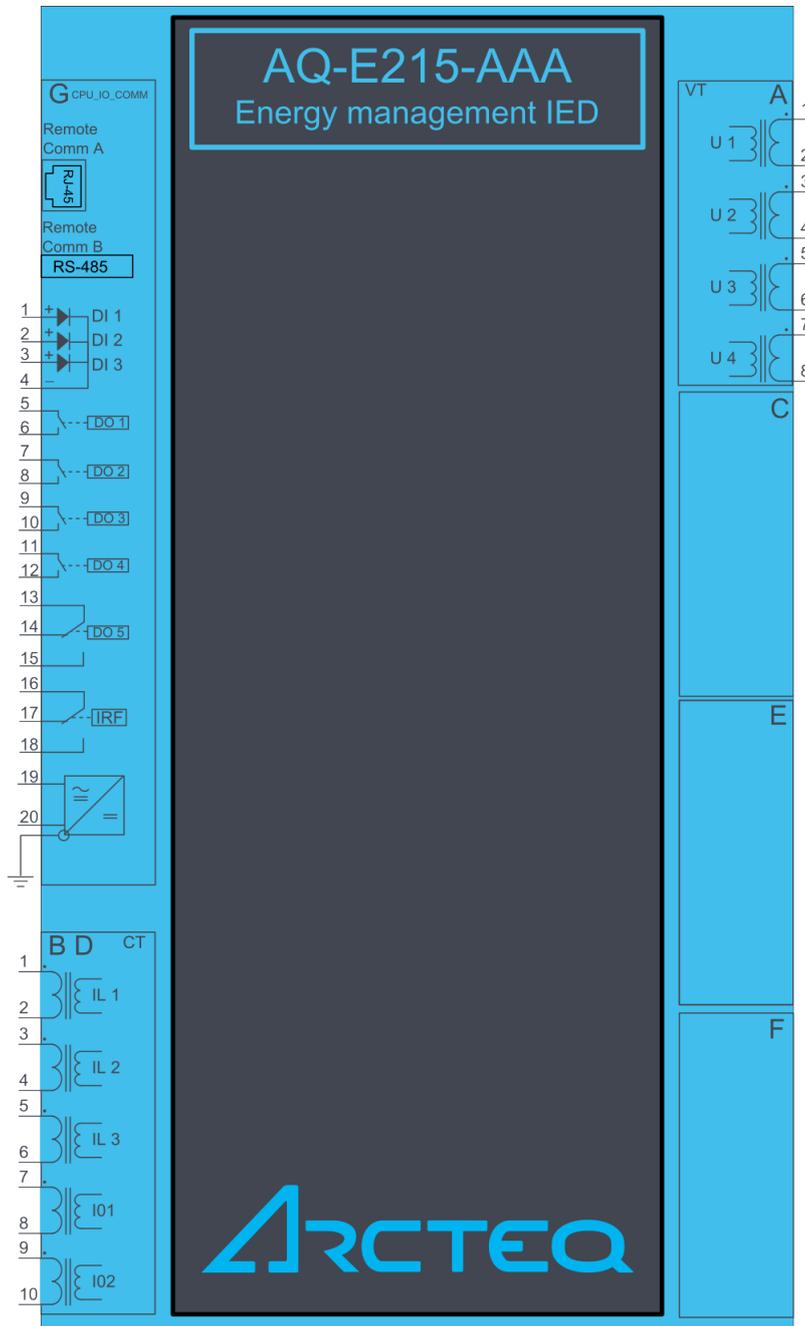


Figure. 7.1 - 102. The AQ-E215 variant with digital input and output modules.

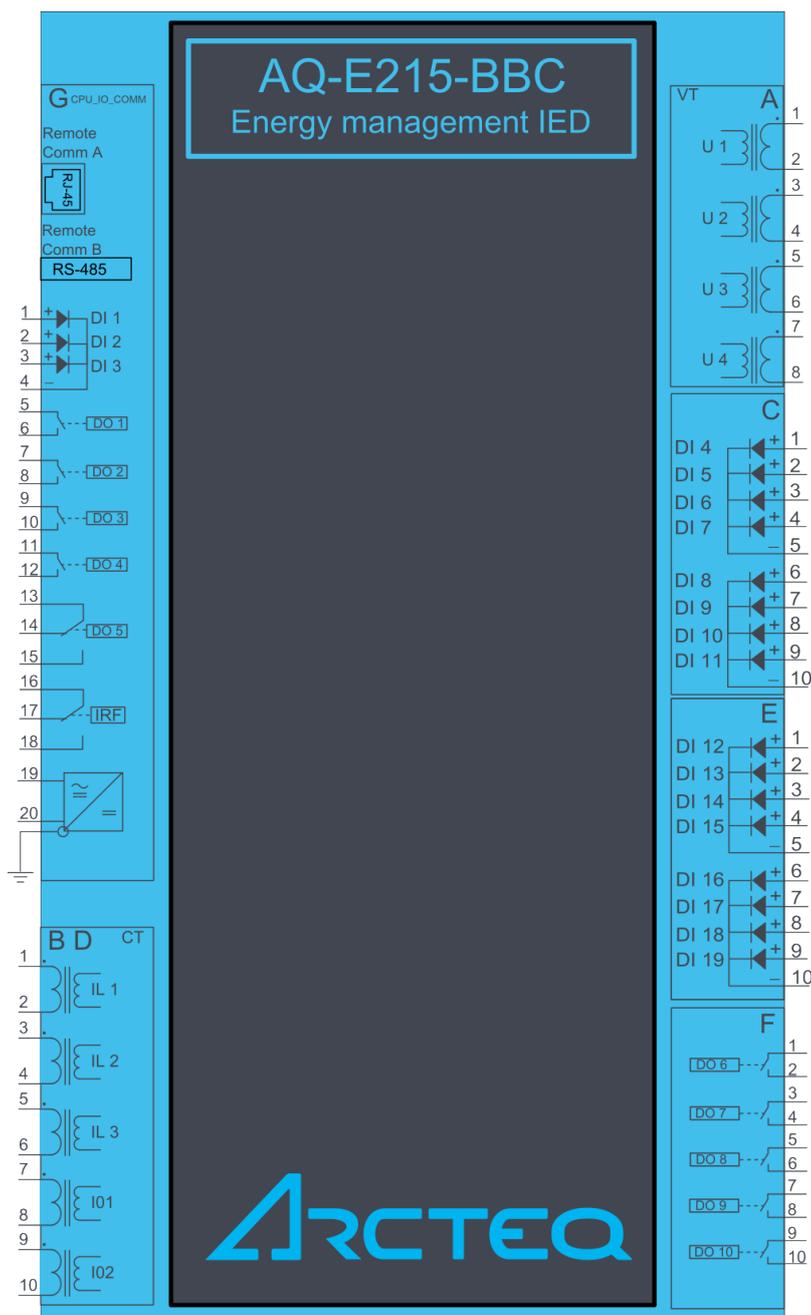
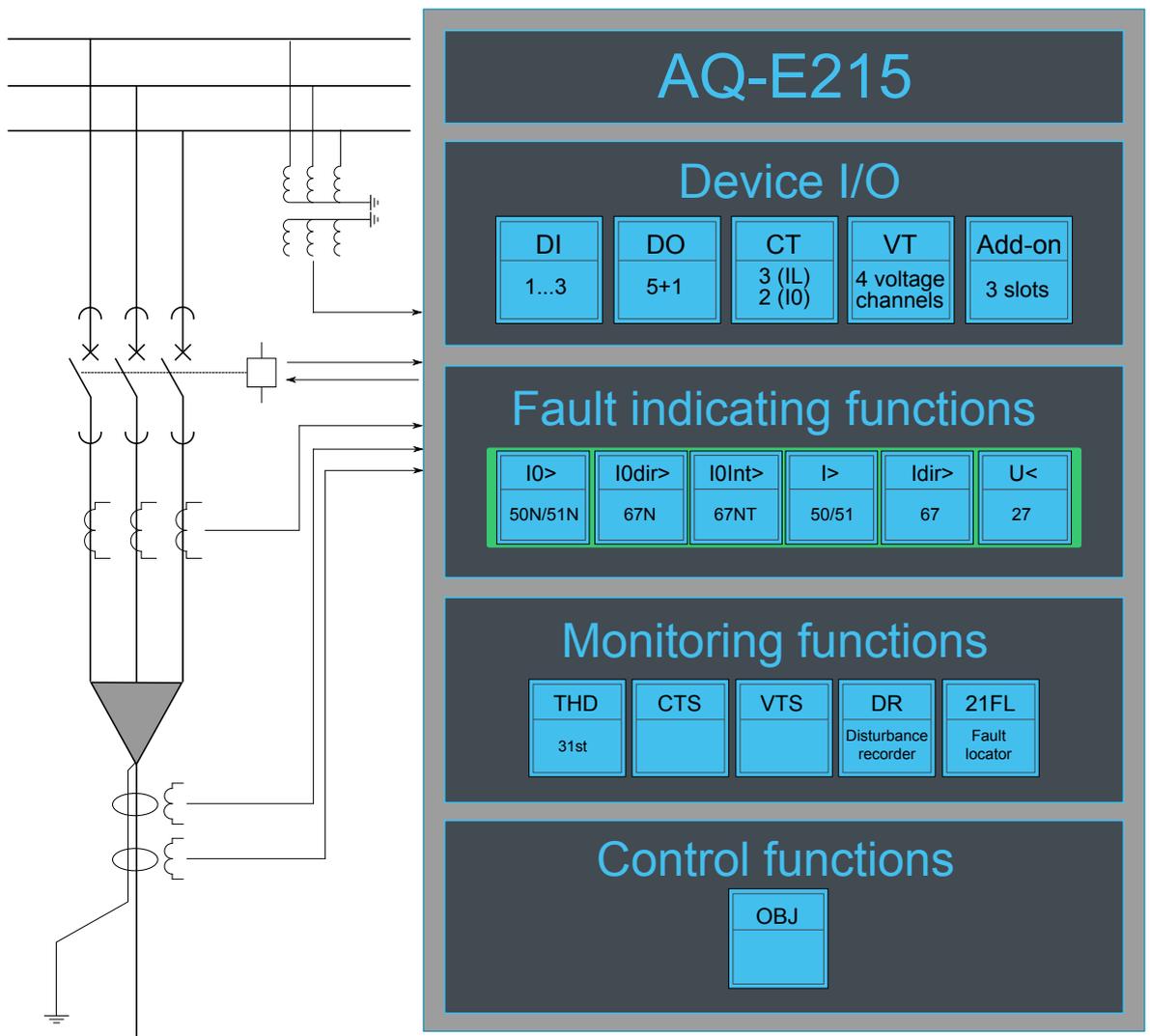


Figure. 7.1 - 103. AQ-E215 application example with function block diagram.

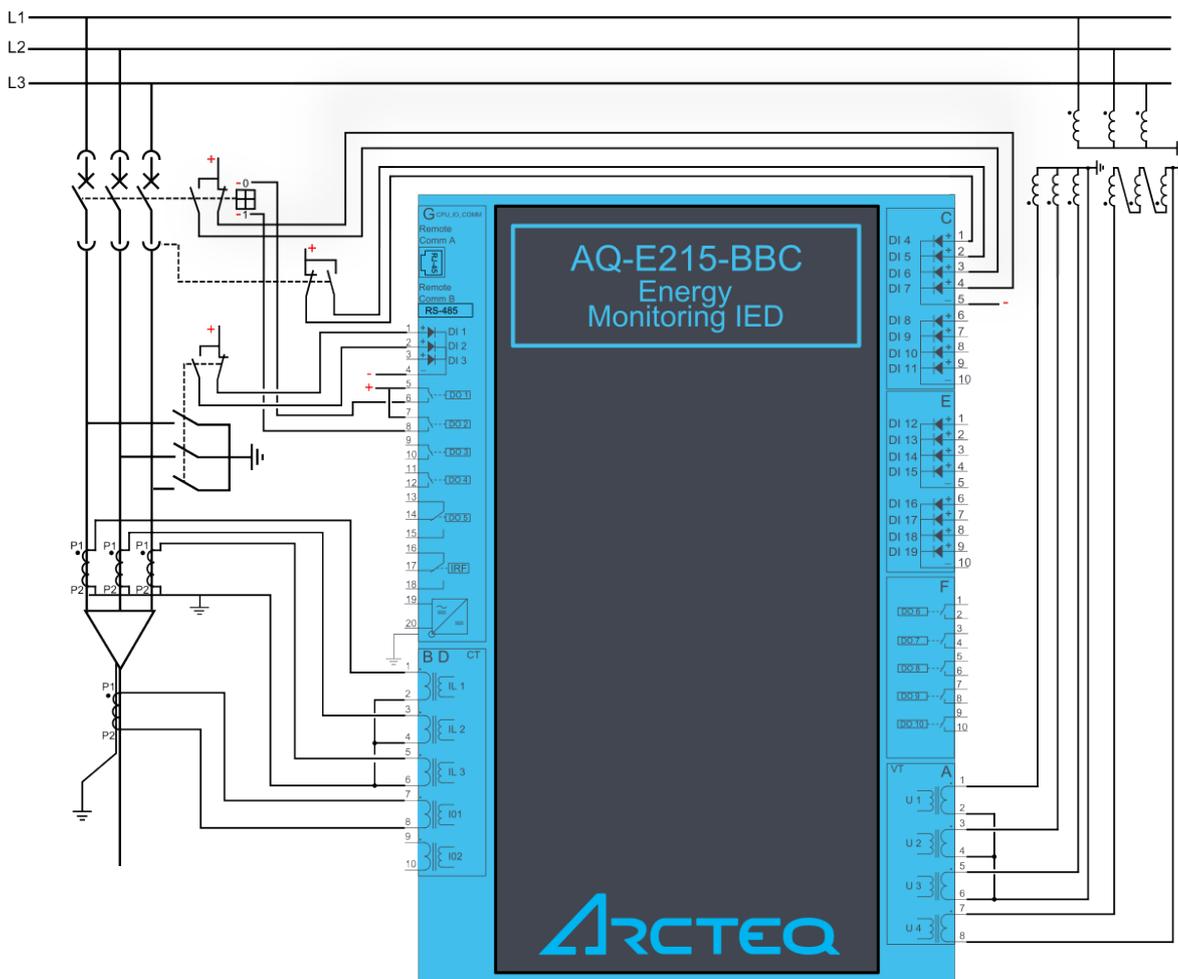


7.2 Application example and its connections

This chapter presents an application example for the energy monitoring IED.

Since three line-to-neutral voltages and the zero sequence voltage (U4) are connected, this application uses the voltage measurement mode "3LN+U0" (see the image below). Additionally, the three phase currents and the residual current (I01) are also connected. The digital inputs are connected to indicate the breaker status, while the digital outputs are used for breaker control.

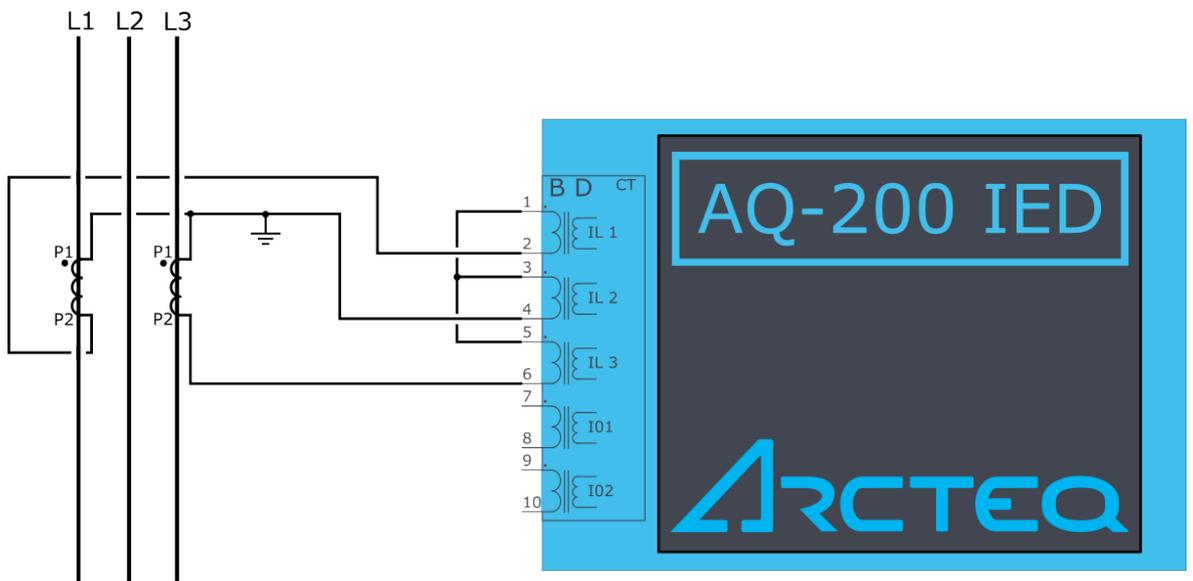
Figure. 7.2 - 104. Application example and its connections.



7.3 Two-phase, three-wire ARON input connection

This chapter presents the two-phase, three-wire ARON input connection for any AQ-200 series IED with a current transformer. The example is for applications with protection CTs for just two phases. The connection is suitable for both motor and feeder applications.

Figure. 7.3 - 105. ARON connection.



The ARON input connection can measure the load symmetrically despite the fact that one of the CTs is missing from the installation. Normally, Phase 2 does not have a current transformer installed as an external fault is much more likely to appear on Lines 1 or 3.

A fault between Line 2 and the earth cannot be detected when the ARON input connection is used. In order to detect an earth fault in Phase 2, a cable core CT must be used.

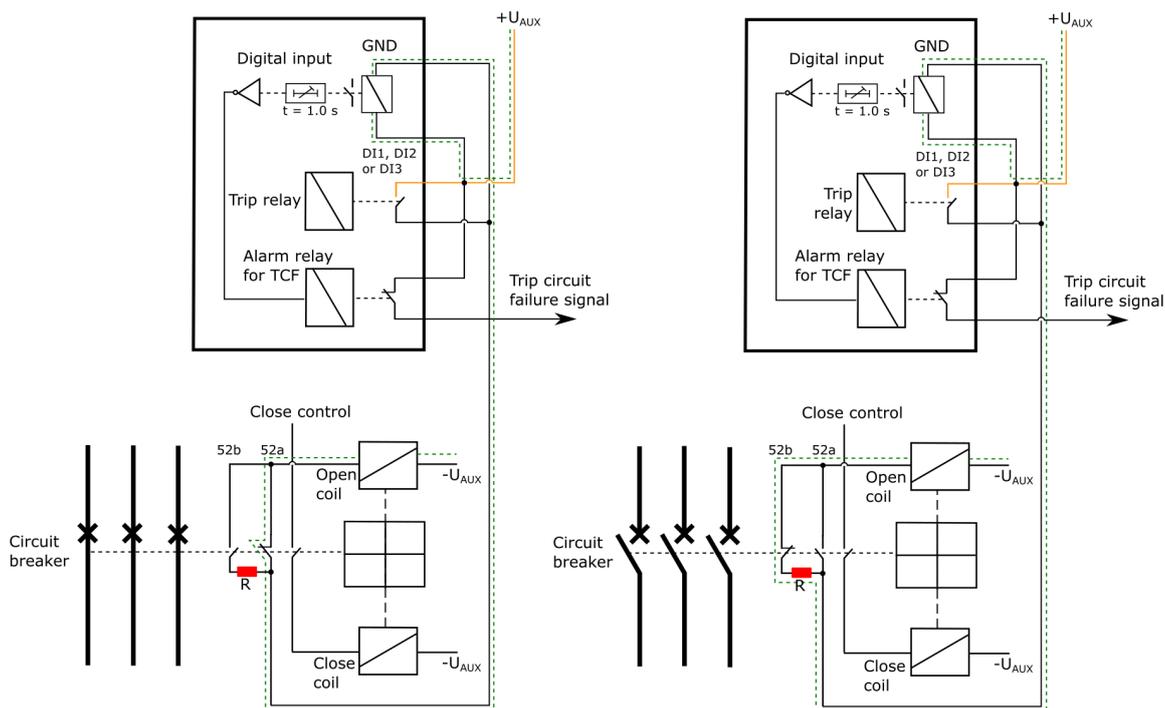
7.4 Trip circuit supervision (95)

Trip circuit supervision is used to monitor the wiring from auxiliary power supply, through the IED's digital output, and all the way to the open coil of the breaker. It is recommended to supervise the health of the trip circuit when breaker is closed.

Trip circuit supervision with one digital input and one non-latched trip output

The figure below presents an application scheme for trip circuit supervision with one digital input and a non-latched trip output. With this connection the current keeps flowing to the open coil of the breaker via the breaker's closing auxiliary contacts (52b) even after the circuit breaker is opened. This requires a resistor which reduces the current: this way the coil is not energized and the relay output does not need to cut off the coil's inductive current.

Figure. 7.4 - 106. Trip circuit supervision with one DI and one non-latched trip output.



Note that the digital input that monitors the circuit is normally closed, and the same applies to the alarm relay if one is used. For monitoring and especially trip circuit supervision purposes it is recommended to use a normally closed contact to confirm the wiring's condition. An active digital input generates a less than 2 mA current to the circuit, which is usually small enough not to make the breaker's open coil operate.

When the trip relay is controlled and the circuit breaker is opening, the digital input is shorted by the trip contact as long as the breaker opens. Normally, this takes about 100 ms if the relay is non-latched. A one second activation delay should, therefore, be added to the digital input. An activation delay that is slightly longer than the circuit breaker's operations time should be enough. When circuit breaker failure protection (CBFP) is used, adding its operation time to the digital input activation time is useful. The whole digital input activation time is, therefore, $t_{DI} = t_{CB} + t_{IEDrelease} + t_{CBFP}$.

The image below presents the necessary settings when using a digital input for trip circuit supervision. The input's polarity must be NC (normally closed) and a one second delay is needed to avoid nuisance alarm while the circuit breaker is controlled open.

Figure. 7.4 - 107. Settings for a digital input used for trip circuit supervision.

Non-latched outputs are seen as hollow circles in the output matrix, whereas latched contacts are painted. See the image below of an output matrix where a non-latched trip contact is used to open the circuit breaker.

Figure. 7.4 - 108. Non-latched trip contact.

| Inputs | OUT1 | OUT2 | OUT3 | OUT4 | OUT5 |
|--------------------|------|------|------|------|------|
| I> START (General) | | | | | |
| I> START(A) | | | | | |
| I> START(B) | | | | | |
| I> START(C) | | | | | |
| I> TRIP (General) | ○ | | | | |
| I> TRIP(A) | | | | | |
| I> TRIP(B) | | | | | |
| I> TRIP(C) | | | | | |
| I> BLOCKED | | | | | |

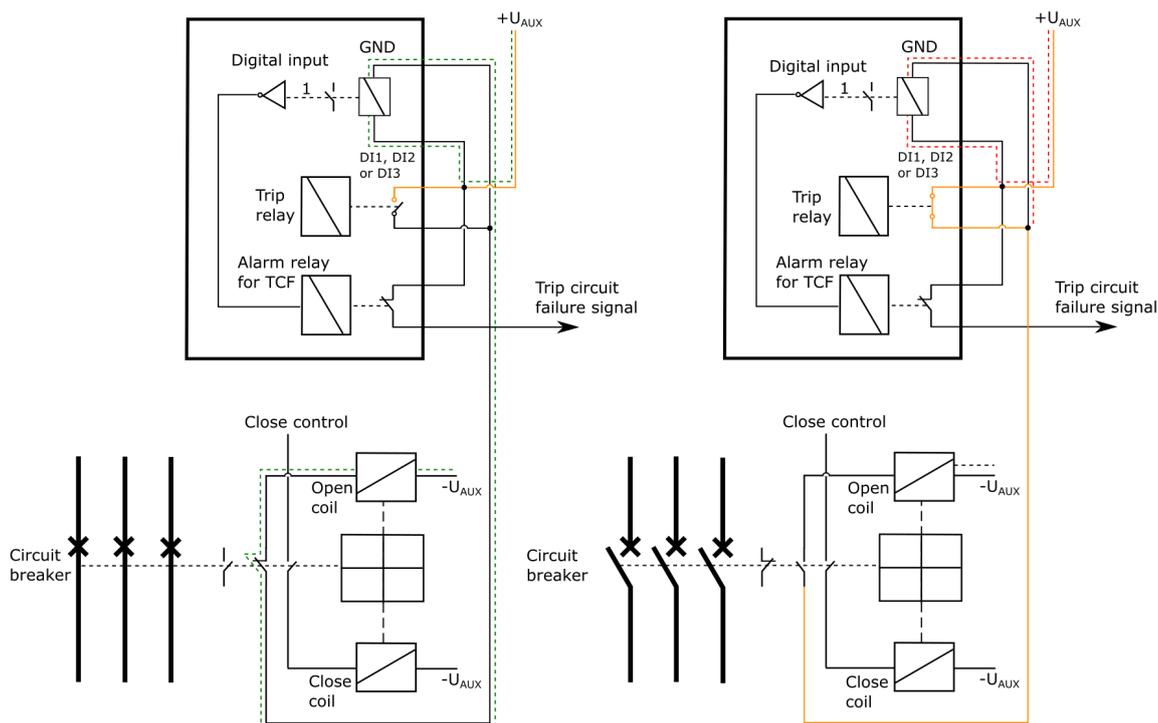
When the auto-reclosing function is used in feeder applications, the trip output contacts must be non-latched. Trip circuit supervision is generally easier and more reliable to build with non-latched outputs.

The open coil remains energized only as long as the circuit breaker is opened and the IED output releases. This takes approximately 100 ms depending on the size and type of the breaker. When the breaker opens, the auxiliary contacts open the inductive circuit; however, the trip contact does not open at the same time. The IED's output relay contact opens in under 50 ms or after a set release delay that takes place after the breaker is opened. This means that the open coil is energized for a while after the breaker has already opened. The coil could even be energized a moment longer if the circuit breaker failure protection has to be used and the incomer performs the trip.

Trip circuit supervision with one digital input and one connected, non-latched trip output

There is one main difference between non-latched and latched control in trip circuit supervision: when using the latched control, the trip circuit (in an open state) cannot be monitored as the digital input is shorted by the IED's trip output.

Figure. 7.4 - 109. Trip circuit supervision with one DI and one latched output contact.

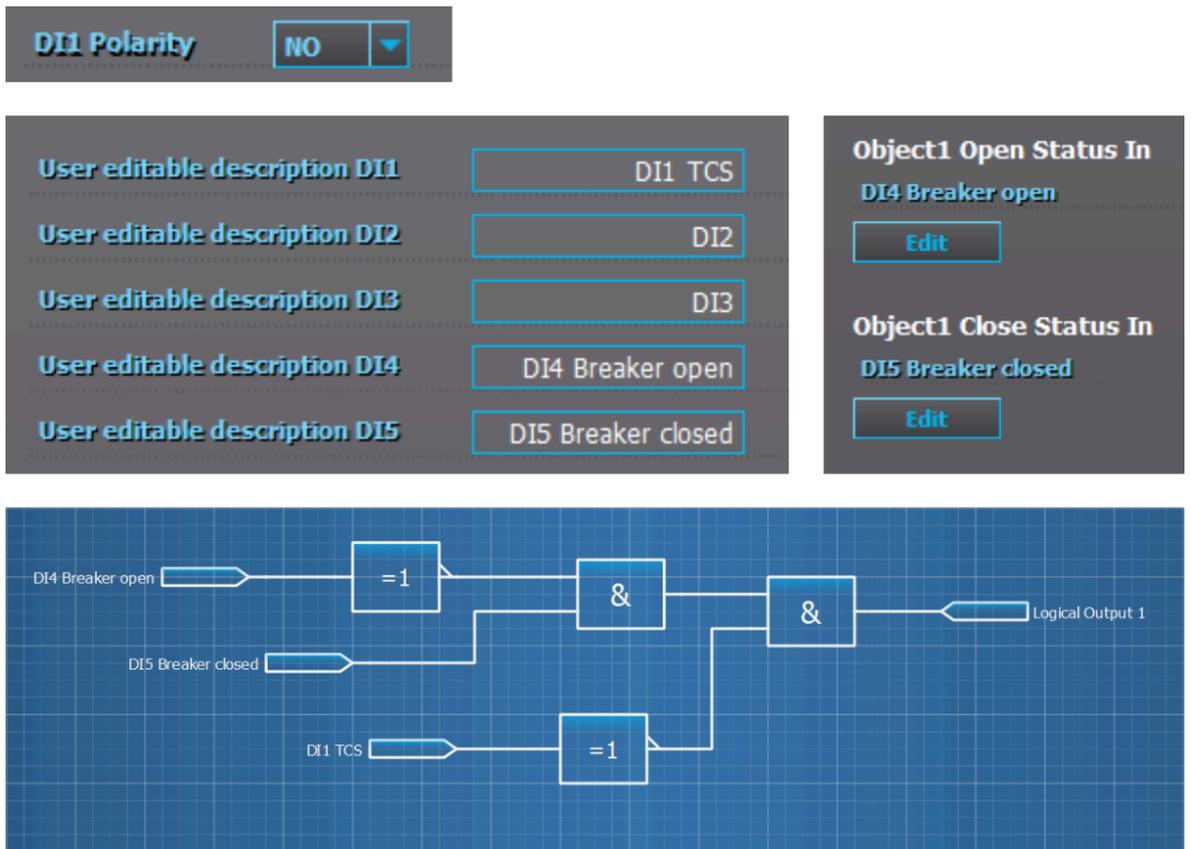


The trip circuit with a latched output contact can be monitored, but only when the circuit breaker's status is "Closed". Whenever the breaker is open, the supervision is blocked by an internal logic scheme. Its disadvantage is that the user does not know whether or not the trip circuit is intact when the breaker is closed again.

The following logic scheme (or similar) blocks the supervision alarm when the circuit breaker is open. The alarm is issued whenever the breaker is closed and whenever the inverted digital input ("TCS") activates. A normally closed digital input activates only when there is something wrong with the trip circuit and the auxiliary power goes off. Logical output can be used in the output matrix or in SCADA as the user wants.

The image below presents a block scheme when a non-latched trip output is not used.

Figure. 7.4 - 110. Example block scheme.



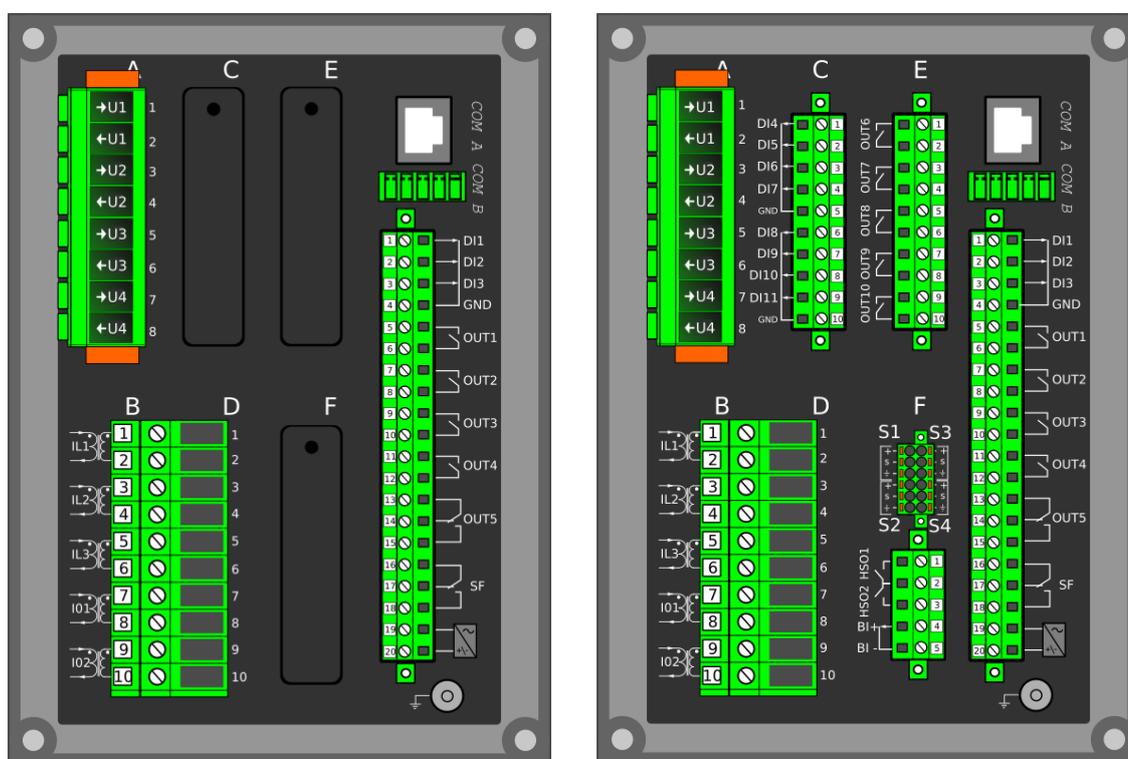
8 Construction and installation

8.1 Construction

AQ-X215 is a member of the modular and scalable AQ-200 series, and it includes three (3) configurable and modular add-on card slots. As a standard configuration the device includes the CPU module (which consists of the CPU, a number of inputs and outputs, and the power supply) as well as one separate voltage measurement module and one separate current measurement module.

The images below present the modules of both the non-optional model (AQ-X215-XXXXXXX-AAA, on the left) and the fully optional model (AQ-X215-XXXXXXX-BCD, on the right).

Figure. 8.1 - 111. Modular construction of AQ-X215.



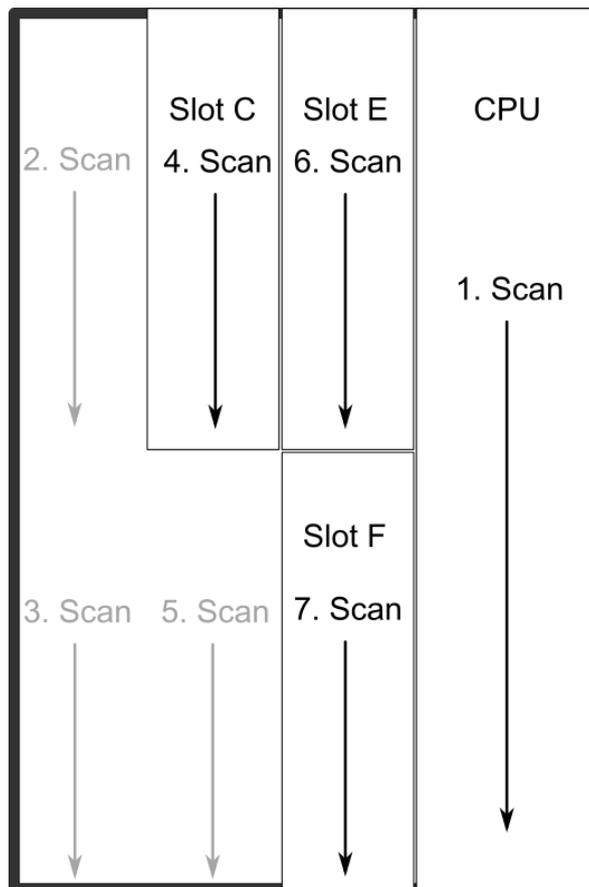
The modular structure of AQ-X215 allows for scalable solutions for different application requirements. In non-standard configurations Slots C, E and F accept all available add-on modules, such as digital I/O modules, integrated arc protection or another special module. The only difference between the slots affecting device scalability is that Slots E and F also support communication options.

When an add-on module is inserted into the device, the start-up scan searches for modules according to their type designation code. If the module location or content is not what the device expects, the IED does not take additional modules into account and instead issues a configuration error message. In field upgrades, therefore, the add-on module must be ordered from Arcteq Relays Ltd. or its representative who can then provide the module with its corresponding unlocking code to allow the device to operate correctly once the hardware configuration has been upgraded. This also means that the module's location in the device cannot be changed without updating the device configuration data which, again, requires the unlocking code.

When an I/O module is inserted into the device, the module location affects the naming of the I/O. The I/O scanning order in the start-up sequence is as follows: the CPU module I/O, Slot C, Slot E, and Slot F. This means that the digital input channels DI1, DI2 and DI3 as well as the digital output channels OUT1, OUT2, OUT3, OUT4 and OUT5 are always located in the CPU module. If additional I/O cards are installed, their location and card type affect the I/O naming.

The figure below presents the start-up hardware scan order of the device as well as the I/O naming principles.

Figure. 8.1 - 112. AQ-X215 hardware scanning and I/O naming principles.



1. Scan
The start-up system; detects and self-tests the CPU module, voltages, communication and the I/O; finds and assigns "DI1", "DI2", "DI3", "OUT1", "OUT2", "OUT3", "OUT4" and "OUT5".
2. Scan
Scans Slot A and finds the four channels of the VT module (fixed for AQ-X215). If the VTM is not found, the device issues an alarm.
3. Scan
Scans Slot B, which should always remain empty in AQ-X215 devices. If it is not empty, the device issues an alarm.
4. Scan
Scans Slot C, and moves to the next slot if Slot C is empty. If the scan finds an 8DI module (that is, a module with eight digital inputs), it reserves the designations "DI4", "DI5", "DI6", "DI7", "DI8", "DI9", "DI10" and "DI11" to this slot. If the scan finds a DO5 module (that is, a module with five digital outputs), it reserves the designations "OUT6", "OUT7", "OUT8", "OUT9" and "OUT10" to this slot. The I/O is then added if the type designation code (e.g. AQ-P215-PH0AAAA-BBC) matches with the existing modules in the device. If the code and the modules do not match, the device issues and alarm. An alarm is also issued if the device expects to find a module here but does not find one.

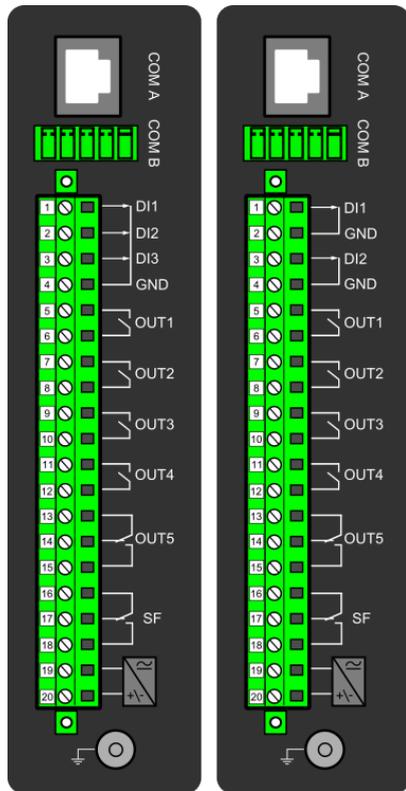
5. Scan
Scans Slot D and finds the five channels of the CT module (fixed for AQ-X215). If the CTM is not found, the device issues an alarm.
6. Scan
Scans Slot E, and moves to the next slot if Slot E is empty. If the scan finds an 8DI module, it reserves the designations "DI4", "DI5", "DI6", "DI7", "DI8", "DI9", "DI10" and "DI11" to this slot. If Slot C also has an 8DI module (and therefore has already reserved these designations), the device reserves the designations "DI12", "DI13", "DI14", "DI15", "DI16", "DI17", "DI18" and "DI19" to this slot. If the scan finds a 5DO module, it reserves the designations "OUT6", "OUT7", "OUT8", "OUT9" and "OUT10" to this slot. Again, if Slot C also has a 5DO and has therefore already reserved these designations, the device reserves the designations "OUT11", "OUT12", "OUT13", "OUT14" and "OUT15" to this slot. If the scan finds the arc protection module, it reserves the sensor channels ("S1", "S2", "S3", "S4"), the high-speed outputs ("HSO1", "HSO2"), and the digital input channel ("ArcBI") to this slot.
7. Scan
A similar operation to Scan 6 (checks which designations have been reserved by modules in previous slots and numbers the new ones accordingly).

Thus far this document has only explained the installation of I/O add-on cards to the option module slots. This is because all other module types are treated in a same way. For example, when an additional communication port is installed into the upper port of the communication module, its designation is Communication port 3 or higher, as Communication ports 1 and 2 already exist in the CPU module (which is scanned, and thus designated, first). After a communication port is detected, it is added into the device's communication space and its corresponding settings are enabled.

The fully optioned example case of AQ-X215-XXXXXX-BCD (the first image pair, on the right) has a total of 11 digital input channels available: three (DI1...DI3) in the CPU module, and eight (DI4...DI11) in Slot C. It also has a total of 10 digital output channels available: five (DO1...DO5) in the CPU module, and five (DO6...DO10) in Slot E. These same principles apply to all non-standard configurations in the AQ-X215 IED family.

8.2 CPU module

Figure. 8.2 - 113. CPU module.



Module connectors

Table. 8.2 - 138. Module connector descriptions.

| Connector | Description | |
|------------|---|--|
| COM A | Communication port A, or the RJ-45 port. Used for the setting tool connection and for IEC 61850, Modbus/TCP, IEC 104, DNP3 and station bus communications. | |
| COM B | Communication port B, or the RS-485 port. Used for the SCADA communications for the following protocols: Modbus/RTU, Modbus I/O, SPA, DNP3, IEC 101 and IEC 103. The pins have the following designations: Pin 1 = DATA +, Pin 2 = DATA -, Pin 3 = GND, Pins 4 & 5 = Terminator resistor enabled by shorting. | |
| | Model with 3 digital inputs | Model with 2 digital inputs |
| X 1 | Digital input 1, nominal threshold voltage 24 V, 110 V or 220 V. | Digital input 1, nominal threshold voltage 24 V, 110 V or 220 V. |
| X 2 | Digital input 2, nominal threshold voltage 24 V, 110 V or 220 V. | GND for digital input 1. |
| X 3 | Digital input 3, nominal threshold voltage 24 V, 110 V or 220 V. | Digital input 2, nominal threshold voltage 24 V, 110 V or 220 V. |
| X 4 | Common GND for digital inputs 1, 2 and 3. | GND for digital input 2. |
| X 5:6 | Output relay 1, with a normally open (NO) contact. | |
| X 7:8 | Output relay 2, with a normally open (NO) contact. | |
| X 9:10 | Output relay 3, with a normally open (NO) contact. | |
| X 11:12 | Output relay 4, with a normally open (NO) contact. | |
| X 13:14:15 | Output relay 5, with a changeover contact. | |

| Connector | Description |
|------------|---|
| X 16:17:18 | System fault's output relay, with a changeover contact. Pins 16 and 17 are closed when the unit has a system fault or is powered OFF. Pins 16 and 18 are closed when the unit is powered ON and there is no system fault. |
| X 19:20 | Power supply IN. Either 85...265 VAC/DC (model A; order code "H") or 18...75 DC (model B; order code "L"). Positive side (+) to Pin 20. |
| GND | The relay's earthing connector. |

By default, the CPU module (combining the CPU, the I/O and the power supply) is included in all AQ-2xx IEDs to provide two standard communication ports and the relay's basic digital I/O. The module can be ordered to include 2 or 3 digital inputs.

The current consumption of the digital inputs is 2 mA when activated, while the range of the operating voltage is 24 V/110 V/220 V depending on the ordered hardware. All digital inputs are scanned in 5 ms program cycles, and their pick-up and release delays as well as their NO/NC selection can be set with software. The digital output controls are also set by the user with software. By default, the digital outputs are controlled in 5 ms program cycles. All output contacts are mechanical. The rated voltage of the NO/NC outputs is 250 VAC/DC.

The auxiliary voltage is defined in the ordering code: the available power supply models available are A (85...265 VAC/DC) and B (18...75 DC). For further details, please refer to the "Auxiliary voltage" chapter in the "Technical data" section of this document.

Digital input settings

The settings described in the table below can be found at *Control* → *Device I/O* → *Digital input settings* in the relay settings.

Table. 8.2 - 139. Digital input settings.

| Name | Range | Step | Default | Description |
|----------------------|--|---------|-------------|--|
| Dlx Polarity | 0: NO (Normally open) 1: NC (Normally closed) | - | 0: NO | Selects whether the status of the digital input is 1 or 0 when the input is energized. |
| Dlx Activation delay | 0.000...1800.000 s | 0.001 s | 0.000 s | Defines the delay for the status change from 0 to 1. |
| Dlx Drop-off time | 0.000...1800.000 s | 0.001 s | 0.000 s | Defines the delay for the status change from 1 to 0. |
| Dlx AC mode | 0: Disabled 1: Enabled | - | 0: Disabled | Selects whether or not a 30-ms deactivation delay is added to account for alternating current. |

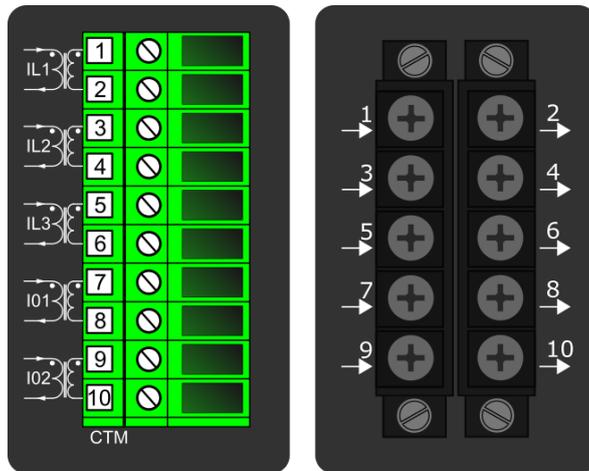
Scanning cycle

All digital inputs are scanned in a 5 ms cycle, meaning that the state of an input is updated every 0...5 milliseconds. When an input is used internally in the device (either in setting group change or logic), it takes additional 0...5 milliseconds to operate. Theoretically, therefore, it takes 0...10 milliseconds to change the group when a digital input is used for group control or a similar function. In practice, however, the delay is between 2...8 milliseconds about 95 % of the time. When a digital input is connected directly to a digital output (T1...Tx), it takes an additional 5 ms round. Therefore, when a digital input controls a digital output internally, it takes 0...15 milliseconds in theory and 2...13 milliseconds in practice.

Please note that the mechanical delay of the relay is **not** included in these approximations.

8.3 Current measurement module

Figure. 8.3 - 114. Module connections with standard and ring lug terminals.



| Connector | Description |
|-----------|---|
| CTM 1-2 | Phase current measurement for phase L1 (A). |
| CTM 3-4 | Phase current measurement for phase L2 (B). |
| CTM 5-6 | Phase current measurement for phase L3 (C). |
| CTM 7-8 | Coarse residual current measurement I01. |
| CTM 9-10 | Fine residual current measurement I02. |

A basic current measurement module with five channels includes three-phase current measurement inputs as well as coarse and fine residual current inputs. The CT module is available with either standard or ring lug connectors.

The current measurement module is connected to the secondary side of conventional current transformers (CTs). The nominal current for the phase current inputs is 5 A. The input nominal current can be scaled for secondary currents of 1...10 A. The secondary currents are calibrated to nominal currents of 1 A and 5 A, which provide $\pm 0.5\%$ inaccuracy when the range is $0.005...4 \times I_n$.

The measurement ranges are as follows:

- Phase currents 25 mA...250 A (RMS)
- Coarse residual current 5 mA...150 A (RMS)
- Fine residual current 1 mA...75 A (RMS)

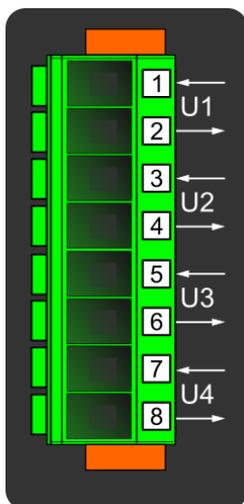
The characteristics of phase current inputs are as follows:

- The angle measurement inaccuracy is less than ± 0.2 degrees with nominal current.
- The frequency measurement range of the phase current inputs is 6...1800 Hz with standard hardware.
- The quantization of the measurement signal is applied with 18-bit AD converters, and the sample rate of the signal is 64 samples/cycle when the system frequency ranges from 6 Hz to 75 Hz.

For further details please refer to the "Current measurement" chapter in the "Technical data" section of this document.

8.4 Voltage measurement module

Figure. 8.4 - 115. Voltage measurement module.



| Connector | Description |
|-----------|--|
| VTM 1-2 | Configurable voltage measurement input U1. |
| VTM 3-4 | Configurable voltage measurement input U2. |
| VTM 5-6 | Configurable voltage measurement input U3. |
| VTM 7-8 | Configurable voltage measurement input U4. |

A basic voltage measurement module with four channels includes four voltage measurement inputs that can be configured freely.

The voltage measurement module is connected to the secondary side of conventional voltage transformers (VTs) or directly to low-voltage systems secured by fuses. The nominal voltage can be set between 100...400 V. Voltages are calibrated in a range of 0...240 V, which provides $\pm 0.2\%$ inaccuracy in the same range.

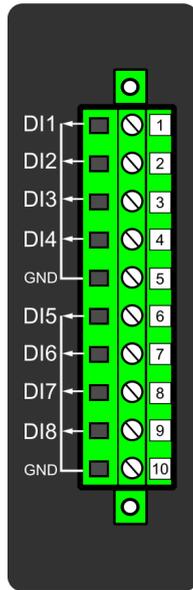
The voltage input characteristics are as follows:

- The measurement range is 0.5...480.0 V per channel.
- The angle measurement inaccuracy is less than ± 0.5 degrees within the nominal range.
- The frequency measurement range of the voltage inputs is 6...1800 Hz with standard hardware.
- The quantization of the measurement signal is applied with 18-bit AD converters, and the sample rate of the signal is 64 samples/cycle when the system frequency ranges from 6 Hz to 75 Hz.

For further details please refer to the "Voltage measurement" chapter in the "Technical data" section of this document.

8.5 Digital input module (optional)

Figure. 8.5 - 116. Digital input module (DI8) with eight add-on digital inputs.



| Connector | Description (x = the number of digital inputs in other modules that precede this one in the configuration) |
|-----------|--|
| X 1 | Dlx + 1 |
| X 2 | Dlx + 2 |
| X 3 | Dlx + 3 |
| X 4 | Dlx + 4 |
| X 5 | Common earthing for the first four digital inputs. |
| X 6 | Dlx + 5 |
| X 7 | Dlx + 6 |
| X 8 | Dlx + 7 |
| X 9 | Dlx + 8 |
| X 10 | Common earthing for the other four digital inputs. |

The DI8 module is an add-on module with eight (8) galvanically isolated digital inputs. This module can be ordered directly to be installed into the device in the factory, or it can be upgraded in the field after the device's original installation when required. The properties of the inputs in this module are the same as those of the inputs in the main processor module. The current consumption of the digital inputs is 2 mA when activated, while the range of the operating voltage is from 0...265 VAC/DC. The activation and release thresholds are set in the software and the resolution is 1 V. All digital inputs are scanned in 5 ms program cycles, and their pick-up and release delays as well as their NO/NC selection can be set with software.

For the naming convention of the digital inputs provided by this module please refer to the chapter titled "Construction and installation".

For technical details please refer to the chapter titled "Digital input module" in the "Technical data" section of this document.

Setting up the activation and release delays

The settings described in the table below can be found at *Control* → *Device I/O* → *Digital input settings* in the relay settings.

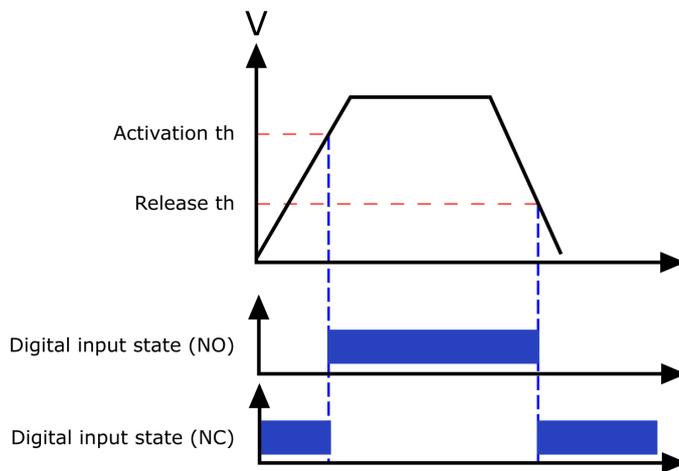
Table. 8.5 - 140. Digital input settings of DI8 module.

| Name | Range | Step | Default | Description |
|--------------------------|--|---------|-------------|--|
| Dlx Polarity | 0: NO (Normally open) 1: NC (Normally closed) | - | 0: NO | Selects whether the status of the digital input is 1 or 0 when the input is energized. |
| Dlx Activation threshold | 16.0...200.0 V | 0.1 V | 88 V | Defines the activation threshold for the digital input. When "NO" is the selected polarity, the measured voltage exceeding this setting activates the input. When "NC" is the selected polarity, the measured voltage exceeding this setting deactivates the input. |
| Dlx Release threshold | 10.0...200.0 V | 0.1 V | 60V | Defines the release threshold for the digital input. When "NO" is the selected polarity, the measured voltage below this setting deactivates the input. When "NC" is the selected polarity, the measured voltage below this setting activates the input. |
| Dlx Activation delay | 0.000...1800.000 s | 0.001 s | 0.000 s | Defines the delay when the status changes from 0 to 1. |
| Dlx Drop-off time | 0.000...1800.000 s | 0.001 s | 0.000 s | Defines the delay when the status changes from 1 to 0. |
| Dlx AC Mode | 0: Disabled 1: Enabled | - | 0: Disabled | Selects whether or not a 30-ms deactivation delay is added to take the alternating current into account. The "Dlx Release threshold" parameter is hidden and forced to 10 % of the set "Dlx Activation threshold" parameter. |
| Dlx Counter | 0...2 ³² -1 | 1 | 0 | Displays the number of times the digital input has changed its status from 0 to 1. |
| Dlx Clear counter | 0: - 1: Clear | - | 0: - | Resets the Dlx counter value to zero. |

The user can set the activation threshold individually for each digital input. When the activation and release thresholds have been set properly, they will result in the digital input states to be activated and released reliably. The selection of the normal state between normally open (NO) and normally closed (NC) defines whether or not the digital input is considered activated when the digital input channel is energized.

The diagram below depicts the digital input states when the input channels are energized and de-energized.

Figure. 8.5 - 117. Digital input state when energizing and de-energizing the digital input channels.



Digital input voltage measurements

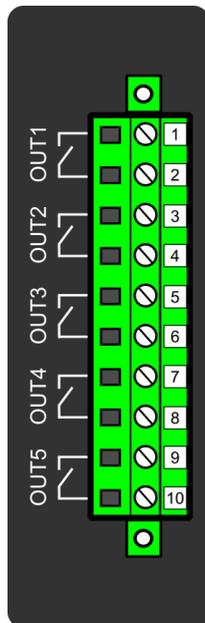
Digital input option card channels measure voltage on each channel. The measured voltage can be seen at *Control* → *Device IO* → *Digital inputs* → *Digital input voltages*.

Table. 8.5 - 141. Digital input channel voltage measurement.

| Name | Range | Step | Description |
|-----------------|-------------------|---------|---|
| Dlx Voltage now | 0.000...275.000 V | 0.001 V | Voltage measurement of a digital input channel. |

8.6 Digital output module (optional)

Figure. 8.6 - 118. Digital output module (DO5) with five add-on digital outputs.



| Connector | Description |
|-----------|--|
| X 1-2 | OUTx + 1 (1 st and 2 nd pole NO) |
| X 3-4 | OUTx + 2 (1 st and 2 nd pole NO) |

| Connector | Description |
|-----------|--|
| X 5-6 | OUTx + 3 (1 st and 2 nd pole NO) |
| X 7-8 | OUTx + 4 (1 st and 2 nd pole NO) |
| X 9-10 | OUTx + 5 (1 st and 2 nd pole NO) |

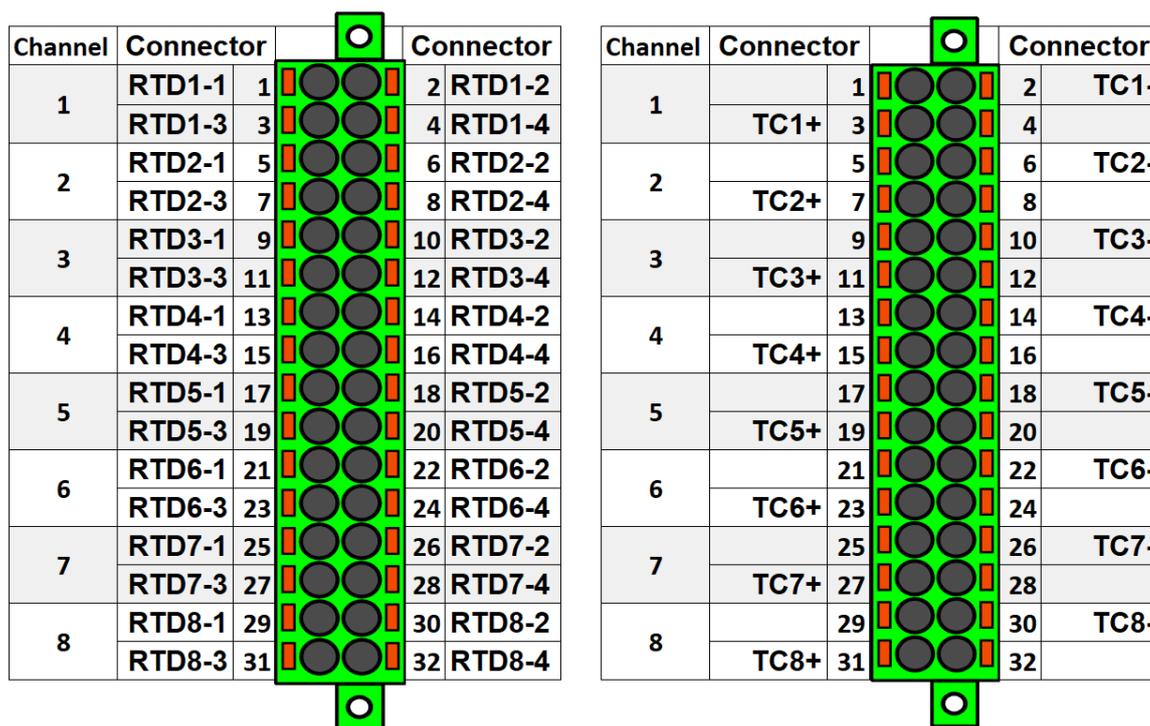
The DO5 module is an add-on module with five (5) digital outputs. This module can be ordered directly to be installed into the device in the factory, or it can be upgraded in the field after the device's original installation when required. The properties of the outputs in this module are the same as those of the outputs in the main processor module. The user can set the digital output controls with software. All digital outputs are scanned in 5 ms program cycles, and their contacts are mechanical in type. The rated voltage of the NO/NC outputs is 250 VAC/DC.

For the naming convention of the digital inputs provided by this module please refer to the chapter titled "Construction and installation".

For technical details please refer to the chapter titled "Digital output module" in the "Technical data" section of this document.

8.7 RTD input module (optional)

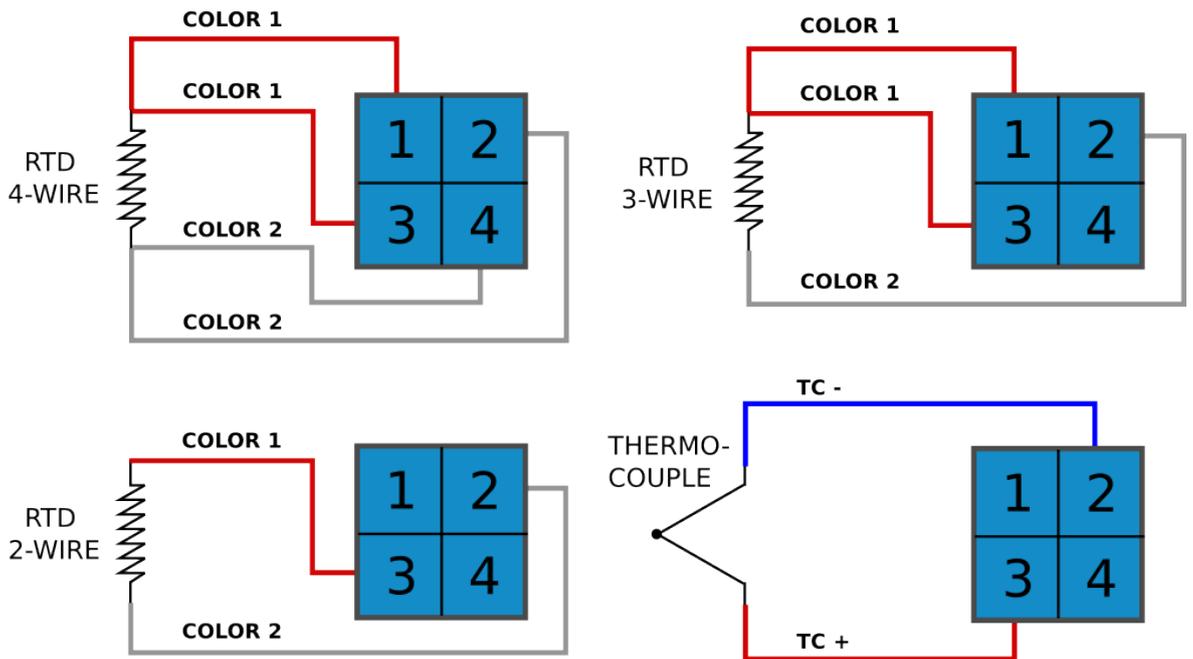
Figure. 8.7 - 119. RTD input module connectors.



The RTD input module is an add-on module with eight (8) RTD input channels. Each input supports 2-wire, 3-wire and 4-wire RTD sensors as well as thermocouple (TC) sensors. The sensor type can be selected with software for two groups, four channels each. The supported sensor types are as follows:

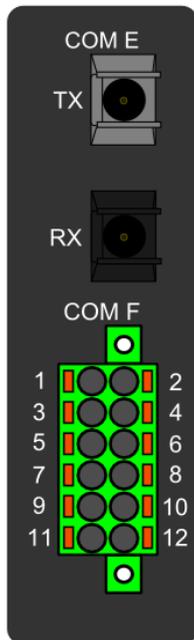
- Supported RTD sensors: Pt100, Pt1000
- Supported thermocouple sensors: type K (NiCh/NiAl), type J (Fe/constantan), type T (Cu/constantan) and type S (Cu/CuNi compensating).

Figure. 8.7 - 120. Different sensor types and their connections.



8.8 Serial RS-232 communication module (optional)

Figure. 8.8 - 121. Serial RS-232 module connectors.



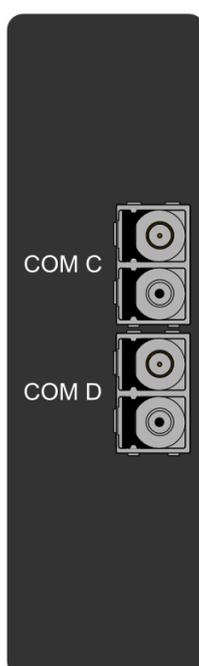
| Connector | Name | Description |
|-----------|----------------------------|---|
| COM E | Serial fiber (GG/PP/GP/PG) | <ul style="list-style-type: none"> Serial-based communications Wavelength 660 nm Compatible with 50/125 μm, 62.5/125 μm, 100/140 μm, and 200 μm Plastic-Clad Silica (PCS) fiber Compatible with ST connectors |

| Connector | Name | Description |
|----------------|-----------------------|--|
| COM F – Pin 1 | +24 V input | Optional external auxiliary voltage for serial fiber |
| COM F – Pin 2 | GND | Optional external auxiliary voltage for serial fiber |
| COM F – Pin 3 | - | - |
| COM F – Pin 4 | - | - |
| COM F – Pin 5 | RS-232 RTS | Serial based communications |
| COM F – Pin 6 | RS-232 GND | Serial based communications |
| COM F – Pin 7 | RS-232 TX | Serial based communications |
| COM F – Pin 8 | RS-232 RX | Serial based communications |
| COM F – Pin 9 | - | - |
| COM F – Pin 10 | +3.3 V output (spare) | Spare power source for external equipment (45 mA) |
| COM F – Pin 11 | - | - |
| COM F – Pin 12 | - | - |

The option card includes two serial communication interfaces: COM E is a serial fiber interface with glass/plastic option, COM F is an RS-232 interface.

8.9 LC 100 Mbps Ethernet communication module (optional)

Figure. 8.9 - 122. LC 100 Mbps Ethernet module connectors.

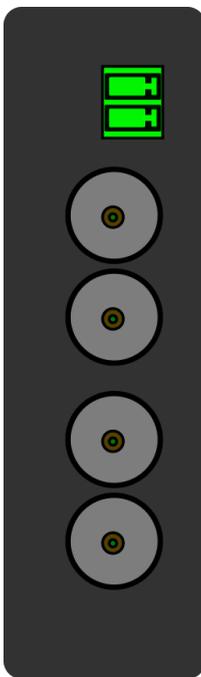


| Connector | Description |
|-----------|---|
| COM C: | <ul style="list-style-type: none"> • Communication port C, LC fiber connector. • 62.5/125 μm or 50/125 μm multimode (glass). • Wavelength 1300 nm. |
| COM D: | <ul style="list-style-type: none"> • Communication port D, LC fiber connector. • 62.5/125 μm or 50/125 μm multimode (glass). • Wavelength 1300 nm. |

The optional LC 100 Mbps Ethernet card supports both HSR and PRP protocols. The card has two PRP/HSR ports, which are 100 Mbps fiber ports.

8.10 Double ST 100 Mbps Ethernet communication module (optional)

Figure. 8.10 - 123. Double ST 100 Mbps Ethernet communication module connectors.



| Connector | Description |
|-------------------|---|
| Two-pin connector | <ul style="list-style-type: none"> • IRIG-B input |
| ST connectors | <ul style="list-style-type: none"> • Duplex ST connectors (IRIG-B input) • 62.5/125 μm or 50/125 μm multimode fiber • Transmitter wavelength: 1260...1360 nm (nominal: 1310 nm) • Receiver wavelength: 1100...1600 nm • 100BASE-FX • Up to 2 km |

This option cards supports redundant ring configuration and multidrop configurations. Redundant communication can be implemented by Ethernet switches that support Rapid Spanning Tree Protocol (RSTP). Please note that each ring can only contain AQ-200 series devices, and any third party devices must be connected to a separate ring.

For other redundancy options, please refer to the option card "LC 100 Mbps Ethernet communication module".

The images below present two example configurations: the first displays a ring configuration (note how the third party devices are connected in a separate ring), while the second displays a multidrop configuration.

Figure. 8.10 - 124. Example of a ring configuration.

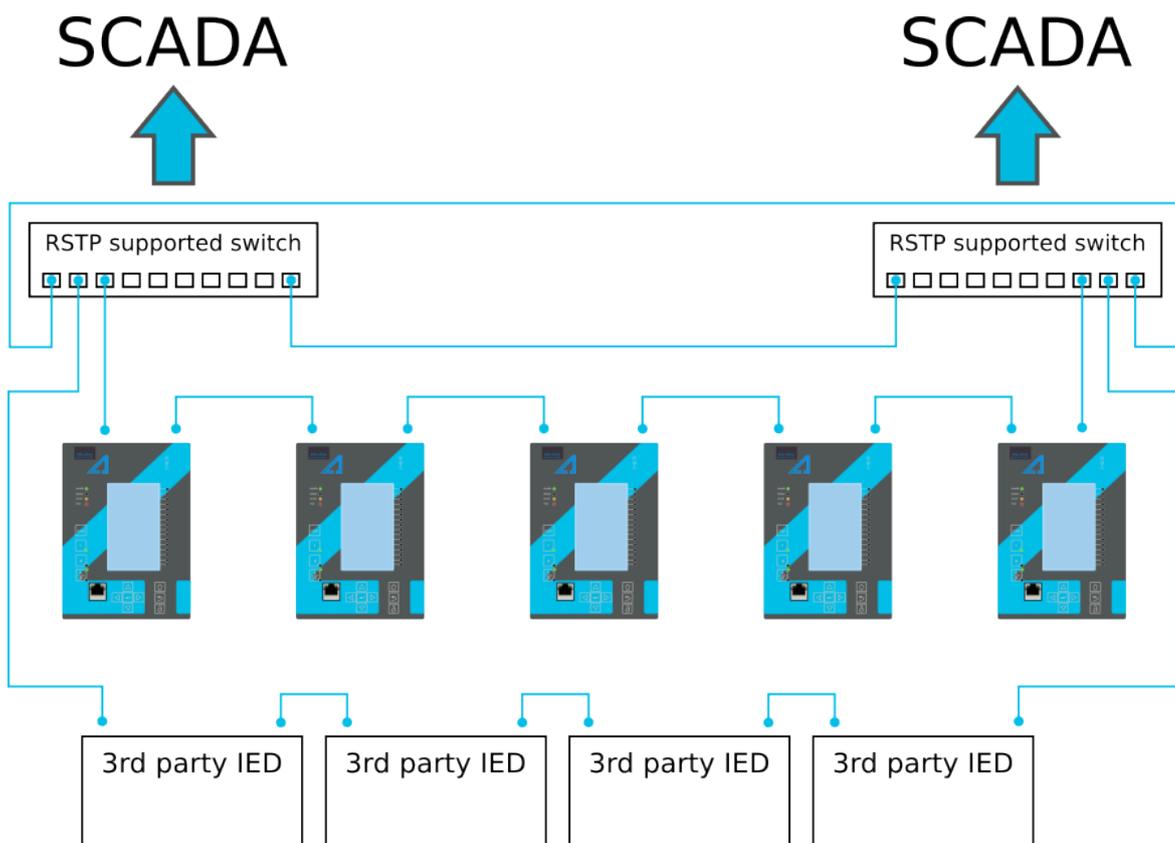
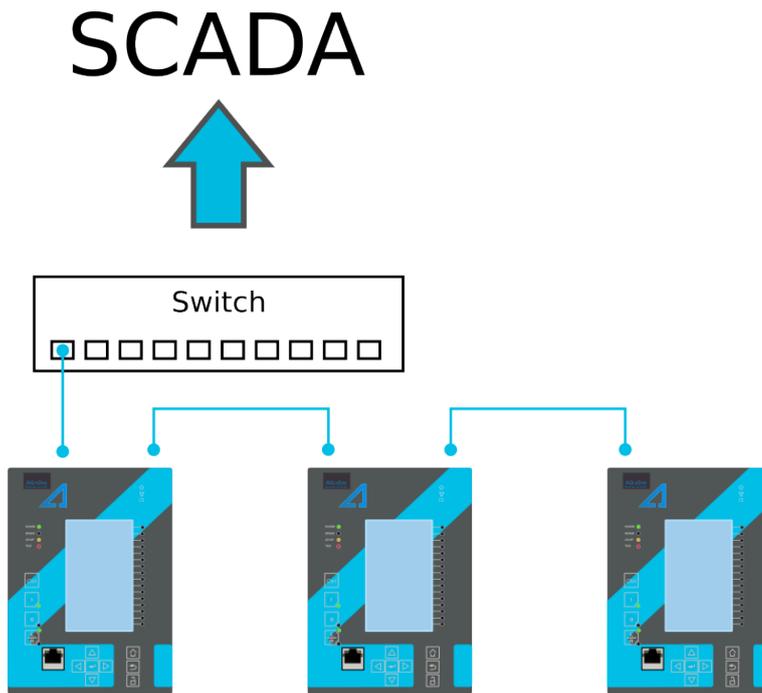


Figure. 8.10 - 125. Example of a multidrop configuration.



8.11 Double RJ-45 10/100 Mbps Ethernet communication module (optional)

Figure. 8.11 - 126. Double RJ-45 10/100 Mbps Ethernet communication module.



| Connector | Description |
|-------------------|--|
| Two-pin connector | <ul style="list-style-type: none"> IRIG-B input |

| Connector | Description |
|------------------|---|
| RJ-45 connectors | <ul style="list-style-type: none"> • Two Ethernet ports • RJ-45 connectors • 10BASE-T and 100BASE-TX |

This option card supports multidrop configurations.

For other redundancy options, please refer to the option card "LC 100 Mbps Ethernet communication module".

The images below present two example configurations: the first displays a ring configuration (note how the third party devices are connected in a separate ring), while the second displays a multidrop configuration.

Figure. 8.11 - 127. Example of a ring configuration.

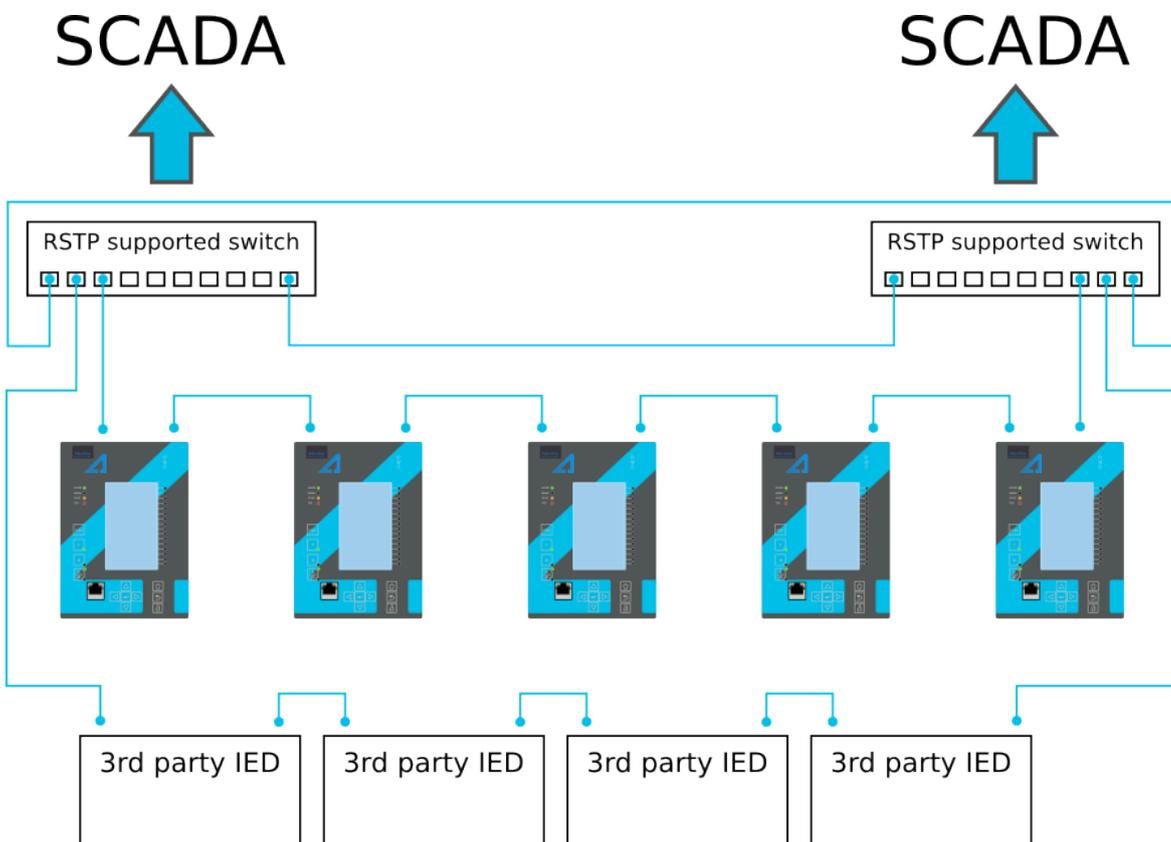
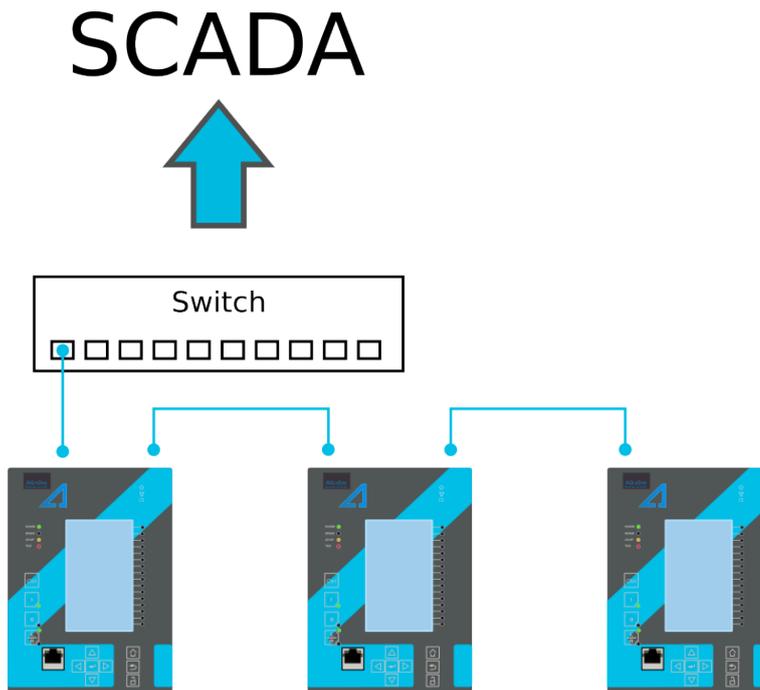
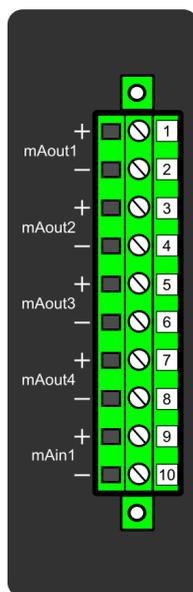


Figure. 8.11 - 128. Example of a multidrop configuration.



8.12 Milliampere (mA) I/O module (optional)

Figure. 8.12 - 129. Milliampere (mA) I/O module connections.



| Connector | Description |
|-----------|----------------------------------|
| Pin 1 | mA OUT 1 + connector (0...24 mA) |
| Pin 2 | mA OUT 1 – connector (0...24 mA) |
| Pin 3 | mA OUT 2 + connector (0...24 mA) |
| Pin 4 | mA OUT 2 – connector (0...24 mA) |
| Pin 5 | mA OUT 3 + connector (0...24 mA) |
| Pin 6 | mA OUT 3 – connector (0...24 mA) |

| Connector | Description |
|-----------|----------------------------------|
| Pin 7 | mA OUT 4 + connector (0...24 mA) |
| Pin 8 | mA OUT 4 – connector (0...24 mA) |
| Pin 9 | mA IN 1 + connector (0...33 mA) |
| Pin 10 | mA IN 1 – connector (0...33 mA) |

The milliampere (mA) I/O module is an add-on module with four (4) mA outputs and one (1) mA input. Both the outputs and the input are in two galvanically isolated groups, with one pin for the positive (+) connector and one pin for the negative (–) connector.

This module can be ordered directly to be installed into the device in the factory, or it can be upgraded in the field after the device's original installation when required.

The user sets the mA I/O with the mA outputs control function. This can be done at *Control* → *Device I/O* → *mA outputs* in the relay configuration settings.

8.13 Dimensions and installation

The device can be installed either to a standard 19" rack or to a switchgear panel with cutouts. The desired installation type is defined in the order code. When installing to a rack, the device takes a quarter (1/4) of the rack's width, meaning that a total of four devices can be installed to the same rack next to one another.

The figures below describe the device dimensions (first figure), the device installation (second), and the panel cutout dimensions and device spacing (third).

Figure. 8.13 - 130. Device dimensions.

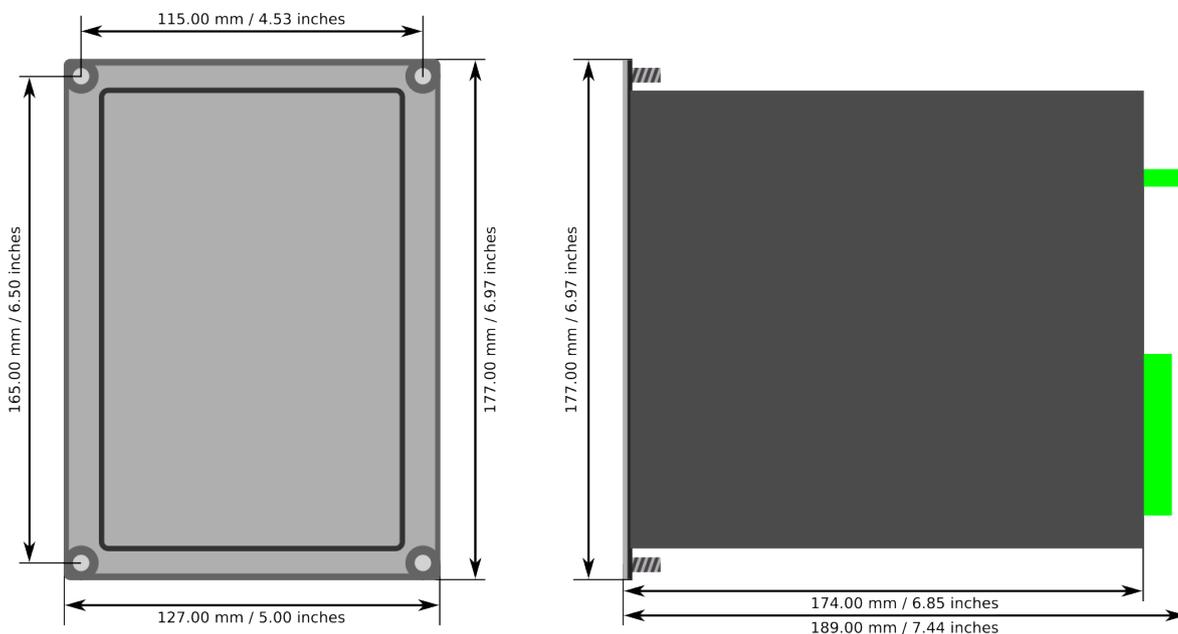


Figure. 8.13 - 131. Device installation.

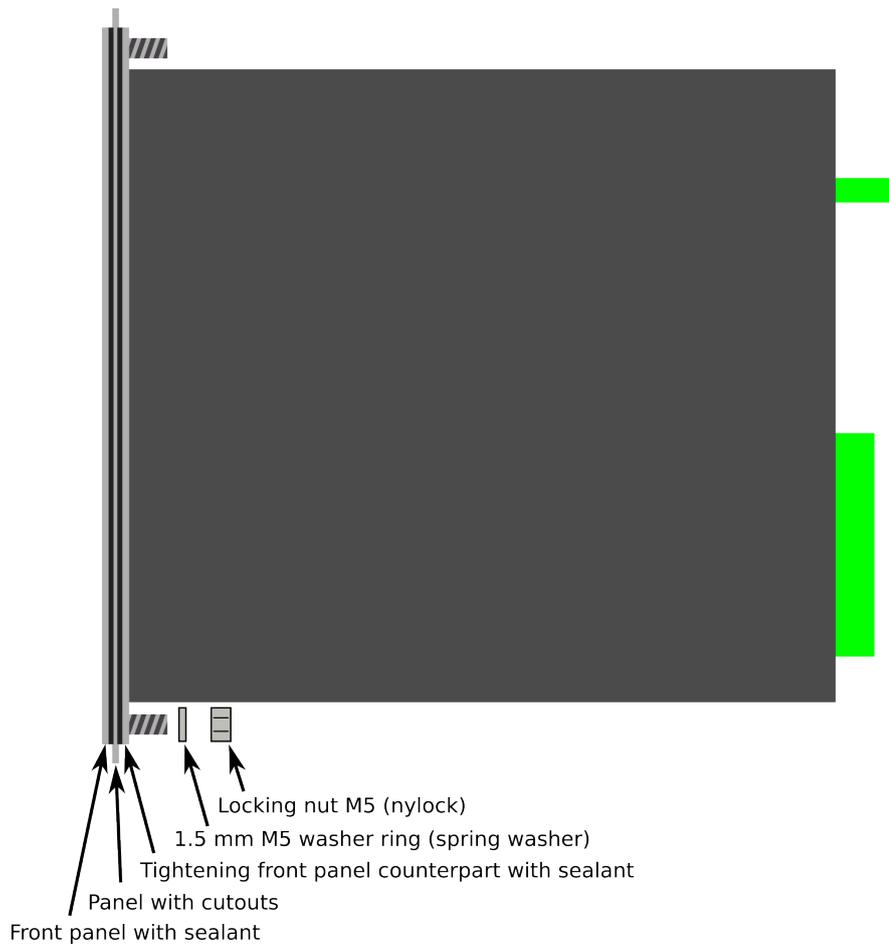
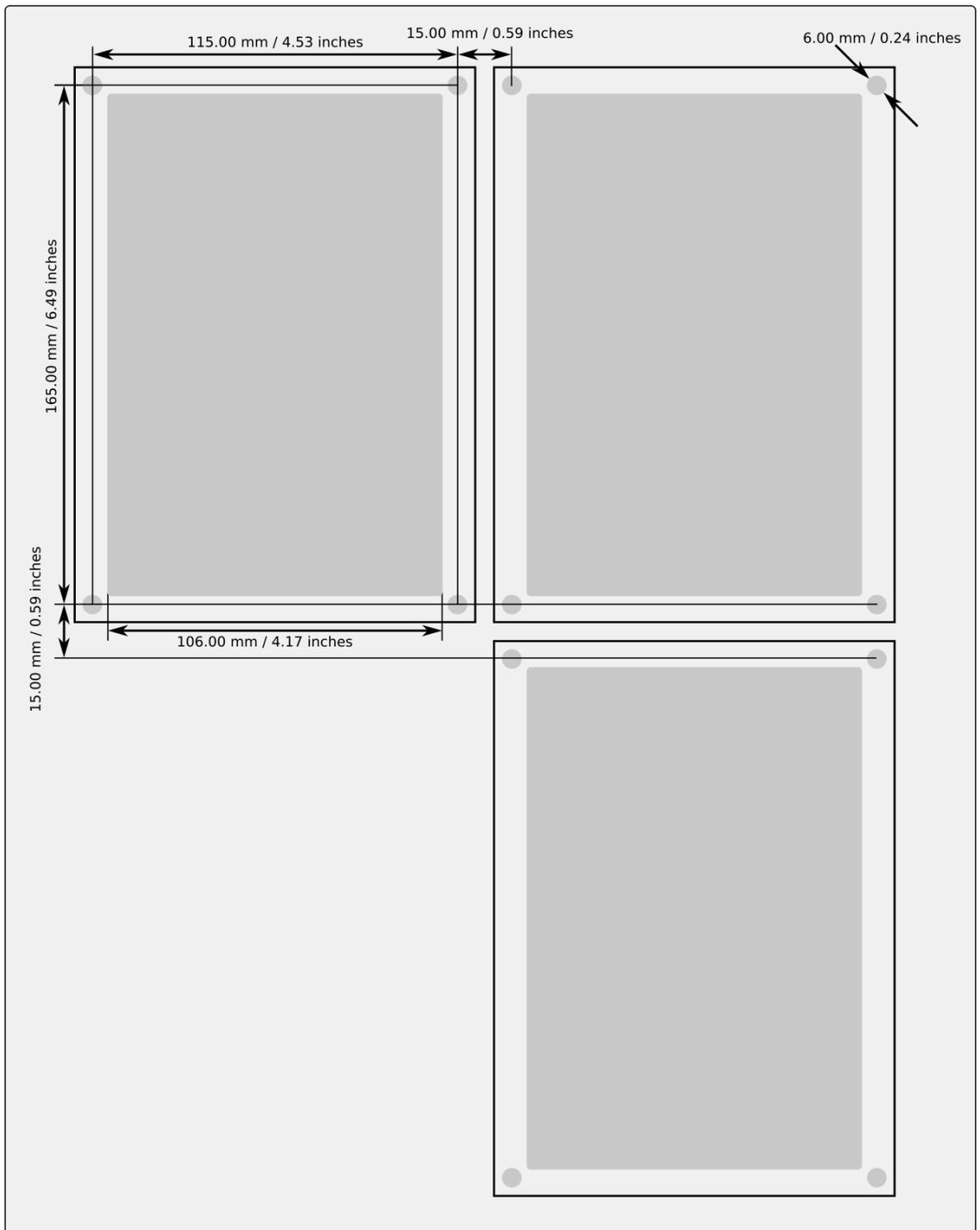


Figure 8.13 - 132. Panel cutout dimensions and device spacing.



9 Technical data

9.1 Hardware

9.1.1 Measurements

9.1.1.1 Current measurement

Table. 9.1.1.1 - 142. Technical data for the current measurement module.

| Connections | |
|-------------------------------------|--|
| Measurement channels/CT inputs | Three phase current inputs: IL1 (A), IL2 (B), IL3 (C) Two residual current inputs: Coarse residual current input I01, Fine residual current input I02 |
| Phase current inputs (A, B, C) | |
| Sample rate | 64 samples per cycle in frequency range 6...75Hz |
| Rated current I_N | 5 A (configurable 0.2...10 A) |
| Thermal withstand | 30 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s) |
| Frequency measurement range | From 6...75Hz fundamental, up to the 31 st harmonic current |
| Current measurement range | 25 mA...250 A (RMS) |
| Current measurement inaccuracy | 0.005...4.000 × I_N < ±0.5 % or < ±15 mA 4...20 × I_N < ±0.5 % 20...50 × I_N < ±1.0 % |
| Angle measurement inaccuracy | < ±0.2° ($I > 0.1$ A) < ±1.0° ($I \leq 0.1$ A) |
| Burden (50/60 Hz) | <0.1 VA |
| Transient overreach | <8 % |
| Coarse residual current input (I01) | |
| Rated current I_N | 1 A (configurable 0.1...10 A) |
| Thermal withstand | 25 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s) |
| Frequency measurement range | From 6...75 Hz fundamental, up to the 31 st harmonic current |
| Current measurement range | 5 mA...150 A (RMS) |
| Current measurement inaccuracy | 0.002...10.000 × I_N < ±0.5 % or < ±3 mA 10...150 × I_N < ±0.5 % |

| | |
|-----------------------------------|--|
| Angle measurement inaccuracy | < $\pm 0.2^\circ$ ($I > 0.05$ A) < $\pm 1.0^\circ$ ($I \leq 0.05$ A) |
| Burden (50/60Hz) | <0.1 VA |
| Transient overreach | <5 % |
| Fine residual current input (I02) | |
| Rated current I_N | 0.2 A (configurable 0.001...10 A) |
| Thermal withstand | 25 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s) |
| Frequency measurement range | From 6...75 Hz fundamental, up to the 31 st harmonic current |
| Current measurement range | 1 mA...75 A (RMS) |
| Current measurement inaccuracy | $0.002...25.000 \times I_N < \pm 0.5 \%$ or $< \pm 0.6$ mA $25...375 \times I_N < \pm 1.0 \%$ |
| Angle measurement inaccuracy | < $\pm 0.2^\circ$ ($I > 0.01$ A) < $\pm 1.0^\circ$ ($I \leq 0.01$ A) |
| Burden (50/60Hz) | <0.1 VA |
| Transient overreach | <5 % |
| Terminal block connection | |
| Terminal block | Phoenix Contact FRONT 4-H-6,35 |
| Solid or stranded wire | |
| Maximum wire diameter | 4 mm ² |



NOTE!

Current measurement accuracy has been verified with 50/60 Hz.

The amplitude difference is 0.2 % and the angle difference is 0.5 degrees higher at 16.67 Hz and other frequencies.

9.1.1.2 Voltage measurement

Table. 9.1.1.2 - 143. Technical data for the voltage measurement module.

| | |
|--------------------------------|---|
| Connection | |
| Measurement channels/VT inputs | 4 independent VT inputs (U1, U2, U3 and U4) |
| Measurement | |
| Sample rate | 64 samples per cycle in frequency range 6...75Hz |
| Voltage measuring range | 0.50...480.00 V (RMS) |
| Voltage measurement inaccuracy | 1...2 V $\pm 1.5 \%$ 2...10 V $\pm 0.5 \%$ 10...480 V $\pm 0.35 \%$ |

| | |
|---------------------------------------|--|
| Angle measurement inaccuracy | ±0.2 degrees (15...300 V) ±1.5 degrees (1...15 V) |
| Voltage measurement bandwidth (freq.) | 7...75 Hz fundamental, up to the 31 st harmonic voltage |
| Terminal block connection | |
| Terminal block | Phoenix Contact PC 5/8-STCL1-7.62 |
| Solid or stranded wire | |
| Maximum wire diameter | 6 mm ² |
| Input impedance | 24.5...24.6 MΩ |
| Burder (50/60 Hz) | <0.02 VA |
| Thermal withstand | 630 V _{RMS} (continuous) |



NOTE!

Voltage measurement accuracy has been verified with 50/60 Hz.

The amplitude difference is 0.2 % and the angle difference is 0.5 degrees higher at 16.67 Hz and other frequencies.

9.1.1.3 Power and energy measurement

Table. 9.1.1.3 - 144. Power and energy measurement accuracy

| | |
|--------------------------------------|--|
| Power measurement P, Q, S | Frequency range 6...75 Hz |
| Inaccuracy | 0.3 % <1.2 × I _N or 3 VA secondary 1.0 % >1.2 × I _N or 3 VA secondary |
| Energy measurement | Frequency range 6...75 Hz |
| Energy and power metering inaccuracy | 0.5% down to 1A RMS (50/60Hz) as standard 0.2% down to 1A RMS (50/60Hz) option available (see the order code for details) |

9.1.1.4 Frequency measurement

Table. 9.1.1.4 - 145. Frequency measurement accuracy.

| | |
|-----------------------------------|---|
| Frequency measurement performance | |
| Frequency measuring range | 6...75 Hz fundamental, up to the 31 st harmonic current or voltage |
| Inaccuracy | 10 mHz |

9.1.2 CPU & Power supply

9.1.2.1 Auxiliary voltage

Table. 9.1.2.1 - 146. Power supply model A

| | |
|-------------------------|--------------------|
| Rated values | |
| Rated auxiliary voltage | 85...265 V (AC/DC) |
| Power consumption | < 7 W < 15 W |

| | |
|----------------------------------|------------------------------------|
| Maximum permitted interrupt time | < 60 ms with 110 VDC |
| DC ripple | < 15 % |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire | |
| Maximum wire diameter | 2.5 mm ² |

Table. 9.1.2.1 - 147. Power supply model B

| | |
|----------------------------------|------------------------------------|
| Rated values | |
| Rated auxiliary voltage | 18...72 VDC |
| Power consumption | < 7 W < 15 W |
| Maximum permitted interrupt time | < 90 ms with 24 VDC |
| DC ripple | < 15 % |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire | |
| Maximum wire diameter | 2.5 mm ² |

9.1.2.2 CPU communication ports

Table. 9.1.2.2 - 148. Front panel local communication port.

| | |
|--------------------|---|
| Port | |
| Port media | Copper Ethernet RJ-45 |
| Number of ports | 1 |
| Port protocols | PC-protocols FTP Telnet |
| Features | |
| Data transfer rate | 100 MB |
| System integration | Cannot be used for system protocols, only for local programming |

Table. 9.1.2.2 - 149. Rear panel system communication port A.

| | |
|-----------------|-----------------------|
| Port | |
| Port media | Copper Ethernet RJ-45 |
| Number of ports | 1 |
| Features | |

| | |
|--------------------|---|
| Port protocols | IEC 61850 IEC 104 Modbus/TCP DNP3 FTP Telnet |
| Data transfer rate | 100 MB |
| System integration | Can be used for system protocols and for local programming |

Table. 9.1.2.2 - 150. Rear panel system communication port B.

| Port | |
|--------------------|---|
| Port media | Copper RS-485 |
| Number of ports | 1 |
| Features | |
| Port protocols | Modbus/RTU IEC 103 IEC 101 DNP3 SPA |
| Data transfer rate | 65 580 kB/s |
| System integration | Can be used for system protocols |

9.1.2.3 CPU digital inputs

Table. 9.1.2.3 - 151. CPU model-isolated digital inputs, with thresholds defined by order code.

| Rated values | |
|---|--|
| Rated auxiliary voltage | 265 V (AC/DC) |
| Nominal voltage | Order code defined: 24, 110, 220 V (AC/DC) |
| Pick-up threshold Release threshold | Order code defined: 19, 90, 170 V Order code defined: 14, 65, 132 V |
| Scanning rate | 5 ms |
| Settings | |
| Pick-up delay | Software settable: 0...1800 s |
| Polarity | Software settable: Normally On/Normally Off |
| Current drain | 2 mA |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire Maximum wire diameter | 2.5 mm ² |

9.1.2.4 CPU digital outputs

Table. 9.1.2.4 - 152. Digital outputs (Normally Open)

| Rated values | |
|--|---|
| Rated auxiliary voltage | 265 V (AC/DC) |
| Continuous carry | 5 A |
| Make and carry 0.5 s Make and carry 3 s | 30 A 15 A |
| Breaking capacity, DC (L/R = 40 ms) at 48 VDC at 110 VDC at 220 VDC | 1 A 0.4 A 0.2 A |
| Control rate | 5 ms |
| Settings | |
| Polarity | Software settable: Normally On/Normally Off |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire Maximum wire diameter | 2.5 mm ² |

Table. 9.1.2.4 - 153. Digital outputs (Change-Over)

| Rated values | |
|--|---|
| Rated auxiliary voltage | 265 V (AC/DC) |
| Continuous carry | 5 A |
| Make and carry 0.5 s Make and carry 3 s | 30 A 15 A |
| Breaking capacity, DC (L/R = 40 ms) at 48 VDC at 110 VDC at 220 VDC | 1 A 0.4 A 0.2 A |
| Control rate | 5 ms |
| Settings | |
| Polarity | Software settable: Normally On/Normally Off |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire Maximum wire diameter | 2.5 mm ² |

9.1.3 Option cards

9.1.3.1 Digital input module

Table. 9.1.3.1 - 154. Technical data for the digital input module.

| Rated values | |
|-------------------------|-------------------|
| Rated auxiliary voltage | 5...265 V (AC/DC) |
| Current drain | 2 mA |

| | |
|----------------------------------|---|
| Scanning rate | 5 ms |
| Activation/release delay | 5...11 ms |
| Settings | |
| Pick-up threshold | Software settable: 16...200 V, setting step 1 V |
| Release threshold | Software settable: 10...200 V, setting step 1 V |
| Pick-up delay | Software settable: 0...1800 s |
| Drop-off delay | Software settable: 0...1800 s |
| Polarity | Software settable: Normally On/Normally Off |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire | |
| Maximum wire diameter | 2.5 mm ² |

9.1.3.2 Digital output module

Table. 9.1.3.2 - 155. Technical data for the digital output module.

| | |
|-------------------------------------|---|
| Rated values | |
| Rated auxiliary voltage | 265 V (AC/DC) |
| Continuous carry | 5 A |
| Make and carry 0.5 s | 30 A |
| Make and carry 3 s | 15 A |
| Breaking capacity, DC (L/R = 40 ms) | |
| at 48 VDC | 1 A |
| at 110 VDC | 0.4 A |
| at 220 VDC | 0.2 A |
| Control rate | 5 ms |
| Settings | |
| Polarity | Software settable: Normally On/Normally Off |
| Terminal block connection | |
| Terminal block | Phoenix Contact MSTB 2,5/5-ST-5,08 |
| Solid or stranded wire | |
| Maximum wire diameter | 2.5 mm ² |

9.1.3.3 Milliampere module (mA out & mA in)

Table. 9.1.3.3 - 156. Technical data for the milliampere module.

| | |
|---------------------|---------------------------|
| Signals | |
| Output magnitudes | 4 × mA output signal (DC) |
| Input magnitudes | 1 × mA input signal (DC) |
| mA input | |
| Range (hardware) | 0...33 mA |
| Range (measurement) | 0...24 mA |
| Inaccuracy | ±0.1 mA |

| | |
|------------------------------------|---|
| Update cycle | 5...10 000 ms, setting step 5 ms |
| Response time @ 5 ms cycle | ~ 15 ms (13...18 ms) |
| Update cycle time inaccuracy | Max. +20 ms above the set cycle |
| mA input scaling range | 0...4000 mA |
| Output scaling range | -1 000 000.0000...1 000 000.0000, setting step 0.0001 |
| mA output | |
| Inaccuracy @ 0...24 mA | ±0.01 mA |
| Response time @ 5 ms cycle [fixed] | < 5 ms |
| mA output scaling range | 0...24 mA, setting step 0.001 mA |
| Source signal scaling range | -1 000 000.000...1 000 000.0000, setting step 0.0001 |

9.1.3.4 RTD input module

Table. 9.1.3.4 - 157. Technical data for the RTD input module.

| |
|---|
| Channels 1-8 |
| 2/3/4-wire RTD and thermocouple sensors |
| Pt100 or Pt1000 |
| Type K, Type J, Type T and Type S |
| Channels 7 & 8 support mA measurement |

9.1.3.5 RS-232 & serial fiber communication module

Table. 9.1.3.5 - 158. Technical data for the RS-232 & serial fiber communication module.

| |
|-------------------------------|
| Ports |
| RS-232 |
| Serial fiber (GG/PP/GP/PG) |
| Serial port wavelength |
| 660 nm |
| Cable type |
| 1 mm plastic fiber |

9.1.3.6 Double LC 100 Mbps Ethernet communication module

Table. 9.1.3.6 - 159. Technical data for the double LC 100 Mbps Ethernet communication module.

| | |
|--------------------------|--|
| Protocols | |
| Protocols | HSR and PRP |
| Ports | |
| Quantity of fiber ports | 2 |
| Communication port C & D | LC fiber connector Wavelength 1300 nm |
| Fiber cable | 50/125 µm or 62.5/125 µm multimode (glass) |

9.1.4 Display

Table. 9.1.4 - 160. Technical data for the HMI LCD display.

| Dimensions and resolution | |
|---------------------------|-----------------------------------|
| Number of dots/resolution | 320 x 160 |
| Size | 84.78 × 49.90 mm (3.34 × 1.96 in) |
| Display | |
| Type of display | LCD |
| Color | Monochrome |

9.2 Functions

9.2.1 Energy monitoring functions

9.2.1.1 Non-directional overcurrent ($I>$; 50/51)

Table. 9.2.1.1 - 161. Technical data for the non-directional overcurrent function.

| Input signals | |
|---|---|
| Current inputs | Phase current inputs: I_{L1} (A), I_{L2} (B), I_{L3} (C) |
| Current input magnitudes | RMS phase currents |
| Pick-up | |
| Pick-up current setting | $0.10 \dots 40.00 \times I_n$, setting step $0.01 \times I_n$ |
| Inaccuracy: - Current | $\pm 0.5 \% I_{set}$ or ± 15 mA ($0.10 \dots 4.0 \times I_{set}$) |
| Instant operation time | |
| Start time and instant operation time (alarm): - I_m/I_{set} ratio > 3 - I_m/I_{set} ratio = 1.05...3 | <35 ms (typically 25 ms) <50 ms |
| Reset | |
| Reset ratio | 97 % of the pick-up current setting |
| Reset time setting Inaccuracy: Reset time | 0.010...10.000 s, step 0.005 s $\pm 1.0 \%$ or ± 35 ms |
| Instant reset time and start-up reset | <50 ms |

9.2.1.2 Non-directional earth fault ($I0>$; 50N/51N)

Table. 9.2.1.2 - 162. Technical data for the non-directional earth fault function.

| Input signals | |
|--------------------------|---|
| Current inputs | Residual current channel I_{01} (Coarse) Residual current channel I_{02} (Fine) Calculated residual current: I_{L1} (A), I_{L2} (B), I_{L3} (C) |
| Current input magnitudes | RMS residual current (I_{01} , I_{02} or calculated I_0) |
| Pick-up | |
| Pick-up current setting | $0.005 \dots 40.00 \times I_n$, setting step $0.001 \times I_n$ |

| | |
|---|--|
| Inaccuracy: - Starting I01 (1 A) - Starting I02 (0.2 A) - Starting I0Calc (5 A) | $\pm 0.5 \% I_{set}$ or $\pm 3 \text{ mA}$ ($0.005 \dots 10.0 \times I_{set}$) $\pm 1.5 \% I_{set}$ or $\pm 1.0 \text{ mA}$ ($0.005 \dots 25.0 \times I_{set}$) $\pm 1.0 \% I_{set}$ or $\pm 15 \text{ mA}$ ($0.005 \dots 4.0 \times I_{set}$) |
| Instant operation time | |
| Start time and instant operation time (alarm): - I_m/I_{set} ratio > 3.5 - I_m/I_{set} ratio = 1.05...3.5 | <45 ms (typical 30 ms) <55 ms |
| Reset | |
| Reset ratio | 97 % of the pick-up current setting |
| Instant reset time and start-up reset | <50 ms |

9.2.1.3 Directional overcurrent (Idir>; 67)

Table. 9.2.1.3 - 163. Technical data for the directional overcurrent function.

| | |
|---|---|
| Measurement inputs | |
| Current inputs | Phase current inputs: I _{L1} (A), I _{L2} (B), I _{L3} (C) |
| Current input magnitudes | RMS phase currents |
| Current input calculations | Positive sequence current angle |
| Voltage inputs | U _{L1} , U _{L2} , U _{L3} U _{L12} , U _{L23} , U _{L31} +U ₀ |
| Voltage input calculation | Positive sequence voltage angle |
| Pick-up | |
| Characteristic direction | Forward (0°), reverse (180°), non-directional |
| Operating sector size (+/-) | 1.00...180.00 deg, setting step 0.10 deg |
| Pick-up current setting | 0.10...40.00 × I _n , setting step 0.01 × I _n |
| Inaccuracy: - Current - U1/I1 angle (U > 15 V) - U1/I1 angle (U = 1...15 V) | $\pm 0.5 \% I_{set}$ or $\pm 15 \text{ mA}$ ($0.10 \dots 4.0 \times I_{set}$) $\pm 0.15^\circ$ $\pm 1.5^\circ$ |
| Instant operation time | |
| Start time and instant operation time (alarm): - I_m/I_{set} ratio > 3 - I_m/I_{set} ratio = 1.05...3 | <35 ms (typical 25 ms) <50 ms |
| Reset | |
| Reset ratio - Current - U1/I1 angle | 97 % of the pick-up current setting 2.0° |
| Instant reset time and start-up reset | <50 ms |

9.2.1.4 Directional earth fault (I0dir>; 67N/32N)

Table. 9.2.1.4 - 164. Technical data for the directional earth fault function.

| | |
|---------------------------|--|
| Measurement inputs | |
| Current inputs | Residual current channel I ₀₁ (Coarse) Residual current channel I ₀₂ (Fine) |
| Current input magnitudes | RMS residual current (I ₀₁ or I ₀₂) |

| | |
|---|--|
| Voltage inputs | Residual voltage from U3 voltage channel Residual voltage from U4 voltage channel |
| Voltage input magnitudes | RMS residual voltage U_0 |
| Pick-up | |
| Characteristic direction | Unearthed (Varmetric 90°) Petersen coil GND (Wattmetric 180°) <u>Earthed</u> (Adjustable sector) |
| When the <u>earthed</u> mode is active: - Tripping area center - Tripping area size (+/-) | 0.00...360.00 deg, setting step 0.10 deg 45.00...135.00 deg, setting step 0.10 deg |
| Pick-up current setting Pick-up voltage setting | 0.005...40.00 × I_n , setting step 0.001 × I_n 1.00...50.00 % U_{0n} , setting step 0.01 % U_{0n} |
| Inaccuracy - Starting I_{O1} (1 A) - Starting I_{O2} (0.2 A) - Starting I_{OCalc} (5 A) - Voltage U_0 and U_{OCalc} - U_0/I_0 angle ($U > 15$ V) - U_0/I_0 angle ($U = 1...15$ V) | ±0.5 % I_{Oset} or ±3 mA (0.005...10.0 × I_{set}) ±1.5 % I_{Oset} or ±1.0 mA (0.005...25.0 × I_{set}) ±1.0 % I_{Oset} or ±15 mA (0.005...4.0 × I_{set}) ±1.0 % U_{Oset} or ±30 mV ±0.1° (I_{OCalc} ±1.0°) ±1.0° |
| Instant operation time | |
| Start time and instant operation time (alarm): - I_m/I_{set} ratio > 3 - I_m/I_{set} ratio = 1.05...3 | <40 ms (typical 30 ms) <50 ms |
| Reset | |
| Reset ratio: - Current and voltage - U_0/I_0 angle | 97 % of the pick-up current and voltage setting 2.0° |
| Instant reset time and start-up reset | <50 ms |

9.2.1.5 Intermittent earth fault ($I_{Oint} >$; 67NT)

Table. 9.2.1.5 - 165. Technical data for the intermittent earth fault function.

| | |
|--|---|
| Measurement inputs | |
| Current input (selectable) | Residual current channel I_{O1} (Coarse) Residual current channel I_{O2} (Fine) |
| Current input magnitudes | Residual current samples |
| Voltage input | Residual voltage from U4 voltage channel |
| Voltage input magnitudes | Zero sequence voltage samples |
| Pick-up | |
| Spikes to trip | 1...50, setting step 1 |
| Pick-up current setting Pick-up voltage setting | 0.05...40.00 × I_n , setting step 0.001 × I_n 1.00...100.00 % U_{0n} , setting step 0.01 % U_{0n} |
| Inaccuracy: - Starting I_{O1} (1 A) - Starting I_{O2} (0.2 A) - Voltage U_0 | ±0.5 % I_{Oset} or ±3 mA (0.005...10.0 × I_{set}) ±1.5 % I_{Oset} or ±1.0 mA (0.005...25.0 × I_{set}) ±1.0 % U_{Oset} or ±30 mV |
| Instant operation time | |
| Start time and instant operation time (alarm): - I_m/I_{set} ratio 1.05→ | <15 ms |
| Reset time | |

| | |
|---------------------------------------|--------|
| Instant reset time and start-up reset | <50 ms |
|---------------------------------------|--------|

9.2.1.6 Undervoltage (U<; 27)

Table. 9.2.1.6 - 166. Technical data for the undervoltage function.

| Measurement inputs | |
|--|---|
| Voltage inputs | U _{L1} , U _{L2} , U _{L3} U _{L12} , U _{L23} , U _{L31} |
| Voltage input magnitudes | RMS line-to-line or line-to-neutral voltages |
| Pick-up | |
| Pick-up terms | 1 voltage 2 voltages 3 voltages |
| Pick-up setting | 20.00...120.00 %U _n , setting step 0.01 %U _n |
| Inaccuracy: - Voltage | ±1.5 %U _{set} or ±30 mV |
| Low-voltage block | |
| Pick-up setting | 0.00...80.00 %U _n , setting step 0.01 %U _n |
| - Voltage | ±1.5 %U _{set} or ±30 mV |
| Instant operation time | |
| Start time and instant operation time (alarm): - U _m /U _{set} ratio 1.05→ | <65 ms |
| Reset | |
| Reset ratio | 103 % of the pick-up voltage setting |
| Instant reset time and start-up reset | <50 ms |

Note!

- The low-voltage block is not in use when it is set to 0 %U_n.
- The protection stage's TRIP signal is active if the low-voltage block is disabled and the IED is without a voltage injection.

9.2.1.7 Neutral overvoltage (U0>; 59N)

Table. 9.2.1.7 - 167. Technical data for the neutral overvoltage function.

| Input signals | |
|---|--|
| Voltage inputs | Residual voltage from U3 voltage channel Residual voltage from U4 voltage channel Residual voltage calculated from U _{L1} , U _{L2} , U _{L3} |
| Voltage input magnitudes | RMS residual voltage U ₀ Calculated RMS residual voltage U ₀ |
| Pick-up | |
| Pick-up voltage setting | 1.00...50.00 %U _{0n} , setting step 0.01 %U _{0n} |
| Inaccuracy: - Voltage U ₀ - Voltage U _{0Calc} | ±1.5 %U _{0set} or ±30 mV ±150 mV |
| Instant operation time | |

| | |
|---|-------------------------------------|
| Start time and instant operation time (alarm): - U_{0m}/U_{0set} ratio 1.05→ | <50 ms |
| Reset | |
| Reset ratio | 97 % of the pick-up voltage setting |
| Instant reset time and start-up reset | <50 ms |

9.2.2 Control functions

9.2.2.1 Setting group selection

Table. 9.2.2.1 - 168. Technical data for the setting group selection function.

| | |
|----------------------------|--|
| Settings and control modes | |
| Setting groups | 8 independent, control-prioritized setting groups |
| Control scale | Common for all installed functions which support setting groups |
| Control mode | |
| Local | Any digital signal available in the device |
| Remote | Force change overrule of local controls either from the setting tool, HMI or SCADA |
| Operation time | |
| Reaction time | <5 ms from receiving the control signal |

9.2.2.2 Object control and monitoring

Table. 9.2.2.2 - 169. Technical data for the object control and monitoring function.

| | |
|---|--|
| Signals | |
| Input signals | Digital inputs Software signals |
| Output signals | Close command output Open command output |
| Operation time | |
| Breaker traverse time setting | 0.02...500.00 s, setting step 0.02 s |
| Max. close/open command pulse length | 0.02...500.00 s, setting step 0.02 s |
| Control termination time out setting | 0.02...500.00 s, setting step 0.02 s |
| Inaccuracy: - Definite time operating time | ±0.5 % or ±10 ms |
| Breaker control operation time | |
| External object control time | <75 ms |
| Object control during auto-reclosing | See the technical sheet for the auto-reclosing function. |

9.2.3 Monitoring functions

9.2.3.1 Voltage transformer supervision (60)

Table. 9.2.3.1 - 170. Technical data for the voltage transformer supervision function.

| |
|--------------------|
| Measurement inputs |
|--------------------|

| | |
|---|---|
| Voltage inputs | U_{L1}, U_{L2}, U_{L3} $U_{L12}, U_{L23}, U_{L31}$ |
| Voltage input magnitudes | RMS line-to-line or line-to-neutral voltages |
| Pick-up | |
| Pick-up settings: - Voltage (low pick-up) - Voltage (high pick-up) - Angle shift limit | $0.05 \dots 0.50 \times U_N$, setting step $0.01 \times U_N$ $0.50 \dots 1.10 \times U_N$, setting step $0.01 \times U_N$ $2.00 \dots 90.00$ deg, setting step 0.10 deg |
| Inaccuracy: - Voltage - U angle ($U > 1$ V) | $\pm 1.5 \% U_{SET}$ $\pm 1.5^\circ$ |
| External line/bus side pick-up (optional) | $0 \rightarrow 1$ |
| Time delay for alarm | |
| Definite time function operating time setting | $0.00 \dots 1800.00$ s, setting step 0.005 s |
| Inaccuracy: - Definite time (U_M/U_{SET} ratio $> 1.05/0.95$) | $\pm 1.0 \%$ or ± 35 ms |
| Instant operation time (alarm): - U_M/U_{SET} ratio $> 1.05/0.95$ | < 80 ms |
| VTS MCB trip bus/line (external input) | < 50 ms |
| Reset | |
| Reset ratio | 97/103 % of the pick-up voltage setting |
| Reset time setting Inaccuracy: Reset time | $0.010 \dots 10.000$ s, step 0.005 s $\pm 2.0 \%$ or ± 80 ms |
| Instant reset time and start-up reset | < 50 ms |
| VTS MCB trip bus/line (external input) | < 50 ms |

Note!

- When turning on the auxiliary power of an IED, the normal condition of a stage has to be fulfilled before tripping.

9.2.3.2 Total harmonic distortion

Table. 9.2.3.2 - 171. Technical data for the total harmonic distortion function.

| | |
|-------------------------------------|--|
| Input signals | |
| Current inputs | Phase current inputs: I_{L1} (A), I_{L2} (B), I_{L3} (C) Residual current channel I_{01} (Coarse) Residual current channel I_{02} (Fine) |
| Current input magnitudes | Current measurement channels (FFT result) up to the 31 st harmonic component. |
| Pick-up | |
| Operating modes | Power THD Amplitude THD |
| Pick-up setting for all comparators | $0.10 \dots 200.00$ % , setting step 0.01 % |
| Inaccuracy | ± 3 % of the set pick-up value $> 0.5 \times I_N$ setting; 5 mA $< 0.5 \times I_N$ setting. |
| Time delay | |

| | |
|--|---|
| Definite time function operating time setting for all timers | 0.00...1800.00 s, setting step 0.005 s |
| Inaccuracy: - Definite time operating time - Instant operating time, when I_M/I_{SET} ratio > 3 - Instant operating time, when I_M/I_{SET} ratio $1.05 < I_M/I_{SET} < 3$ | $\pm 0.5\%$ or ± 10 ms Typically <20ms Typically <25 ms |
| Reset | |
| Reset time | Typically <10 ms |
| Reset ratio | 97 % |

9.2.3.3 Disturbance recorder

Table. 9.2.3.3 - 172. Technical data for the disturbance recorder function.

| | |
|---------------------------|--|
| Recorded values | |
| Recorder analog channels | 0...20 channels Freely selectable |
| Recorder digital channels | 0...95 channels Freely selectable analog and binary signals 5 ms sample rate (FFT) |
| Performance | |
| Sample rate | 8, 16, 32 or 64 samples/cycle |
| Recording length | 0.000...1800.000 s, setting step 0.001 s The maximum length is determined by the chosen signals. |
| Number of recordings | 0...100, 60 MB of shared flash memory reserved The maximum number of recordings according to the chosen signals and operation time setting combined |

9.3 Tests and environmental

Electrical environment compatibility

Table. 9.3 - 173. Disturbance tests.

| | |
|---|--|
| All tests | CE-approved and tested according to EN 60255-26 |
| Emissions | |
| Conducted emissions: EN 60255-26 Ch. 5.2, CISPR 22 | 150 kHz...30 MHz |
| Radiated emissions: EN 60255-26 Ch. 5.1, CISPR 11 | 30...1 000 MHz |
| Immunity | |
| Electrostatic discharge (ESD): EN 60255-26, IEC 61000-4-2 | Air discharge 15 kV Contact discharge 8 kV |
| Electrical fast transients (EFT): EN 60255-26, IEC 61000-4-4 | Power supply input 4 kV, 5/50 ns, 5 kHz Other inputs and outputs 4 kV, 5/50 ns, 5 kHz |

| | |
|--|---|
| Surge: EN 60255-26, IEC 61000-4-5 | Between wires 2 kV, 1.2/50 μ s Between wire and earth 4 kV, 1.2/50 μ s |
| Radiated RF electromagnetic field: EN 60255-26, IEC 61000-4-3 | f = 80....1 000 MHz, 10 V/m |
| Conducted RF field: EN 60255-26, IEC 61000-4-6 | f = 150 kHz....80 MHz, 10 V (RMS) |

Table. 9.3 - 174. Voltage tests.

| | |
|--------------------------------------|-----------------------------|
| Dielectric voltage test | |
| EN 60255-27, IEC 60255-5, EN 60255-1 | 2 kV (AC), 50 Hz, 1 min |
| Impulse voltage test | |
| EN 60255-27, IEC 60255-5 | 5 kV, 1.2/50 μ s, 0.5 J |

Physical environment compatibility

Table. 9.3 - 175. Mechanical tests.

| | |
|---|---|
| Vibration test | |
| EN 60255-1, EN 60255-27, IEC 60255-21-1 Class 1 | 2...13.2 Hz, \pm 3.5 mm 13.2...100 Hz, \pm 1.0 g |
| Shock and bump test | |
| EN 60255-1, EN 60255-27, IEC 60255-21-2 Class 1 | 20 g, 1 000 bumps/direction. |

Table. 9.3 - 176. Environmental tests.

| | |
|----------------------------|--|
| Damp heat (cyclic) | |
| EN 60255-1, IEC 60068-2-30 | Operational: +25...+55 °C, 93...97 % (RH), 12+12h |
| Dry heat | |
| EN 60255-1, IEC 60068-2-2 | Storage: +70 °C, 16 h Operational: +55 °C, 16 h |
| Cold test | |
| EN 60255-1, IEC 60068-2-1 | Storage: -40 °C, 16 h Operational: -20 °C, 16 h |

Table. 9.3 - 177. Environmental conditions.

| | |
|---|-----------------------------|
| IP classes | |
| Casing protection class | IP54 (front) IP21 (rear) |
| Temperature ranges | |
| Ambient service temperature range | -35...+70 °C |
| Transport and storage temperature range | -40...+70 °C |
| Other | |
| Altitude | <2000 m |

| | |
|----------------------|-----|
| Overvoltage category | III |
| Pollution degree | 2 |

Casing and package

Table. 9.3 - 178. Dimensions and weight.

| Without packaging (net) | |
|-------------------------|--|
| Dimensions | Height: 117 mm (4U) Width: 127 mm (¼ rack) Depth: 174 mm (no cards & connectors) |
| Weight | 1.5 kg |
| With packaging (gross) | |
| Dimensions | Height: 170 mm Width: 242 mm Depth: 219 mm |
| Weight | 2 kg |

10 Ordering information

| | AQ | - | E | 2 | 1 | 5 | - | P | X | X | X | A | X | A | - | X | X | X |
|--|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | | | | | | | | | | | | | | | | | |
| E Energy management | | | | | | | | | | | | | | | | | | |
| Device size | | | | | | | | | | | | | | | | | | |
| 1 1/4 of 19" rack | | | | | | | | | | | | | | | | | | |
| Analog measurement | | | | | | | | | | | | | | | | | | |
| 5 5 Current measurement channels and 4 voltage measurement channels | | | | | | | | | | | | | | | | | | |
| Mounting | | | | | | | | | | | | | | | | | | |
| P Panel mounted | | | | | | | | | | | | | | | | | | |
| Auxiliary voltage | | | | | | | | | | | | | | | | | | |
| H 80...265 VAC/DC | | | | | | | | | | | | | | | | | | |
| L 18...72 VDC | | | | | | | | | | | | | | | | | | |
| Measurement accuracy | | | | | | | | | | | | | | | | | | |
| 0 Power/Energy measurement accuracy class 0.5 | | | | | | | | | | | | | | | | | | |
| 2 Power/Energy measurement accuracy class 0.2S | | | | | | | | | | | | | | | | | | |
| Terminals | | | | | | | | | | | | | | | | | | |
| A Standard | | | | | | | | | | | | | | | | | | |
| B Ring lug terminals | | | | | | | | | | | | | | | | | | |
| Reserved for future use | | | | | | | | | | | | | | | | | | |
| A N/A | | | | | | | | | | | | | | | | | | |
| Digital inputs on power supply module | | | | | | | | | | | | | | | | | | |
| A 3 Digital inputs, 24 V nominal threshold | | | | | | | | | | | | | | | | | | |
| B 3 Digital inputs, 110 V nominal threshold | | | | | | | | | | | | | | | | | | |
| C 3 Digital inputs, 220 V nominal threshold | | | | | | | | | | | | | | | | | | |
| D 2 Digital inputs, 24 V nominal threshold | | | | | | | | | | | | | | | | | | |
| E 2 Digital inputs, 110 V nominal threshold | | | | | | | | | | | | | | | | | | |
| F 2 Digital inputs, 220 V nominal threshold | | | | | | | | | | | | | | | | | | |
| Reserved for future use | | | | | | | | | | | | | | | | | | |
| A N/A | | | | | | | | | | | | | | | | | | |
| Slots C, E, F (3 pcs) | | | | | | | | | | | | | | | | | | |
| A Empty | | | | | | | | | | | | | | | | | | |
| B 8 Digital inputs | | | | | | | | | | | | | | | | | | |
| C 5 Output relays ** | | | | | | | | | | | | | | | | | | |
| F 2 x mA input - 8 x RTD input ** | | | | | | | | | | | | | | | | | | |
| G 2 x RJ-45 100Mb Ethernet & IRIG-B * | | | | | | | | | | | | | | | | | | |
| H 2 x ST 100Mb Ethernet & IRIG-B * | | | | | | | | | | | | | | | | | | |
| I 4 x mA outputs - 1 x mA input ** | | | | | | | | | | | | | | | | | | |
| J Double LC 100Mb Ethernet (HSR, PRP redundant protocols) * | | | | | | | | | | | | | | | | | | |
| L RS-232 - Serial fiber (Plastic-Plastic) * | | | | | | | | | | | | | | | | | | |
| M RS-232 - Serial fiber (Plastic-Glass) * | | | | | | | | | | | | | | | | | | |
| N RS-232 - Serial fiber (Glass-Plastic) * | | | | | | | | | | | | | | | | | | |
| O RS-232 - Serial fiber (Glass-Glass) * | | | | | | | | | | | | | | | | | | |

* One card at most per IED

** Two cards at most per IED

Accessories

| Order code | Description | Note | Manufacturer |
|---------------|--|-----------------------------------|-------------------|
| ADAM-4015-CE | External 6-channel 2 or 3 wires RTD Input module, pre-configured | Requires an external power module | Advanced Co. Ltd. |
| ADAM-4018+-BE | External 8-ch Thermocouple mA Input module, pre-configured | Requires an external power module | Advanced Co. Ltd. |
| AQX033 | Raising frame 87 mm | | Arcteq Ltd. |
| AQX070 | Raising frame 40 mm | | Arcteq Ltd. |
| AQX069 | Combiflex frame | | Arcteq Ltd. |
| AQX097 | Wall mounting bracket | | Arcteq Ltd. |

11 Contact and reference information

Manufacturer

Arcteq Relays Ltd.

Visiting and postal address

Kvartsikatu 2 A 1

65300 Vaasa, Finland

Contacts

| | |
|------------------------------|--|
| Phone: | +358 10 3221 370 |
| Fax: | +358 10 3221 389 |
| Website (general): | arcteq.fi |
| Website (technical support): | support.arcteq.fi |
| E-mail (sales): | sales@arcteq.fi |