AQ-V211

Voltage protection 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	- 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	- 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	- 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.). - Tech data updated: overfrequency, underfrequency and rate-of-change-of-frequency. - Improvements to many drawings and formula images. - Improved and updated IED user interface display images. - AQ-V211 Functions included list Added: Voltage memory, indicator objects, switch-on-to-fault, vector jump protection, programmable control switch, mA output control and measurement recorder. - Fixed reset ratio of under- and overfrequency protection function from 103 % / 97 % to +/- 20 mHz.. - Fixed reset ratio of rate-of-change-of-frequency protection function from 20 mHz/s to 100 mHz/s. - Changed disturbance recorder maximum digital channel amount from 32 to 95. - Added residual current coarse and fine measurement data to disturbance recorder description. - 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. - Protection IED user interface chapter almost completely rewritten and restructured. - 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. - Fixed overvoltage, undervoltage, neutral overvoltage and sequence voltage stage misspelled IDMT curve formula.
Revision	2.04
Date	8.6.2021
Changes	- 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	8.5.2013
Changes	- The first revision for AQ-V211 IED.
Revision	1.01

Date	22.11.2013
Changes	- Application example for trip circuit supervision.
Revision	1.02
Date	30.1.2014
Changes	- Added df/dt and synchrocheck.
Revision	1.03
Date	27.1.2015
Changes	- Added RTD&mA input module, Double LC 100Mb Ethernet card module and Serial RS232 & serial fiber module hardware descriptions. - Added System integration text: SPA. - Replaced positive and negative sequence voltage functions with sequence voltage function description. - Order code updated.
Revision	1.04
Date	16.2.2017
Changes	- Added Programmable Control Switch and Indicator Object descriptions - Order code updated
Revision	1.05
Date	21.12.2017
Changes	- Measurement value recorder description - Event lists revised on several functions - RTD&mA card description improvements - Fault view description added - New U> and U< function measurement modes documented - Order code revised
Revision	1.06
Date	14.8.2018
Changes	- Added mA output option card description and ordercode - Added HMI display technical data

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-V211 voltage protection 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-V211 voltage protection IED. For other AQ-200 series products please consult their respective device manuals.

AQ-V211 offers a modular voltage protection solution for substations with voltage and frequency protection, synchrocheck and synchronizer. There are up to five (5) option card slots available for additional I/O or communication cards. These with the option for powerful logic programming make AQ-V211 optimal for demanding load shedding or automatic transfer applications. AQ-V211 communicates using various protocols including the IEC 61850 substation communication standard.

4 IED user interface

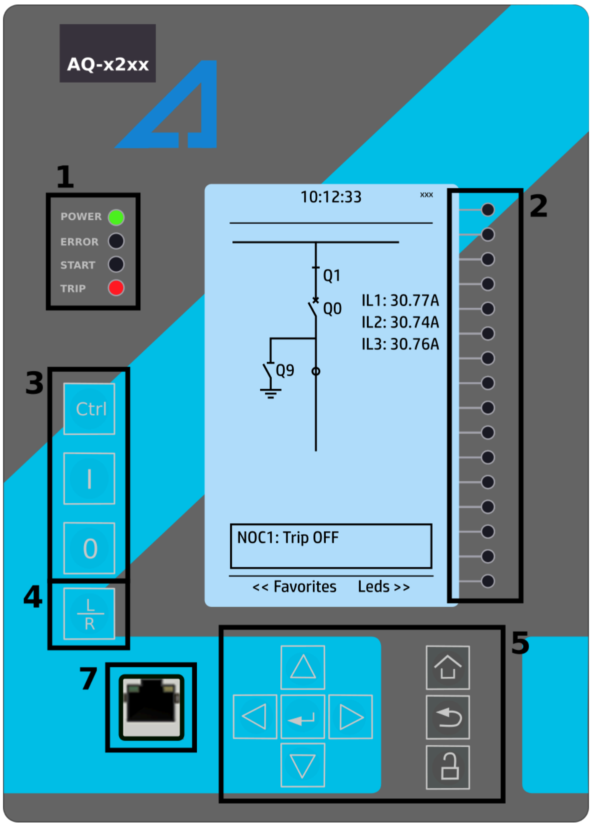
4.1 Panel structure

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.

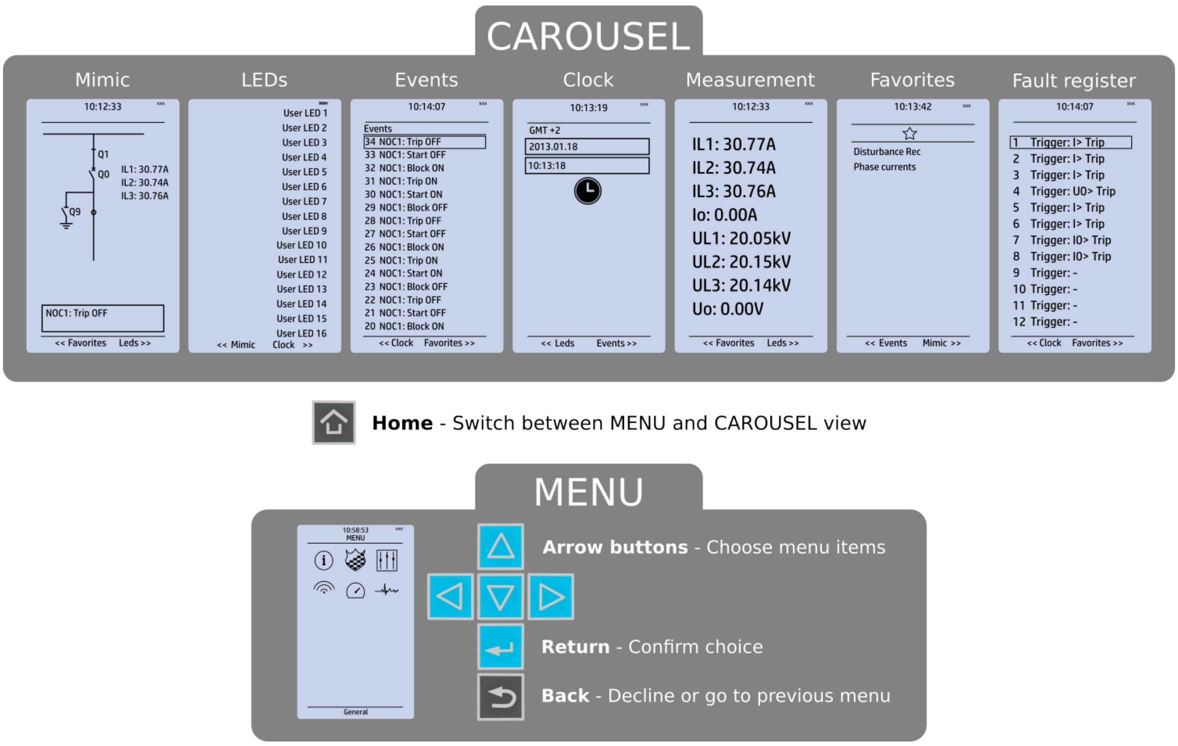
Holding the **I** (object control) button down for five seconds brings up the button test menu. It displays all the physical buttons on the front panel. Pressing any of the listed buttons marks them as tested. When all buttons are marked as having been tested, device will return back to default view.

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

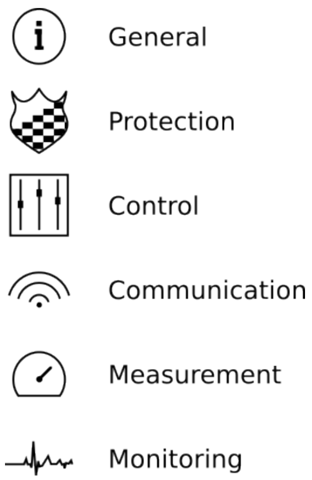
All the settings in this device have been divided into the following six (6) main configuration menus:

- General
- Protection

- Control
- Communication
- Measurement
- Monitoring.

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

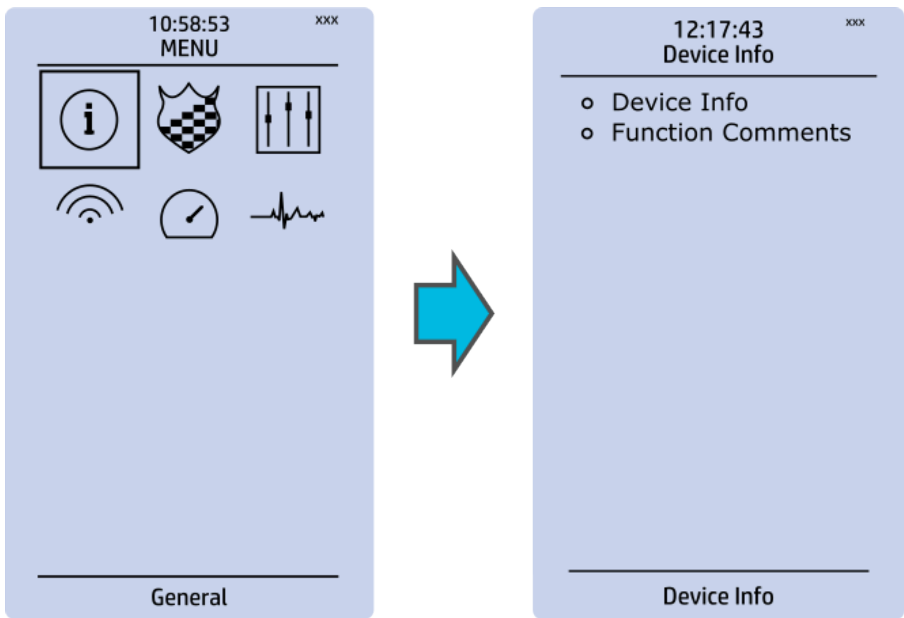
Figure. 4.2.2 - 3. Main configuration menus.



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.

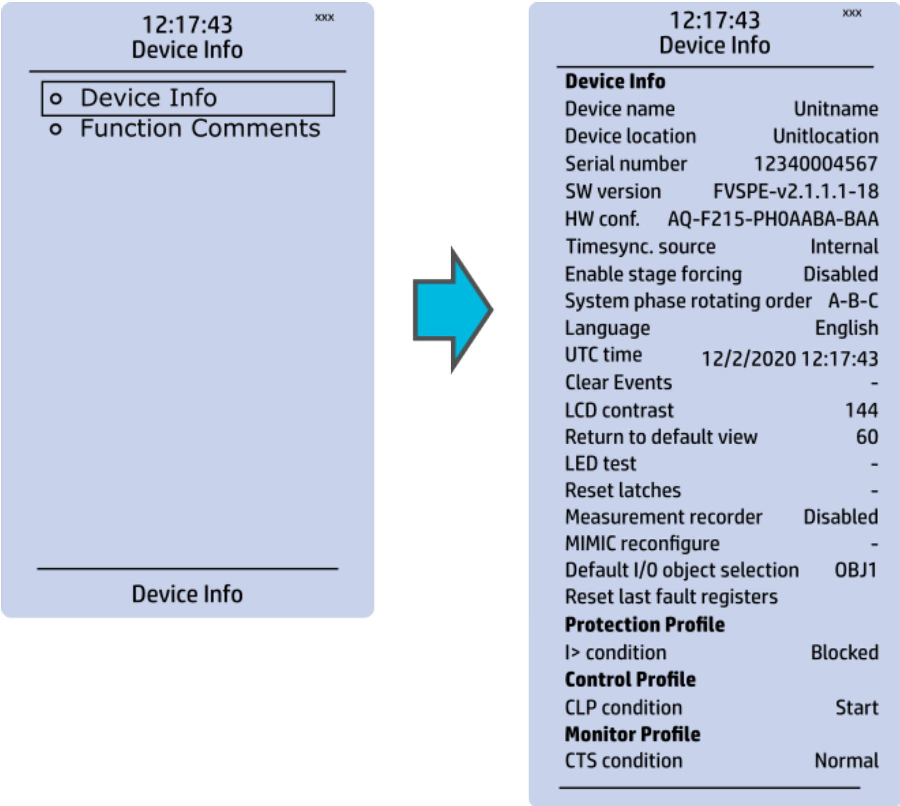


Table. 4.3 - 3. Parameters and indications in the *General* menu.

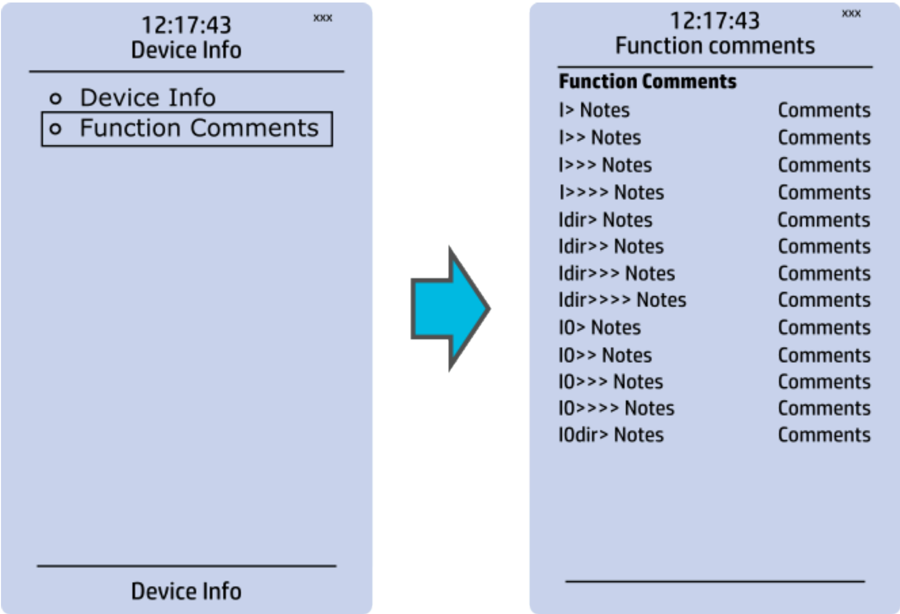
Name	Range	Step	Default	Description
Device name	-	-	Unitname	The file name uses these fields when loading the .aqs configuration file from the AQ-200 unit.
Device location	-	-	Unitlocation	
Serial number	-	-	-	Displays the unit's unique serial number. The serial number is also printed on the sticker 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 *Info* page with the *Force status to* 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 *Tools → Misc → Measurement recorder.*
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.

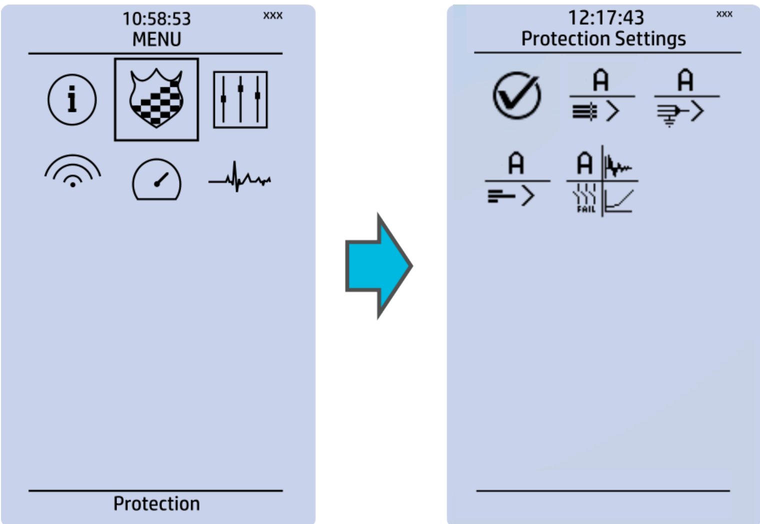
Figure. 4.3 - 6. Function comments.



4.4 Protection menu

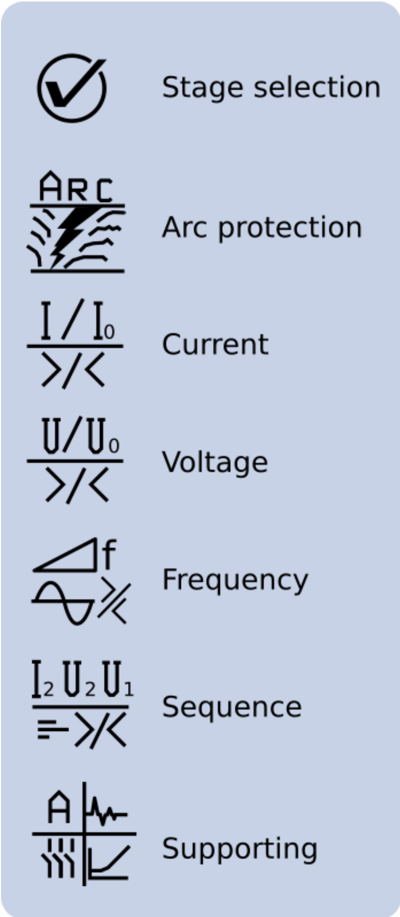
General

Figure. 4.4 - 7. Protection menu structure



The *Protection* main menu includes the *Stage activation* submenu as well as the submenus for all the various protection functions, categorized under the following modules: "Arc protection", "Current", "Voltage", "Frequency", "Sequence" and "Supporting" (see the image below). The available functions depend on the device type in use.

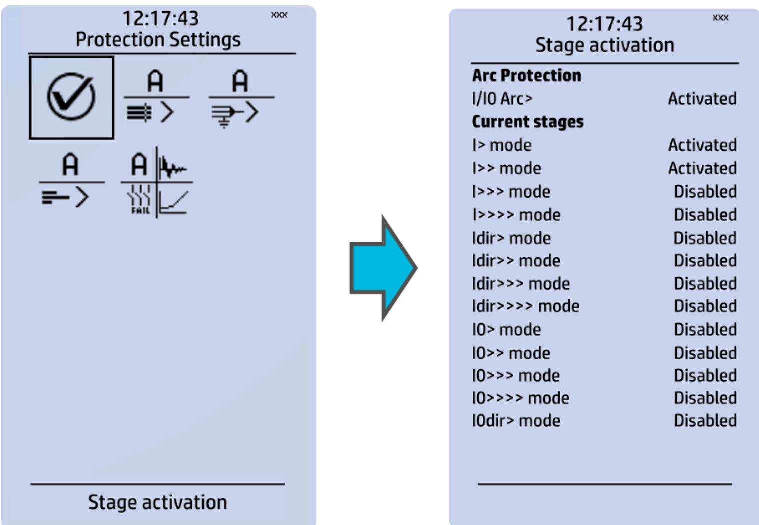
Figure. 4.4 - 8. Protection menu view.



Stage activation

You can activate the various protection stages in the *Stage activation* submenu (see the images below). Each protection stage and supporting function is disabled by default. When you activate one of the stages, its activated menu appears in the stage-specific submenu. For example, the I> (overcurrent) protection stage can be found in the "Current" module, whereas the U< (undervoltage) protection stage can be found in the "Voltage" module.

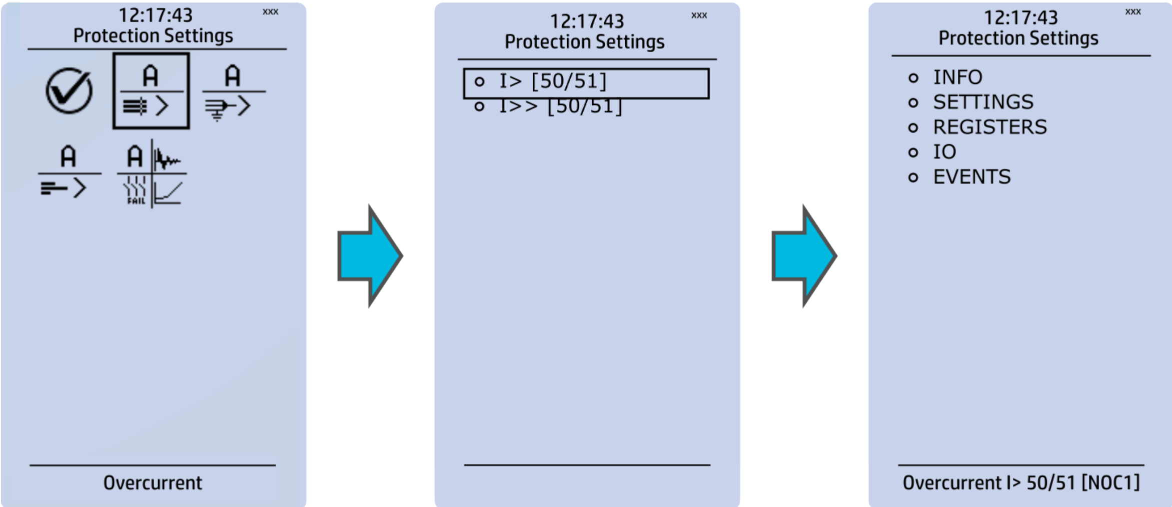
Figure. 4.4 - 9. Submenus for Stage activation.



Example of a protection stage and its use

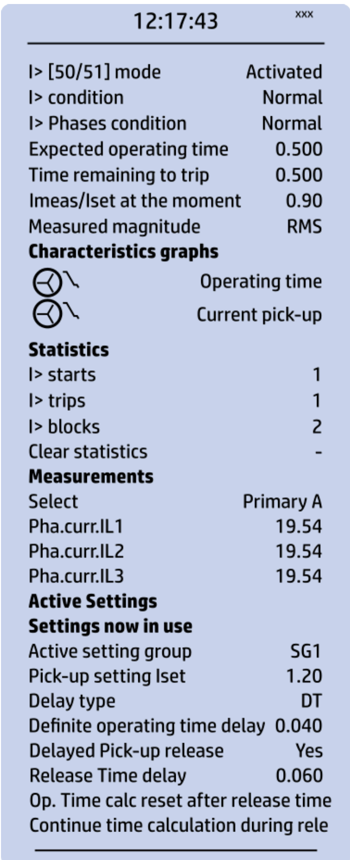
Once a protection stage has been activated in the *Stage activation* submenu, you can open its own submenu. In the image series below, the user has activated three current stages. The user accesses the list of activated current stages through the "Current" module, and selects the I> stage for further inspection.

Figure. 4.4 - 10. Accessing the submenu of an individual activated stage.



Each protection stage and supporting function has five sections in their stage submenus: "Info", "Settings", "Registers", "I/O" and "Events".

Figure. 4.4 - 11. Info.

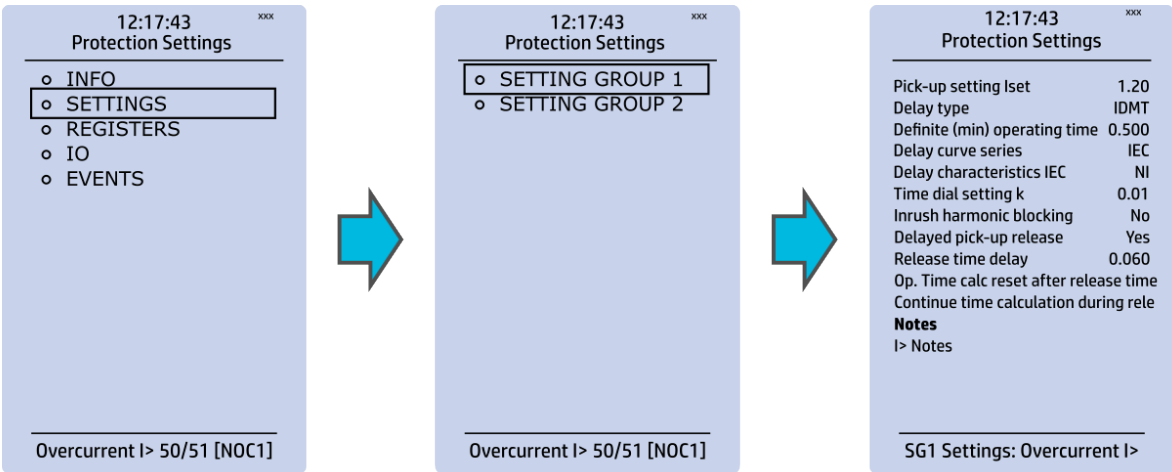


The "Info" section offers many details concerning the function and its status:

- Function condition: indicates the stage's condition which can be Normal, Start, Trip, or Blocked.
- Expected operating time: Expected time delay from detecting a fault to tripping the breaker. This value can vary during a fault if an inverse curve time delay (IDMT) is used.
- Time remaining to trip: When a fault is detected this value counts down towards zero. When zero is reached, the function will trip.
- Imeas/Iset at the moment: Displays the ratio between the measured value and the pick-up level.
- 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).
- Characteristics graphs: opens graphs related to the protection 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 *Stage activation* submenu, you can disable the function through the "Info" section ("Function mode" at the top of the section).

Figure. 4.4 - 12. Settings.

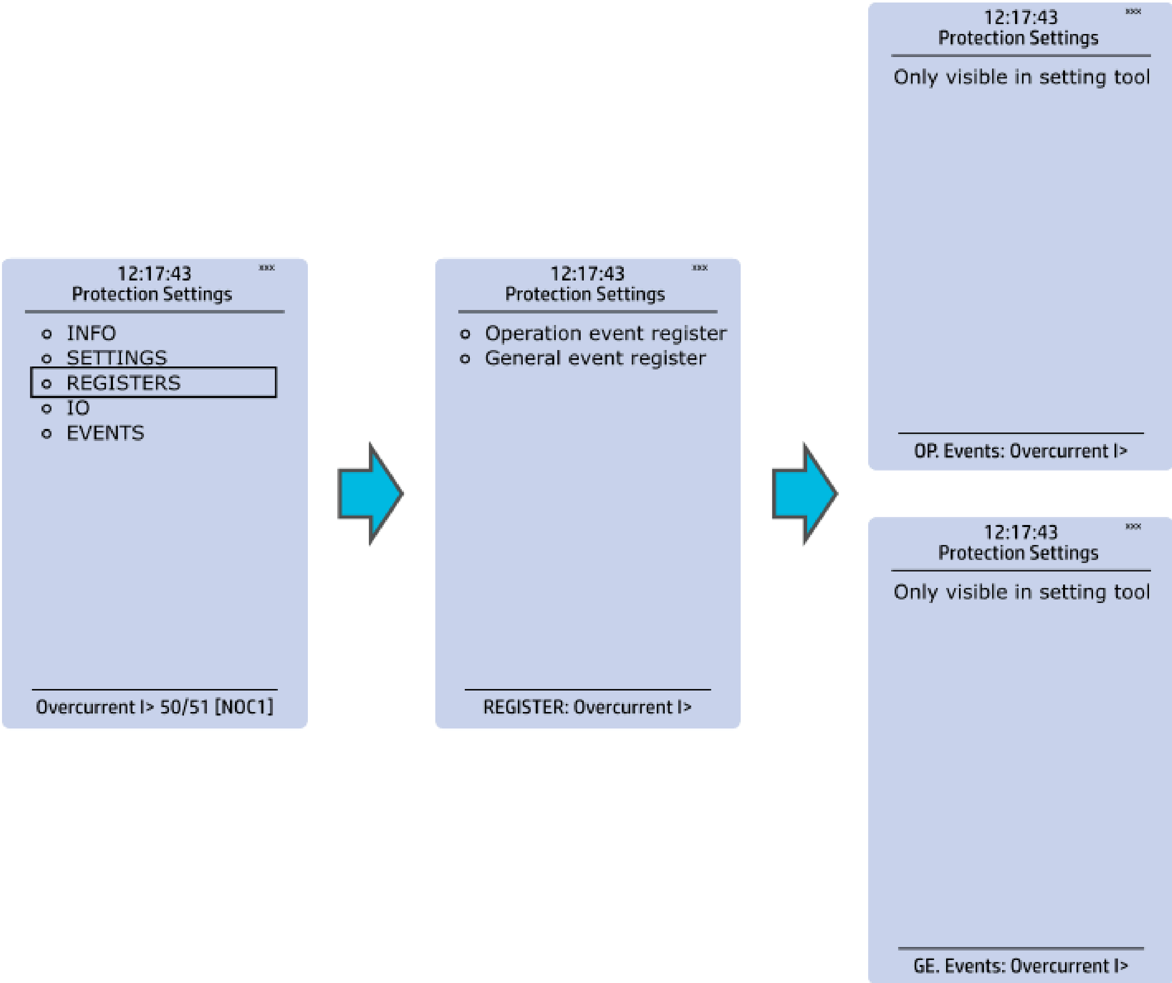


The stage settings vary depending on which protection function they are a part of. By default only one setting group of the eight available setting groups is activated. You can enable more groups in the *Control → Setting groups* menu, although they are set here in the "Settings" section.

Most protection functions follow the same structure:

- Pick-up setting: Defines the fault magnitude. Most functions pick-up value is in relation to the current transformer or voltage transformer nominal, but some functions use kW, ohm, Hz and other units. Voltage and current transformers nominal values can be set at *Measurement → Transformers*.
- Delay type and operating time delay settings are described in detail in chapter *General properties of a protection function*.

Figure. 4.4 - 13. Registers.

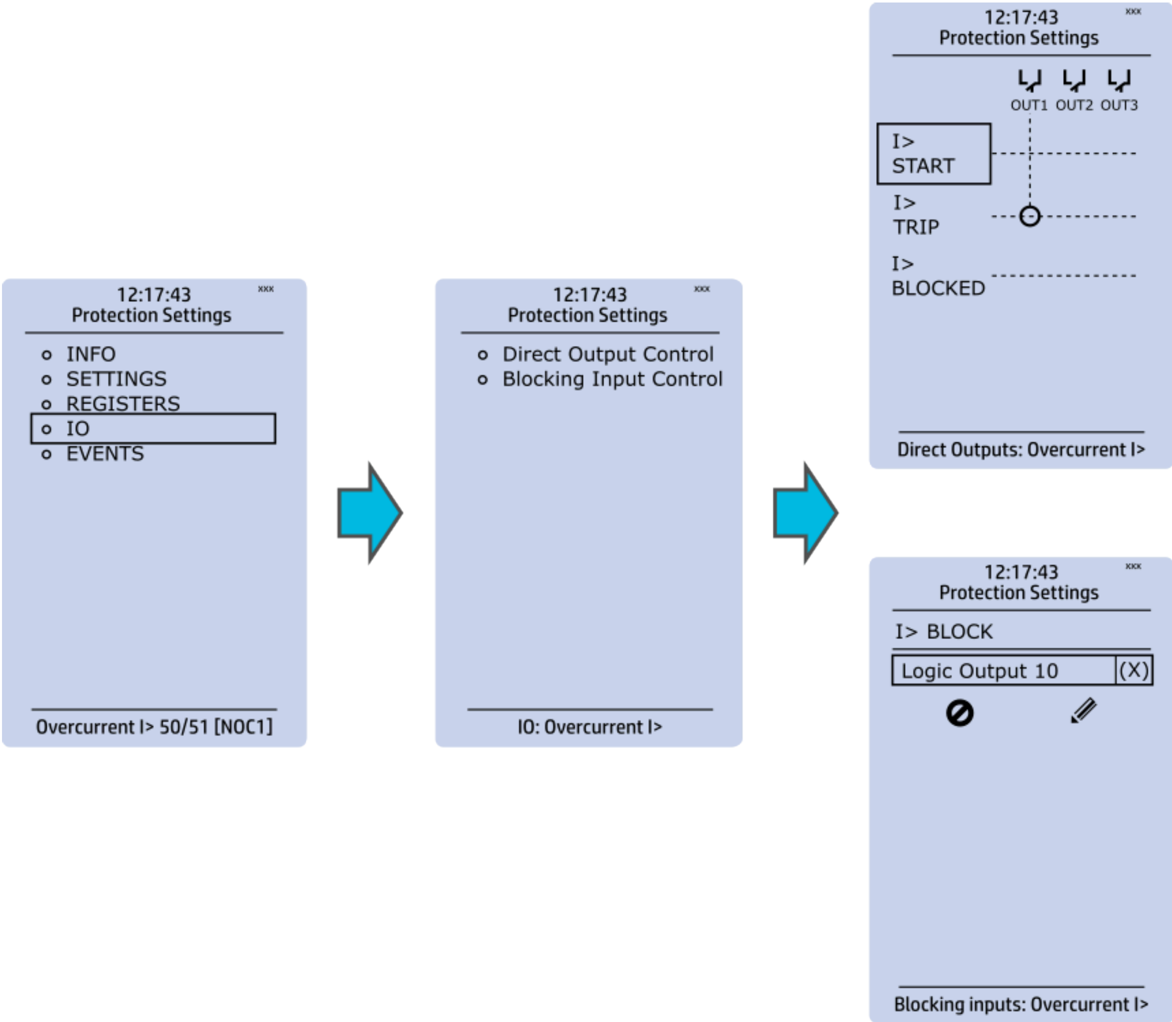


Register menu content is not available in the HMI. It can only be accessed with AQtivate setting tool. Stored in the "Registers" section you can find both "Operation event register" and "General event register".

"Operation event register" stores the function's specific fault 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 protection 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 - 14. I/O.



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 (DI 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:

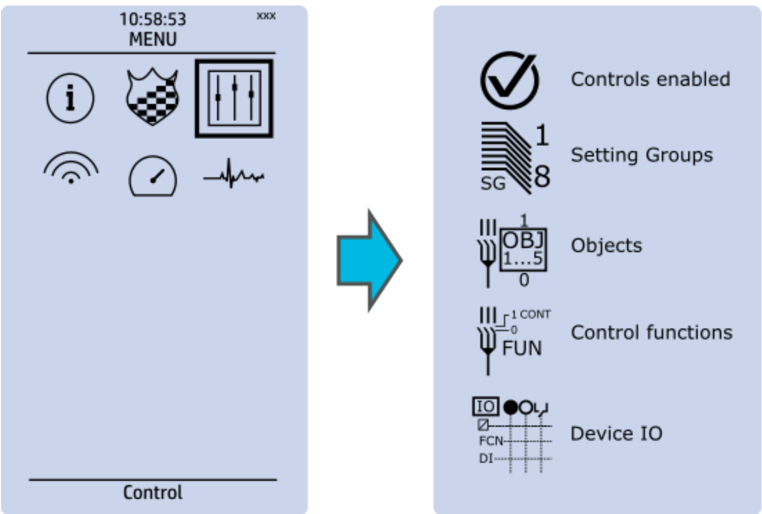
- digital inputs
- logical inputs or outputs
- the START, TRIP or BLOCKED information of another protection stage
- object status information.

Figure. 4.4 - 15. Events.

You can mask on and mask off the protection stage related events in "Event mask". By default events are masked off. You can activate the desired events by masking them ("x"). 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 event history (which can be accessed in the "Events" view in the user view section).

4.5 Control menu

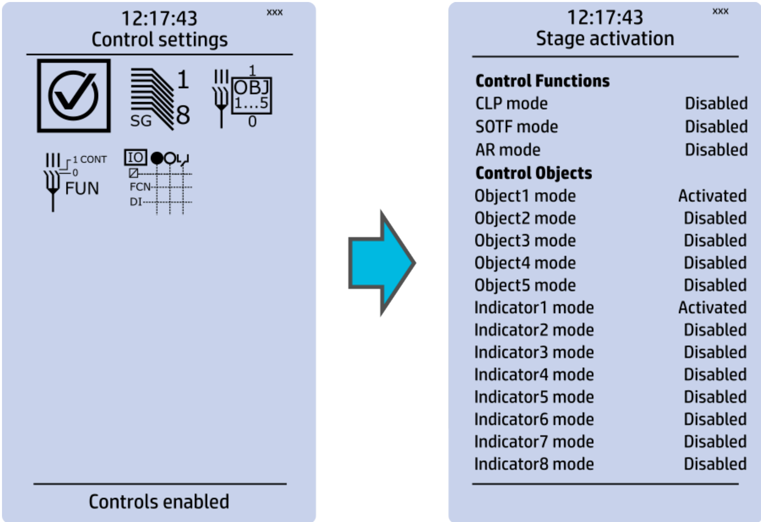
Main menu



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. 4.5 - 16. Controls enabled submenu.

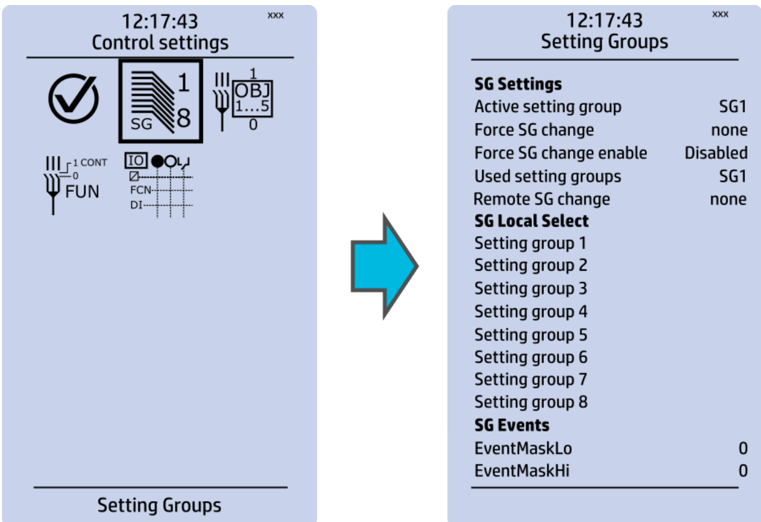


You can activate the selected control functions in the *Controls enabled* submenu. By default all the control functions are disabled. All activated functions can be viewed in the *Control functions* submenu (see the section "Control functions" below for more information).

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. 4.5 - 17. Setting groups submenu.



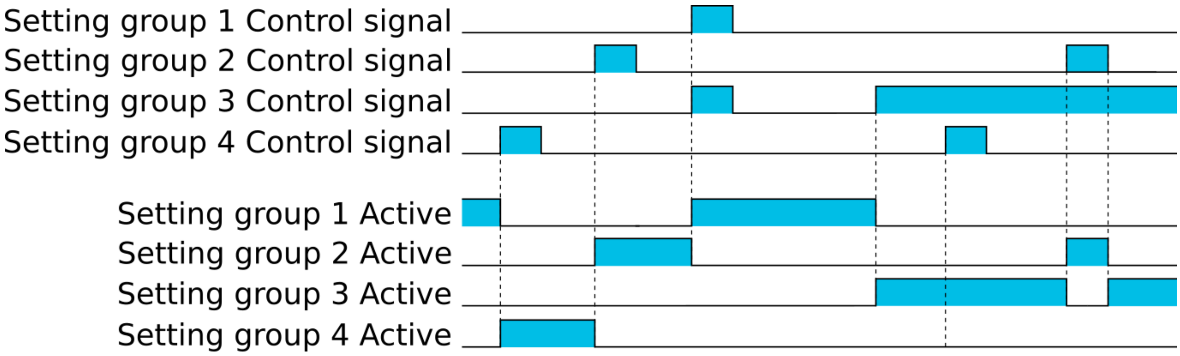
The *Setting groups* submenu displays all the information related to setting group changing, such as the following:

- 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).

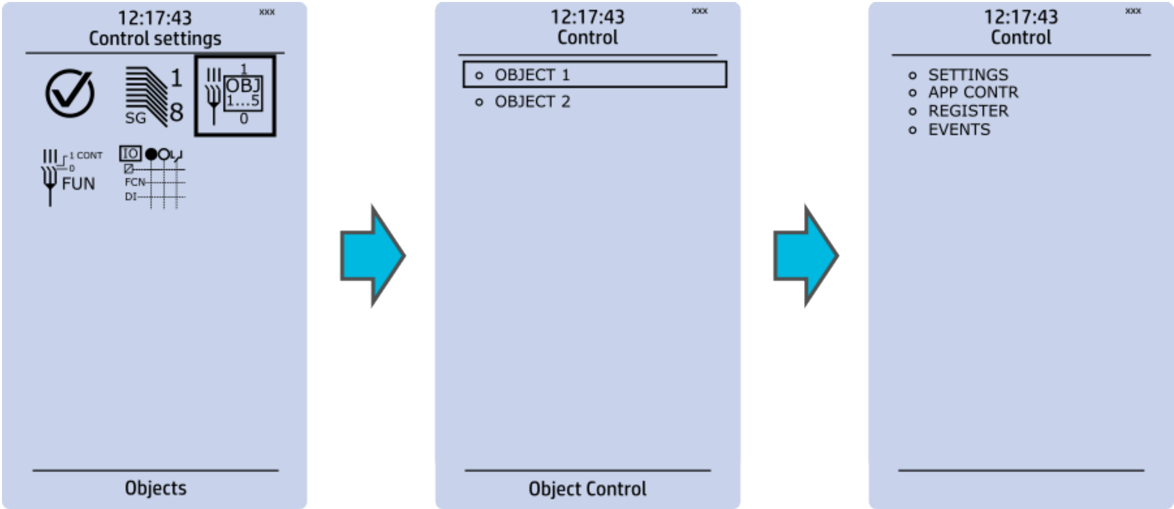
Setting group 1 (SG1) has the highest priority, while Setting group 8 (SG8) has the lowest priority. Setting groups can be controlled with pulses or with both pulses and static signals (see the image below).

Figure. 4.5 - 18. Example of setting group (SG) changing.



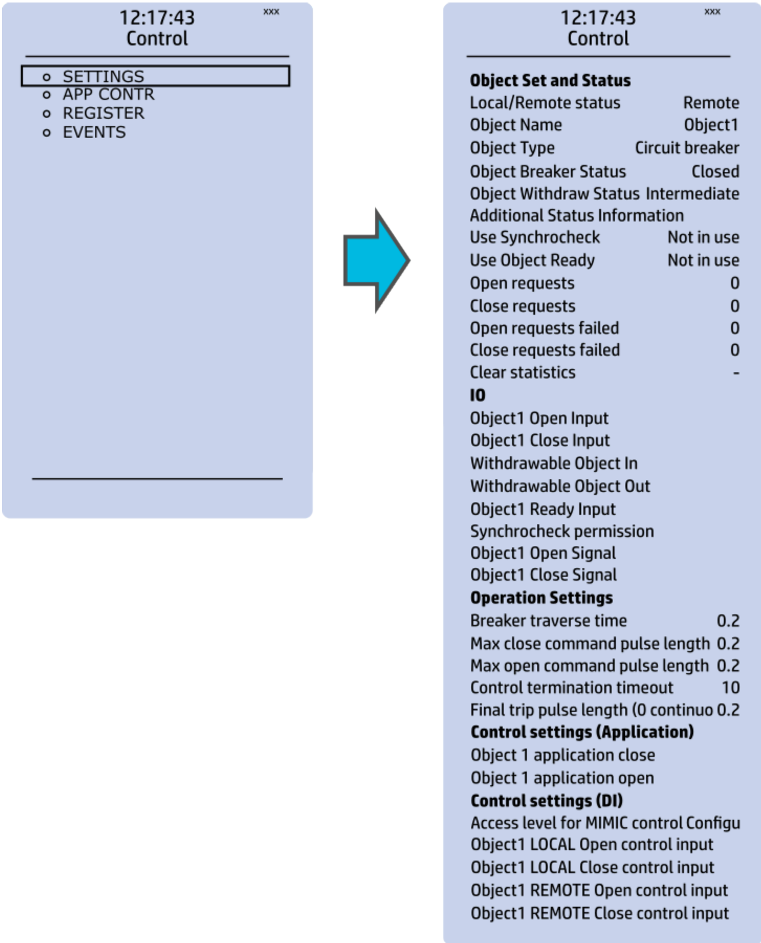
Objects

Figure. 4.5 - 19. 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. 4.5 - 20. 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.

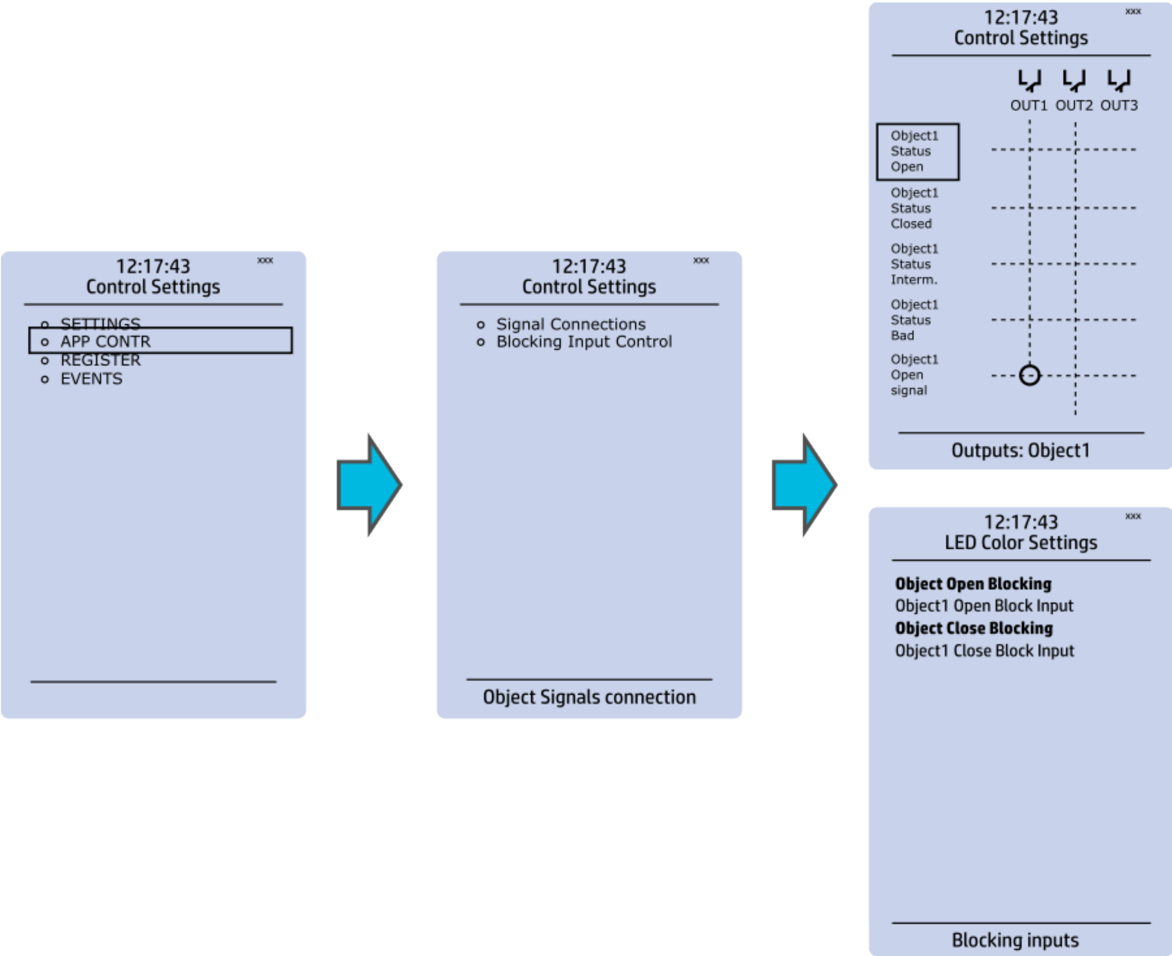
CONTROL SETTINGS (APPLICATION)

- 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.

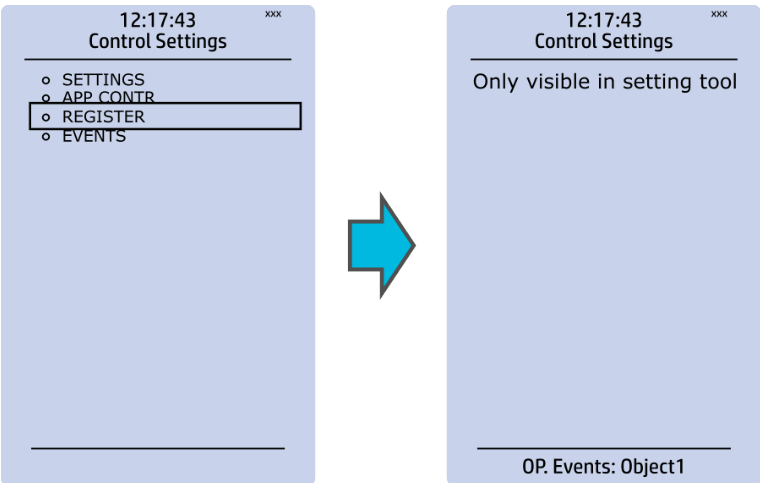
Figure. 4.5 - 21. Application control section.



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. 4.5 - 22. 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.

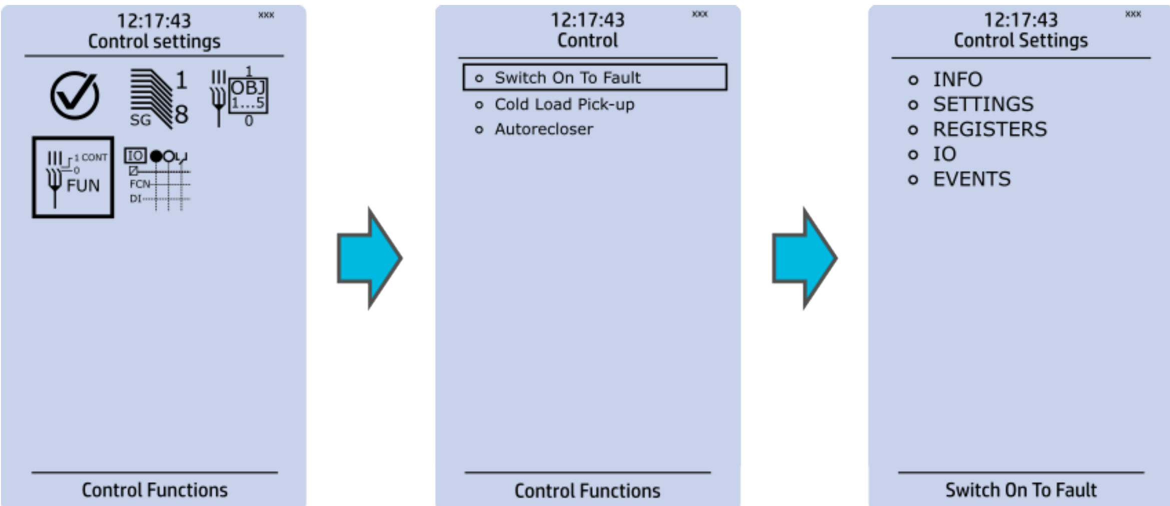
Figure. 4.5 - 23. Events section.

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

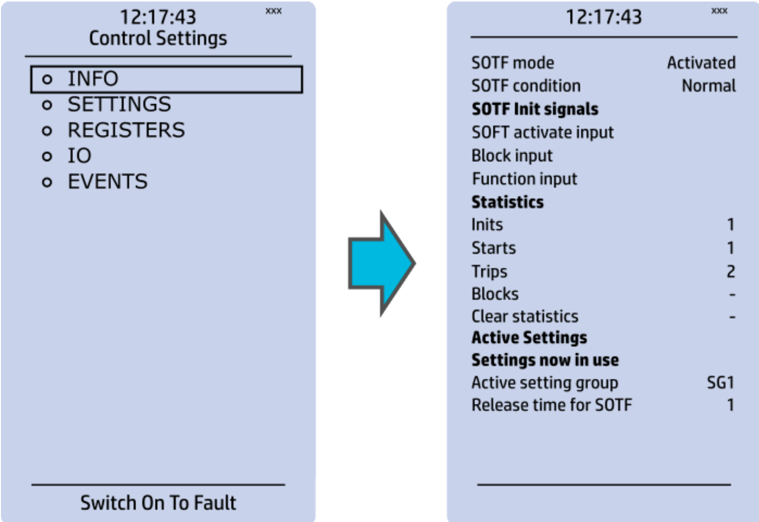
Once a control function has been activated in the *Controls → Controls enabled* submenu, its own submenu can be opened. In the image series below, the user has activated three control functions. The user accesses the list of activated control stages through the "Control functions" module, and selects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

Figure. 4.5 - 24. 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. 4.5 - 25. Info section.

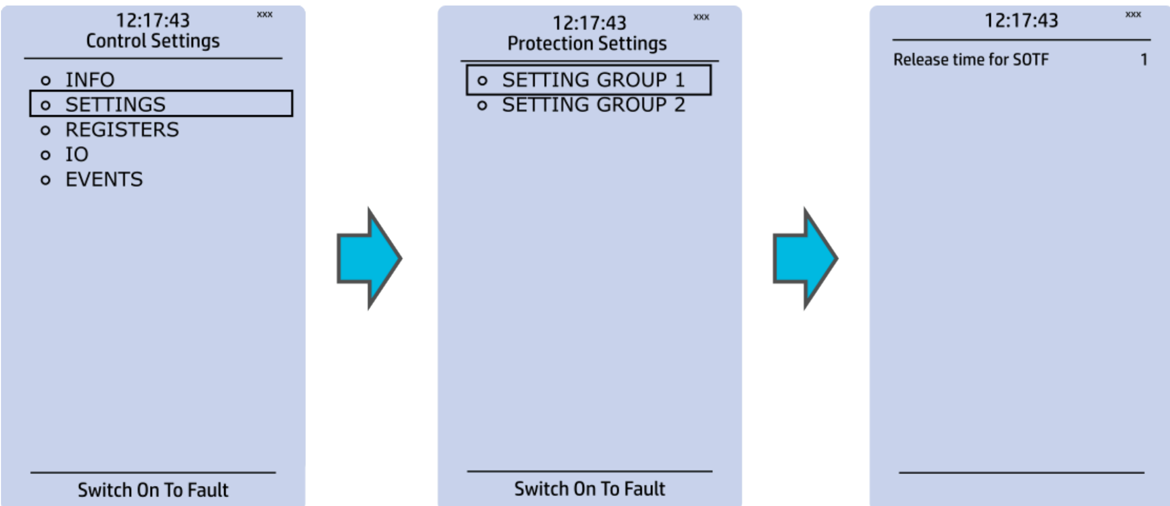


The "Info" section offers many details concerning the function and its status:

- 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).

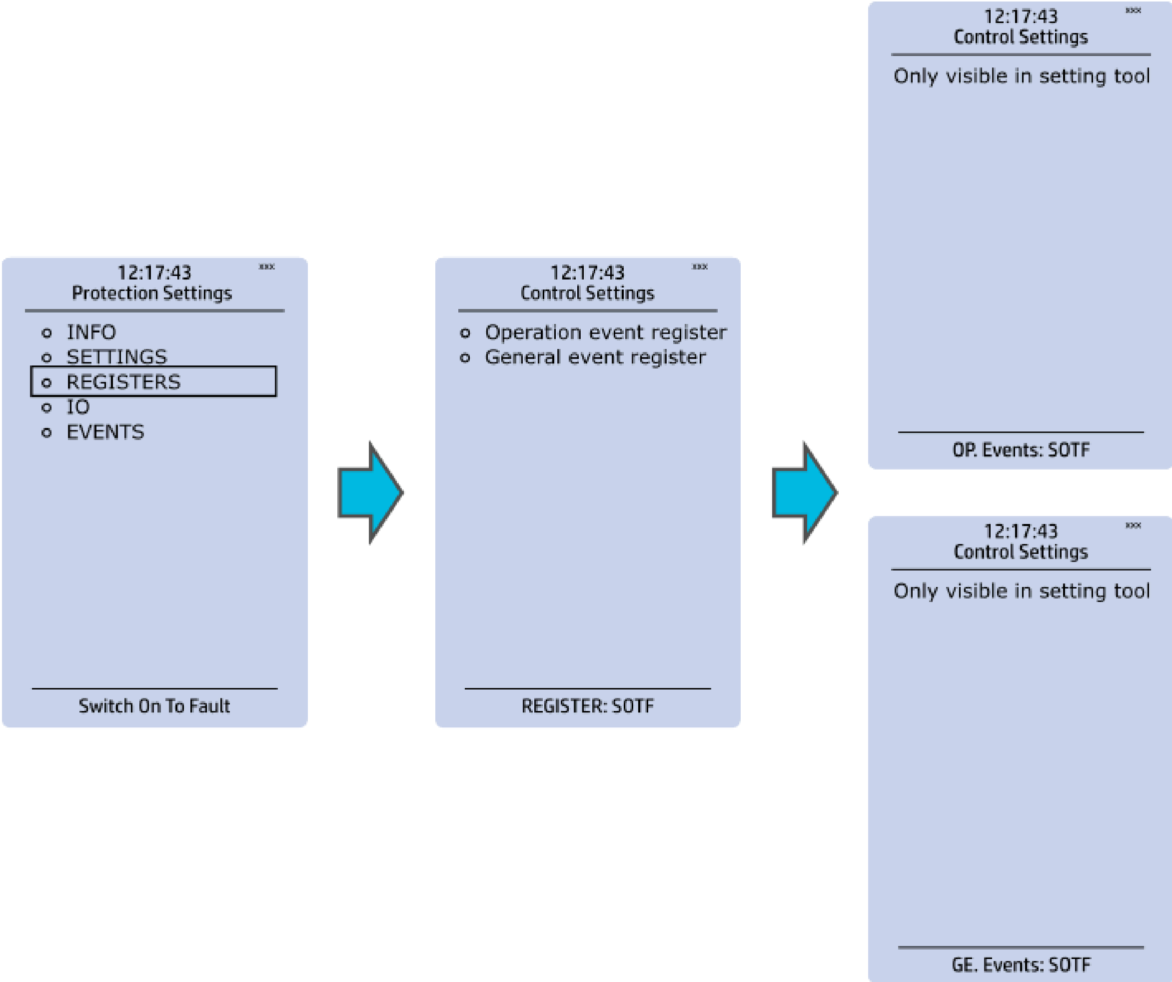
While the function is activated and disabled in the *Control → Controls enabled* submenu, you can disable the function through the "Info" section (the [function name] mode at the top of the section).

Figure. 4.5 - 26. 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. 4.5 - 27. Registers section.

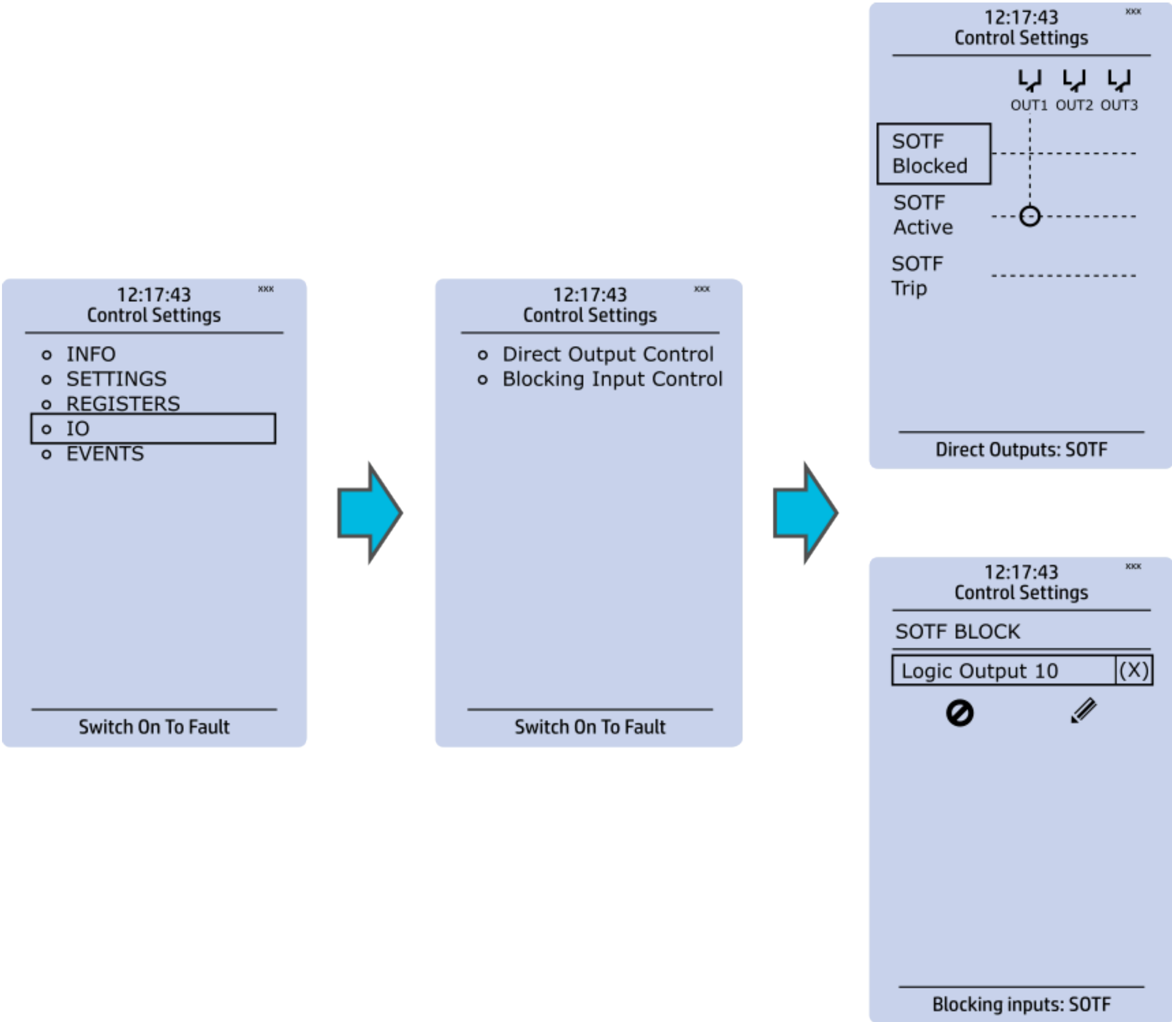


Please note that the content of the "Registers" section is not available in the HMI. It can only be accessed via the AQtivate setting tool. Stored in the "Registers" section you can find both "Operation event register" and "General event register".

"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. 4.5 - 28. 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:

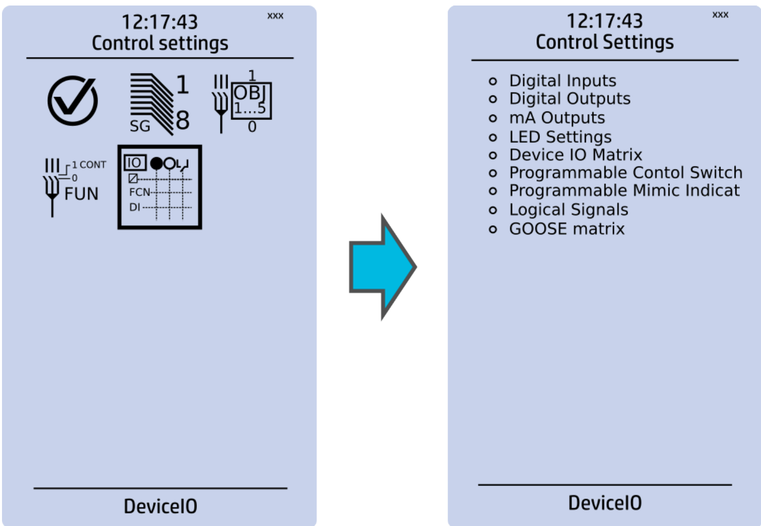
- digital inputs.
- logical inputs or outputs.
- the START, TRIP or BLOCKED information of another protection stage.
- object status information.

Figure. 4.5 - 29. 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).

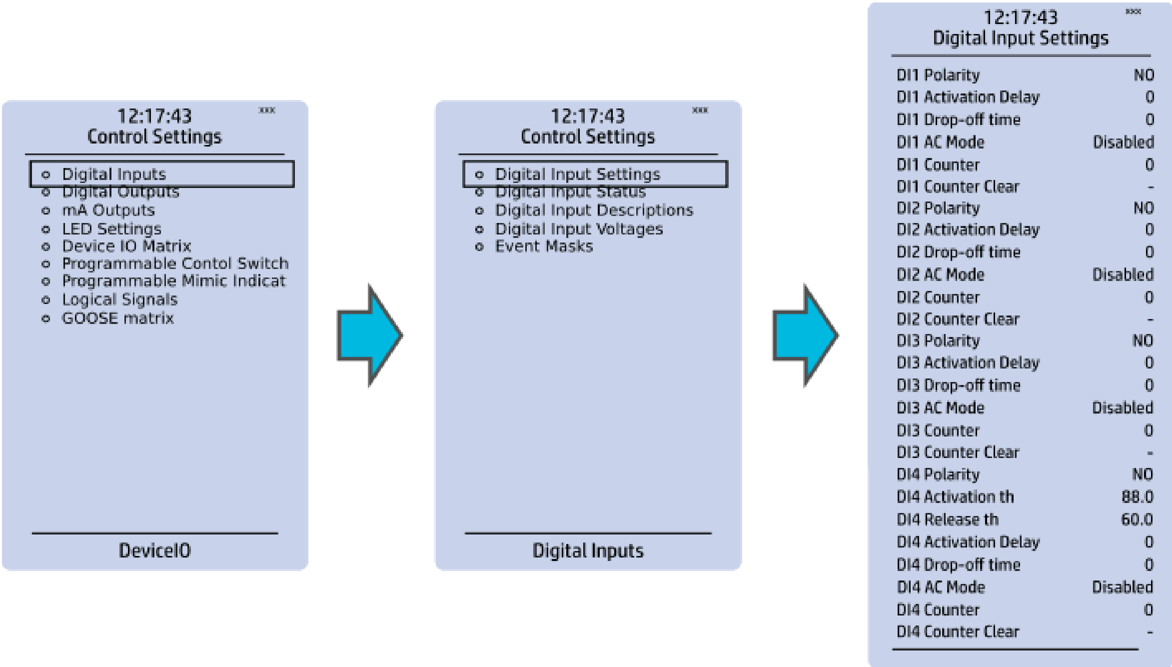
Device I/O

Figure. 4.5 - 30. 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. 4.5 - 31. Digital input section.

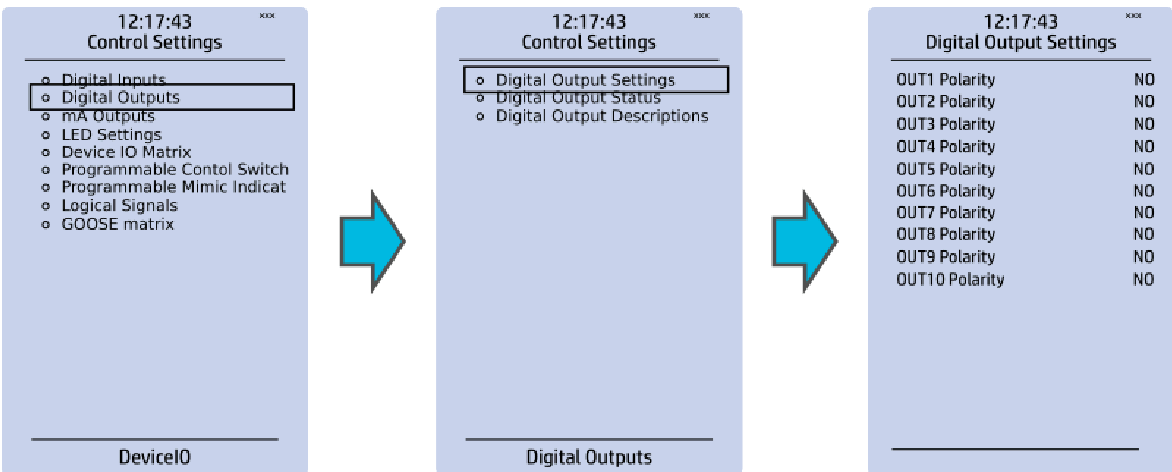


All settings related to digital inputs can be found in the "Digital inputs" section.

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. 4.5 - 32. Digital outputs section.



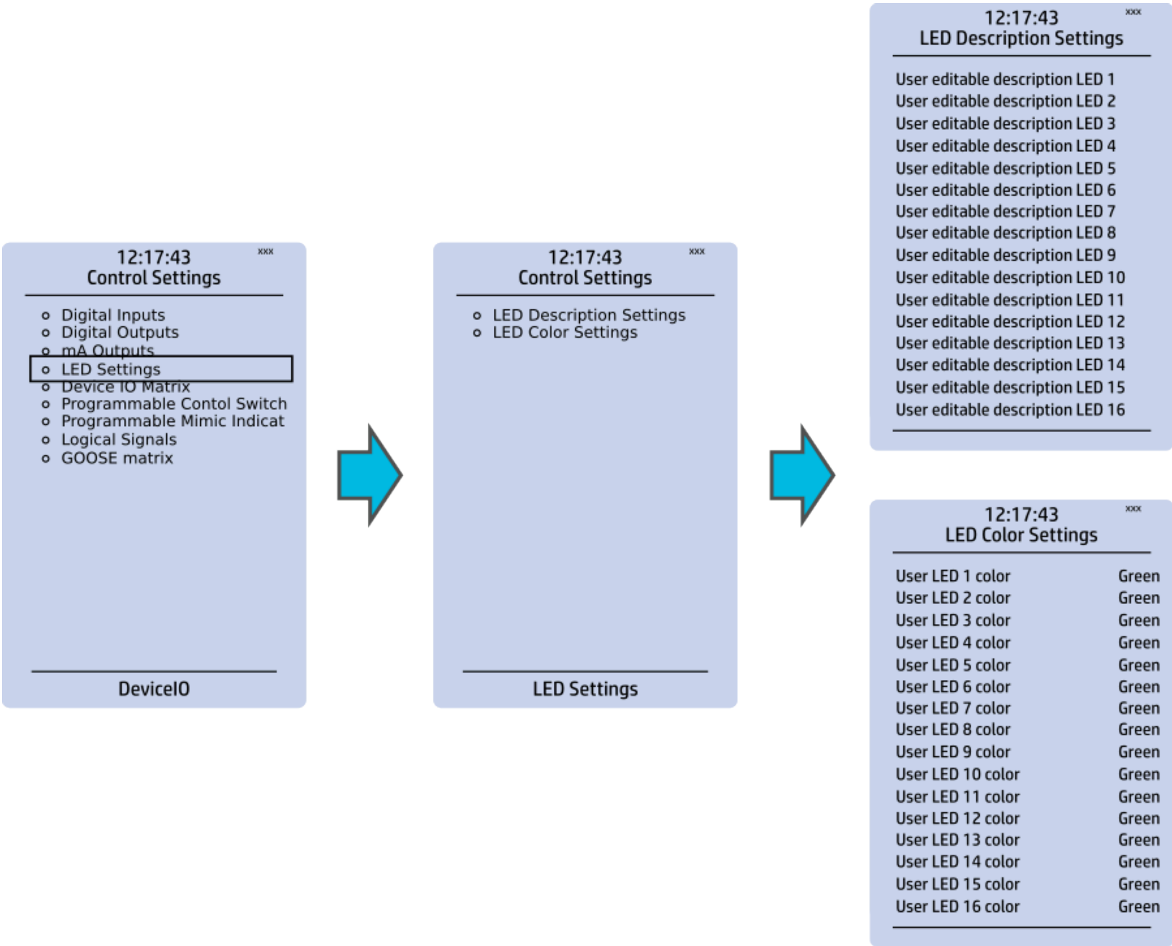
All settings related to digital outputs can be found in the "Digital outputs" section.

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!

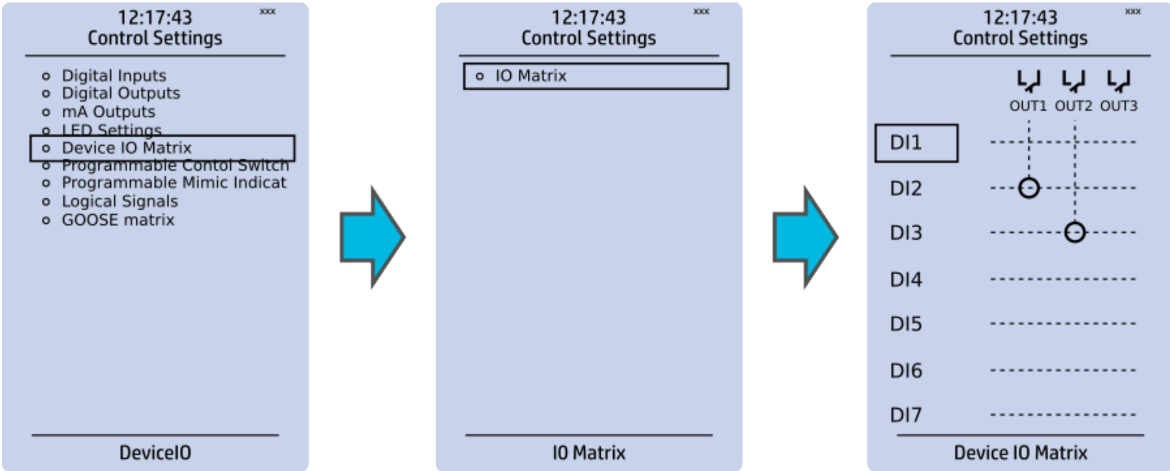
An NC signal goes to the default position (NO) if the relay loses the auxiliary voltage or if the system is fully reset. However, an NC signal does not open during voltage or during System full reset. An NC output signal does not open during a Communication or Protection reset.

Figure. 4.5 - 33. 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.

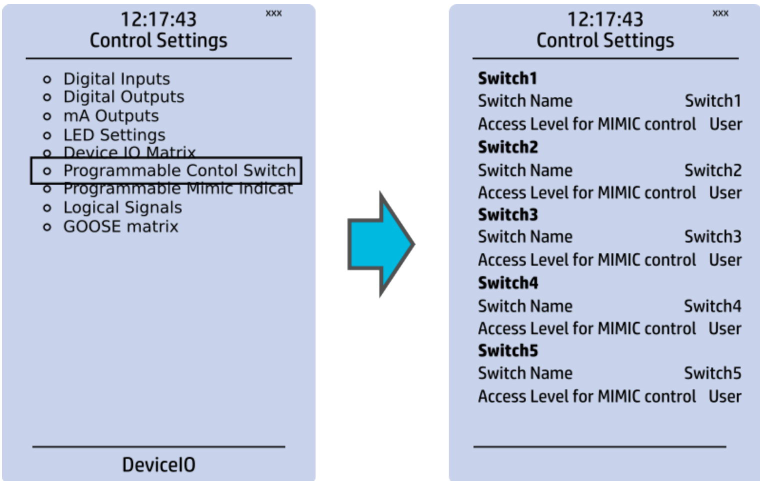
Figure. 4.5 - 34. Device I/O matrix section.



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.

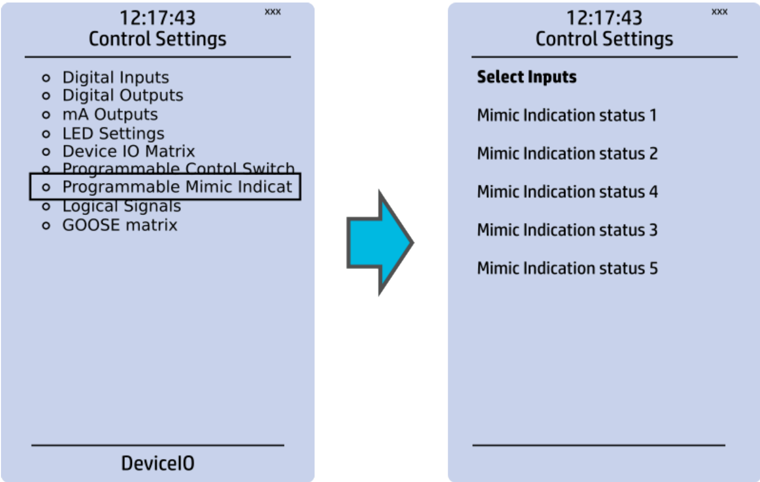
You can clear latched signals by entering the mimic display and the pressing the Back button on the panel.

Figure. 4.5 - 35. Programmable control switch section.



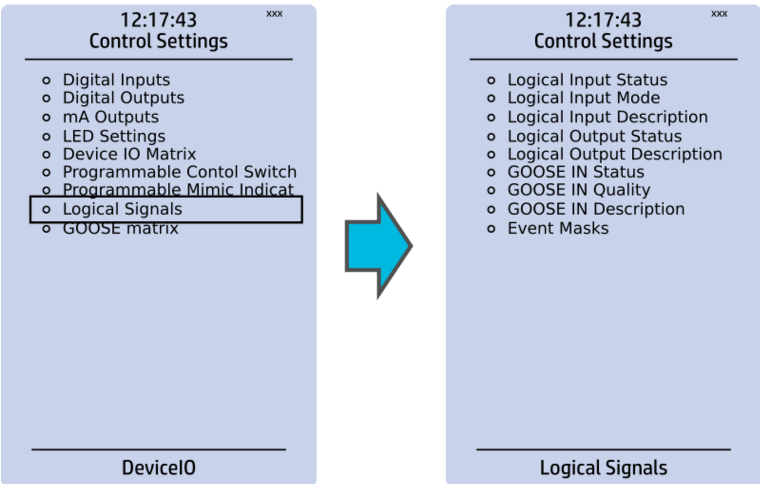
Programmable control switches (PCSs) are switches that can be used to control signals while in the mimic view. These signals can be used in a variety of situations, such as for controlling the logic program, for function blocking, etc. You can name each switch and set the access level to determine who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

Figure. 4.5 - 36. 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. 4.5 - 37. 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.

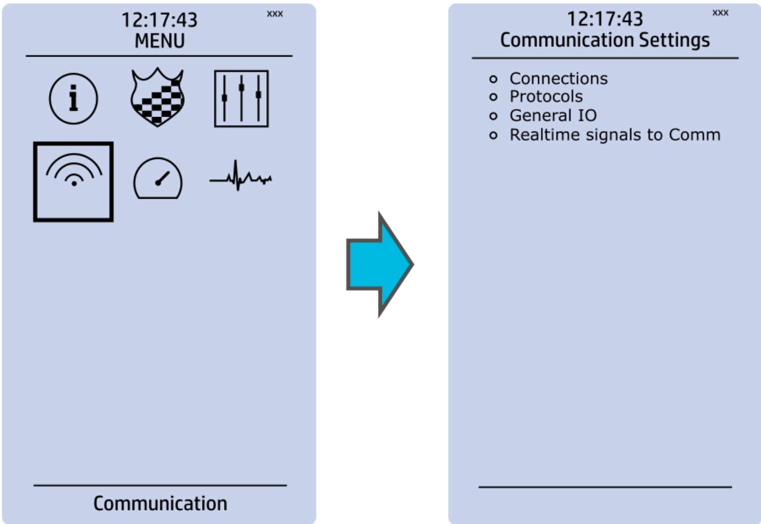
Logical output signals can be used as the end result of a logic that has been built in the AQtivate setting tool. The end result can then be connected to a digital output or a LED in the matrix, block functions and much more.

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.

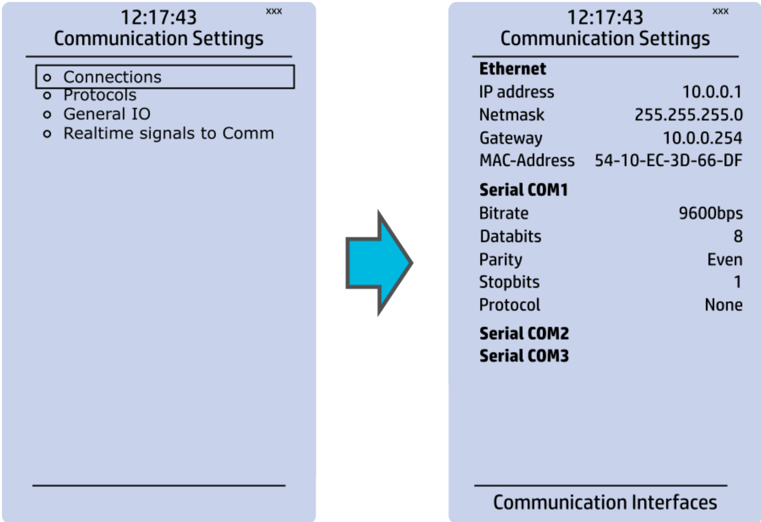
4.6 Communication menu



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. 4.6 - 38. View of the Connections submenu.



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

<u>ETHERNET</u>

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.

<u>SERIAL COM</u>

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!

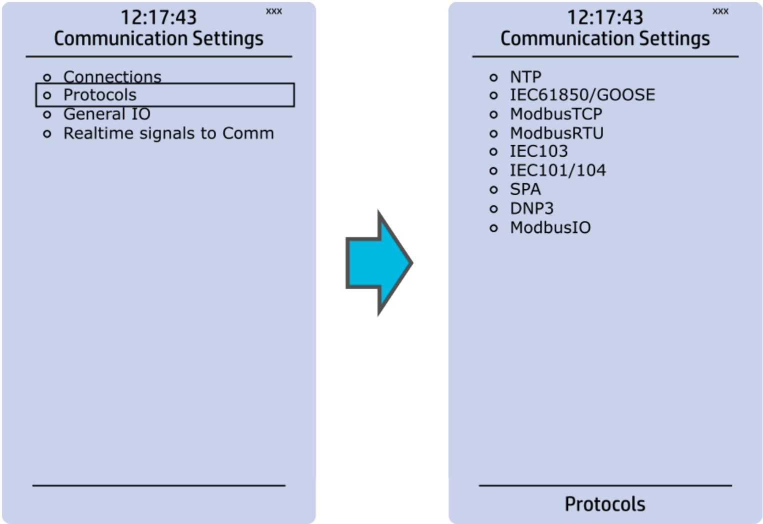
When communicating with a device through a front Ethernet port connection, the IP address is always 192.168.66.9.

<u>SERIAL COM1 & COM2</u>

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

Protocols

Figure. 4.6 - 39. 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:

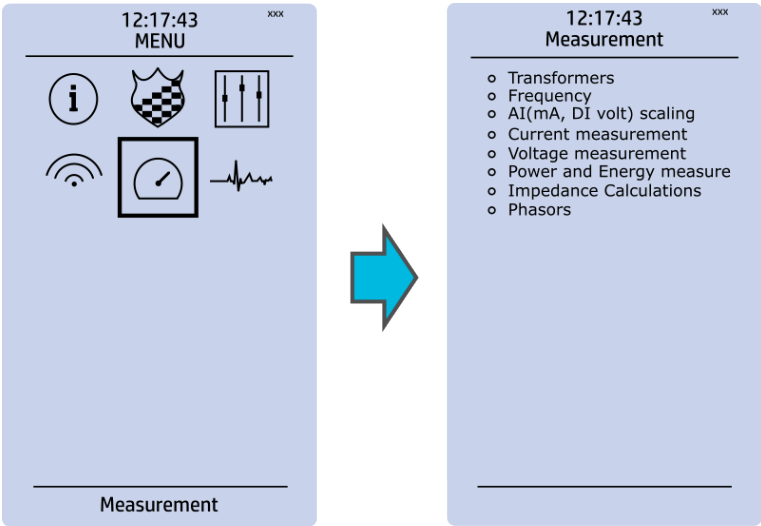
- NTP: this protocol is used for time synchronization over Ethernet, and can be used simultaneously with the ethernet based communication protocols.
- IEC 61850: Ethernet based communication protocol.
- Modbus/TCP: Ethernet communication protocol.
- Modbus/RTU: Serial communication protocol.
- IEC103: 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.

4.7 Measurement menu

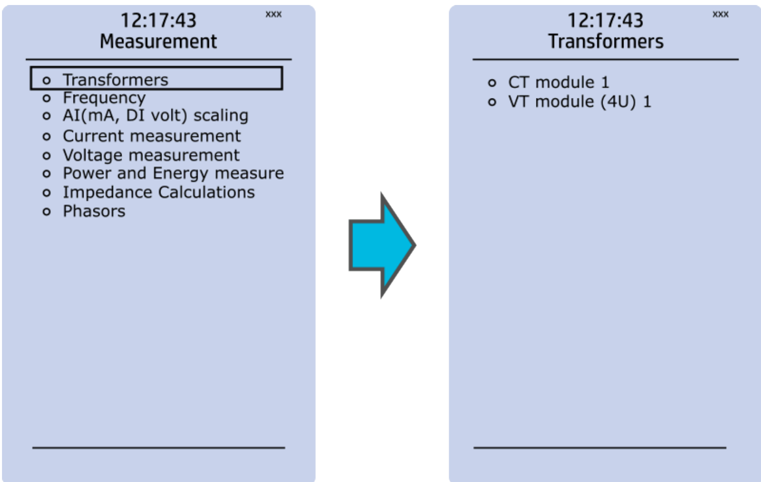
Figure. 4.7 - 40. Measurement section.



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

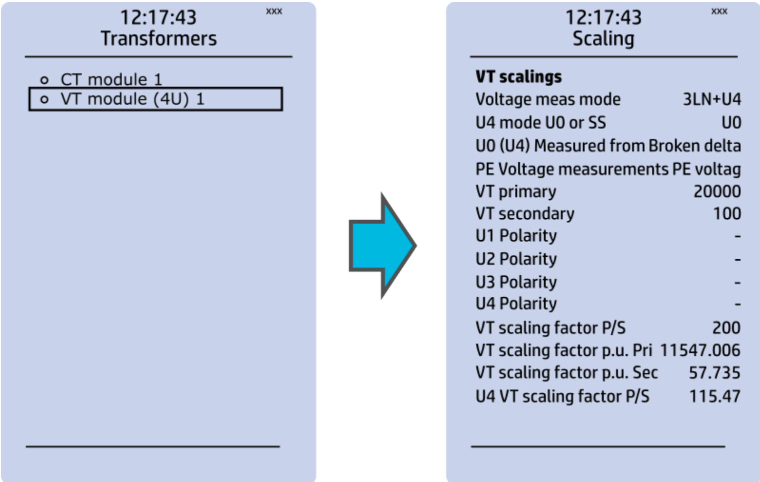
Figure. 4.7 - 41. Transformers section.



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.

VT module

Figure. 4.7 - 42. VT module section.

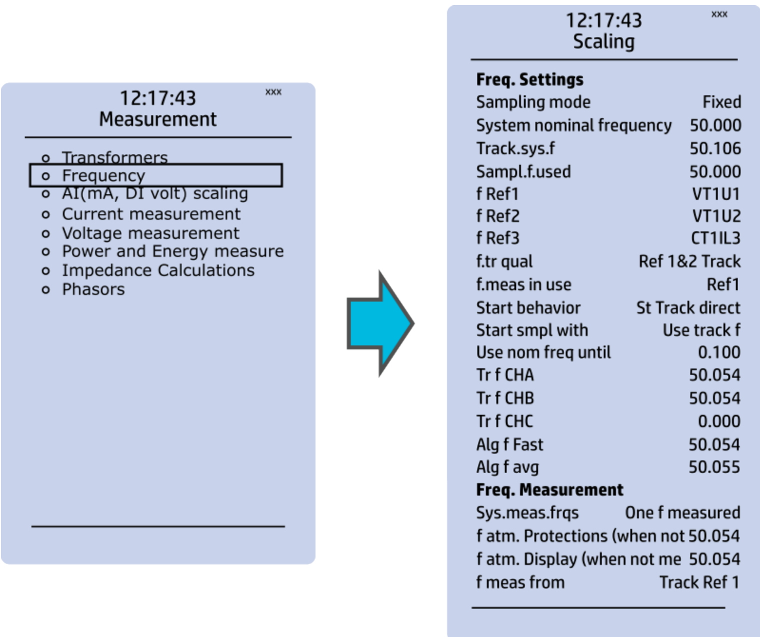


Voltage transformer settings include voltage measurement mode selection, voltage transformer nominal settings and voltage channel polarity switching. Voltage transformer setting defines what kind of voltages are connected to the VT module card. The voltages are: three line-to-line voltages, three line-to-neutral 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

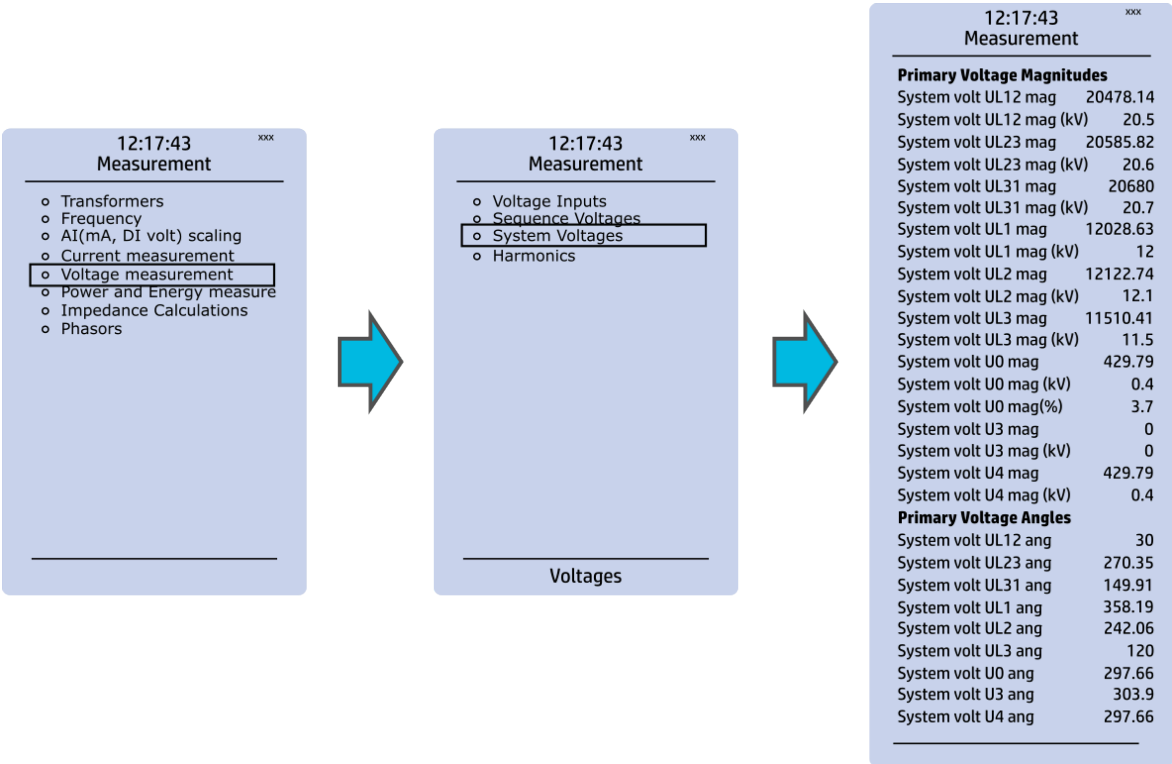
Figure. 4.7 - 43. Frequency submenu.



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.

Voltage measurement

Figure. 4.7 - 44. Voltage measurement submenu and System Voltages menu.



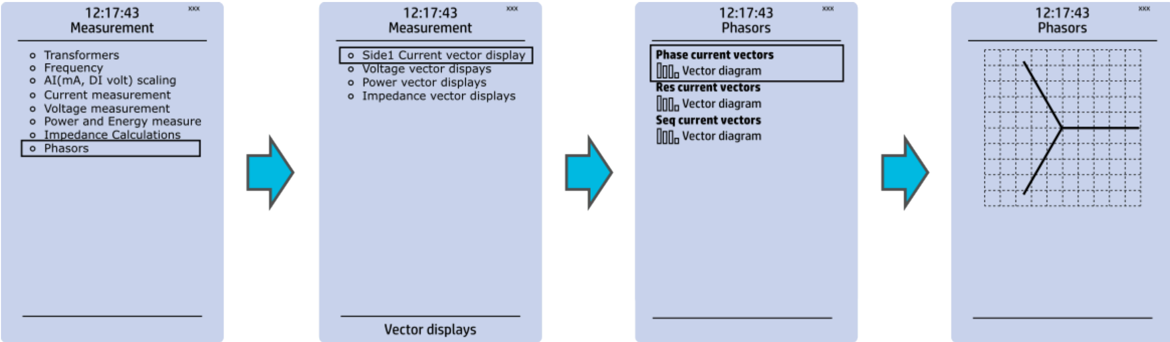
Voltage measurement submenu includes various individual measurements for each phase or phase-to-phase measurement.

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.

Phasors

Figure. 4.7 - 45. Phasors submenu.



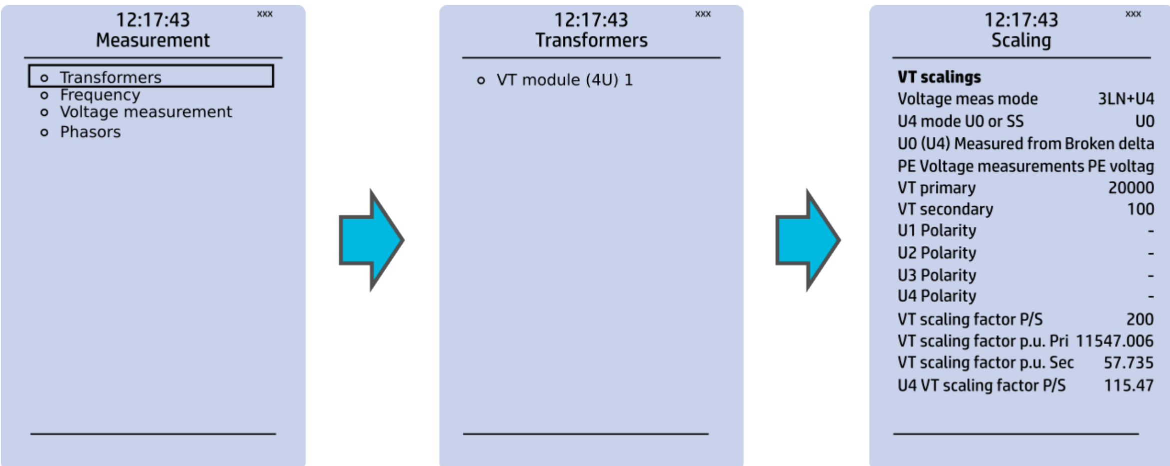
The *Phasors* submenu holds the vector displays for voltages and currents, as well as the various calculated components the IED may have (e.g. power, impedance). Phasors are helpful when solving incorrect wiring issues.

4.8 Measurement menu

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

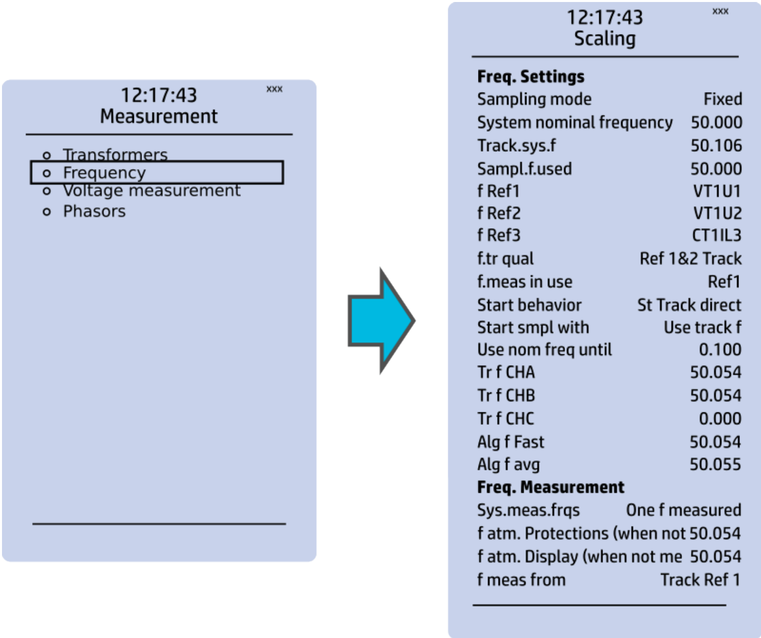
Figure. 4.8 - 46. Transformers submenu.



The AQ-V211 device has only the one voltage transformer module, and its scaling settings can be accessed here. 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 *Transformers* submenu also displays additional information such as VT scaling factors and per-unit values.

Frequency

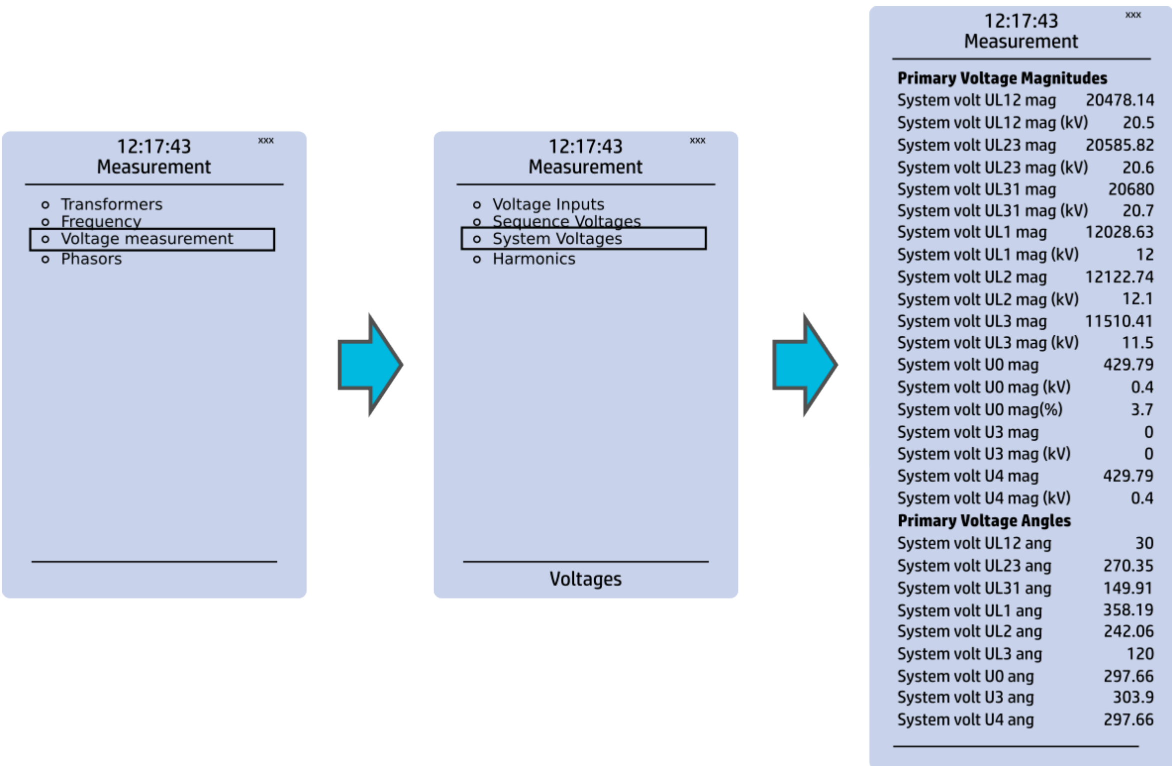
Figure. 4.8 - 47. Frequency submenu.



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 reference measuring points; the order of the reference points can be changed.

Voltage measurement

Figure. 4.8 - 48. Voltage measurement submenu.



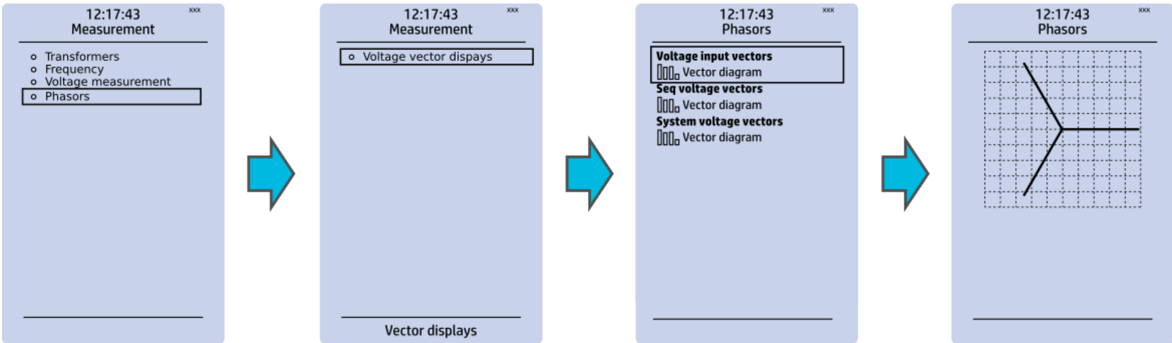
The *Voltage measurement* submenu includes various individual measurements for each phase or phase-to-phase measurement.

The *Voltage measurement* submenu has been 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.

Phasors

Figure. 4.8 - 49. Phasors submenu.

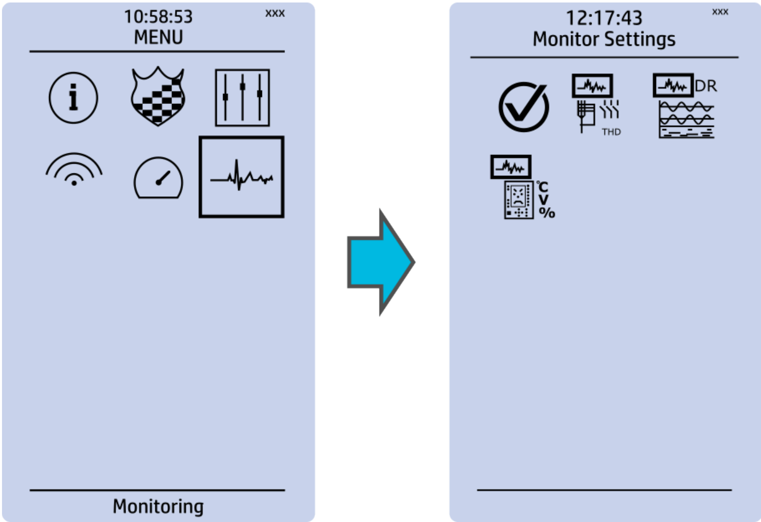


The *Phasors* submenu holds the vector displays for voltages and currents, as well as the various calculated components the IED may have (e.g. power, impedance, admittance). The vectors can be viewed individually, alongside the per-unit values of the measured or calculated components. The primary and secondary amplitudes are also shown. Phasors are helpful when solving incorrect wiring issues.

4.9 Monitoring menu

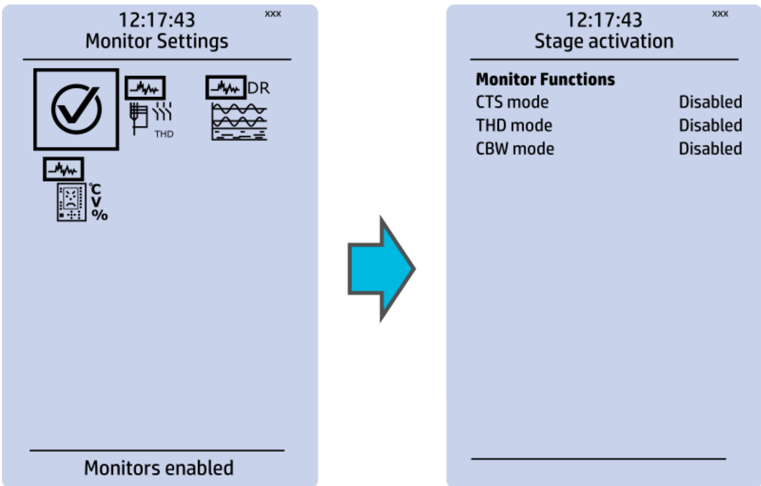
The *Monitoring* main menu includes submenus (see the image below) for enabling the various monitoring functions (*Monitors enabled*), setting the various monitoring functions (*Monitor functions*), controlling the disturbance recorder (*Disturbance REC*) and accessing the device diagnostics (*Device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

Figure. 4.9 - 50. Monitoring menu view.



Monitors enabled

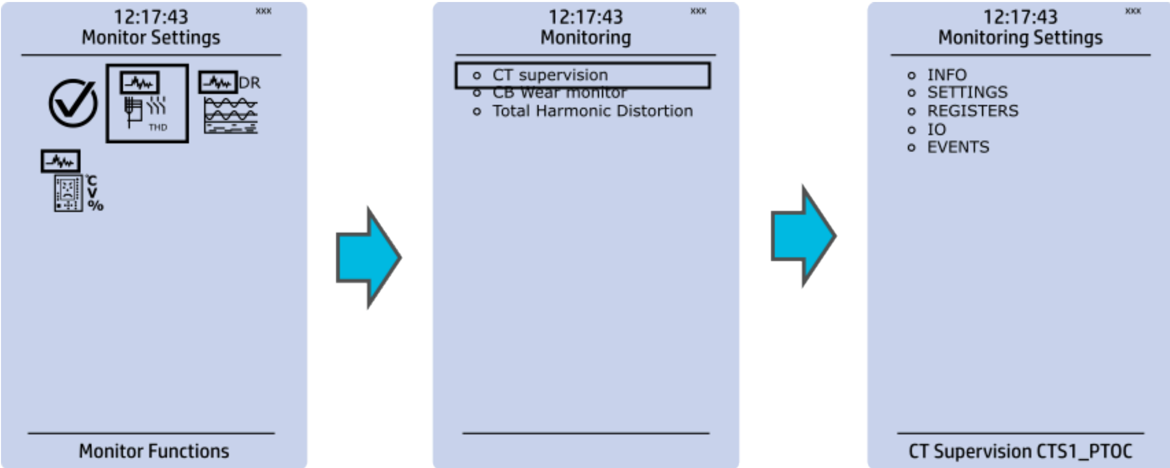
Figure. 4.9 - 51. Monitors enabled submenu.



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

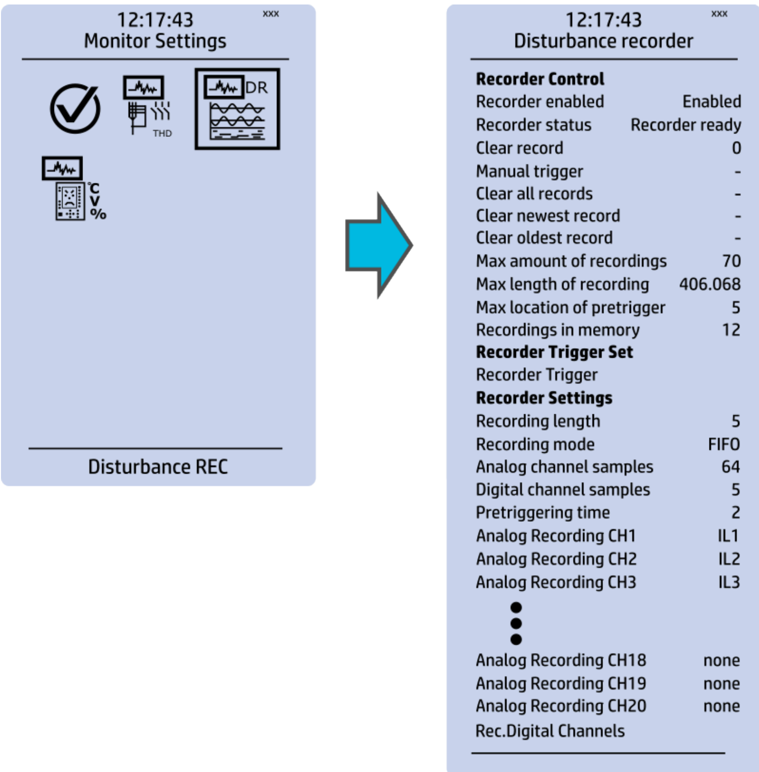
Figure. 4.9 - 52. Monitor function view.



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. 4.9 - 53. Disturbance recorder settings.



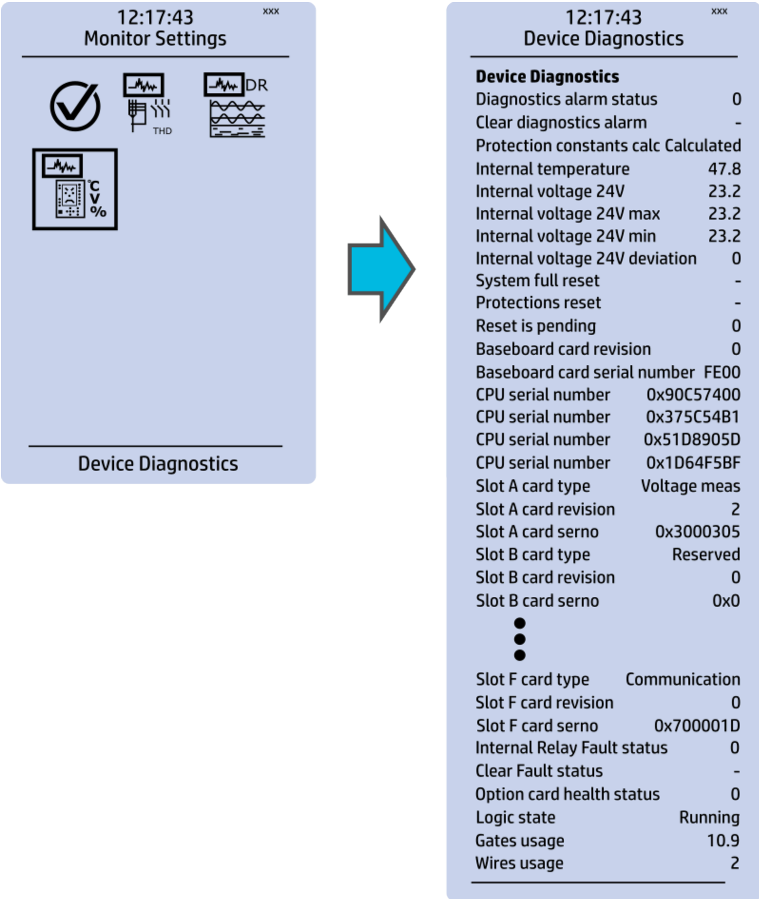
The *Disturbance recorder* submenu has the following settings:

- "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 legnth 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. 4.9 - 54. 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.

4.10 Configuring user levels and their passwords

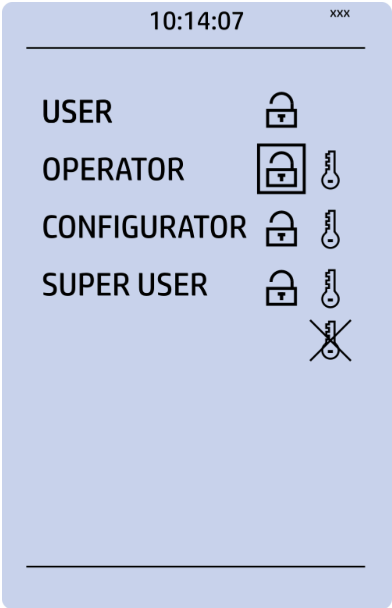
As a factory default, no user level is locked with a password in an IED. In order to activate the different user levels, click the Lock button in the device's HMI and set the desired passwords for the different user levels.

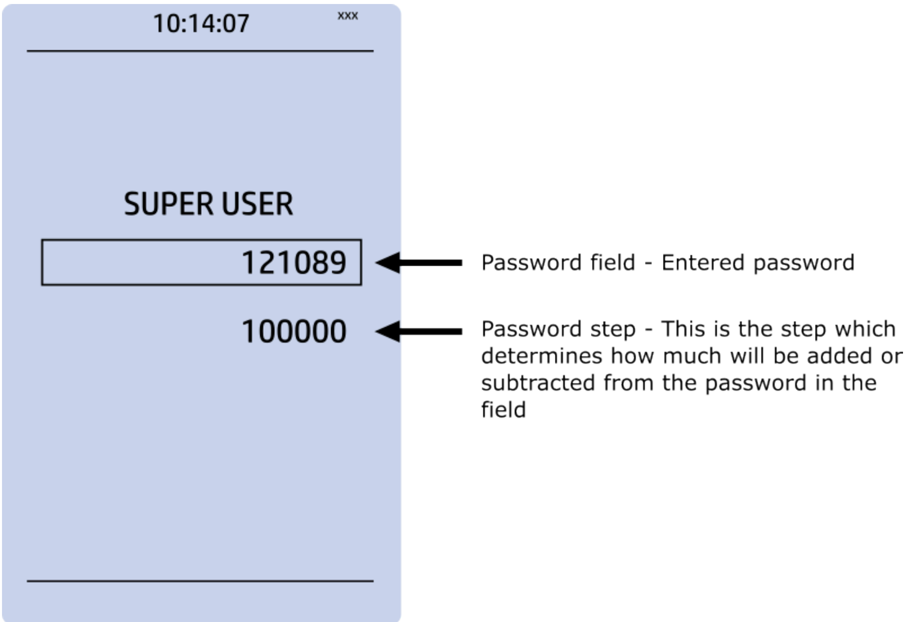
NOTE!

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 (-)





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-V211

The AQ-V211 voltage protection relay includes the following functions as well as the number of stages in those functions.

Table. 5.1 - 4. Protection fucntions of AQ-V211.

Name	IEC	ANSI	Description
OV (4)	U> U>> U>>> U>>>>	59	Overvoltage protection
UV (4)	U< U<< U<<< U<<<<	27	Undervoltage protections
NOV (4)	U0> U0>> U0>>> U0>>>>	59N	Neutral overvoltage protection
FRQV (8)	f> f>> f>>> f>>>> f< f<< f<<< f<<<<	81O/81U	Overfrequency and underfrequency protection
ROCOF (1)	df/dt>/<	81R	Rate-of-change of frequency
VUB (4)	U1/U2>/< U1/U2>>/<< U1/U2>>>/<<< U1/U2>>>>/<<<<	47/27P/59PN	Sequence voltage protection
CBFP (1)	CBFP	50BF/52BF	Circuit breaker failure protection
VMEM (1)	-	-	Voltage memory
PGS (1)	PGx>/<	99	Programmable stage

Table. 5.1 - 5. Control functions of AQ-V211.

Name	IEC	ANSI	Description
SGS	-	-	Setting group selection
OBJ	-	-	Object control and monitoring (5 objects available)
CIN	-	-	Indicator object monitoring (5 indicators available)
SOTF	SOTF	-	Switch-on-to-fault
VJP	$\Delta\varphi$	78	Vector jump
PCS	-	-	Programmable control switch

Name	IEC	ANSI	Description
mA output	-	-	Milliampere output control
SYN	ΔV/Δa/Δf	25	Synchrocheck function
GSYN	ΔV/Δa/Δf	25	Synchronizer (only in Function package B!)

Table. 5.1 - 6. Monitoring functions of AQ-V211.

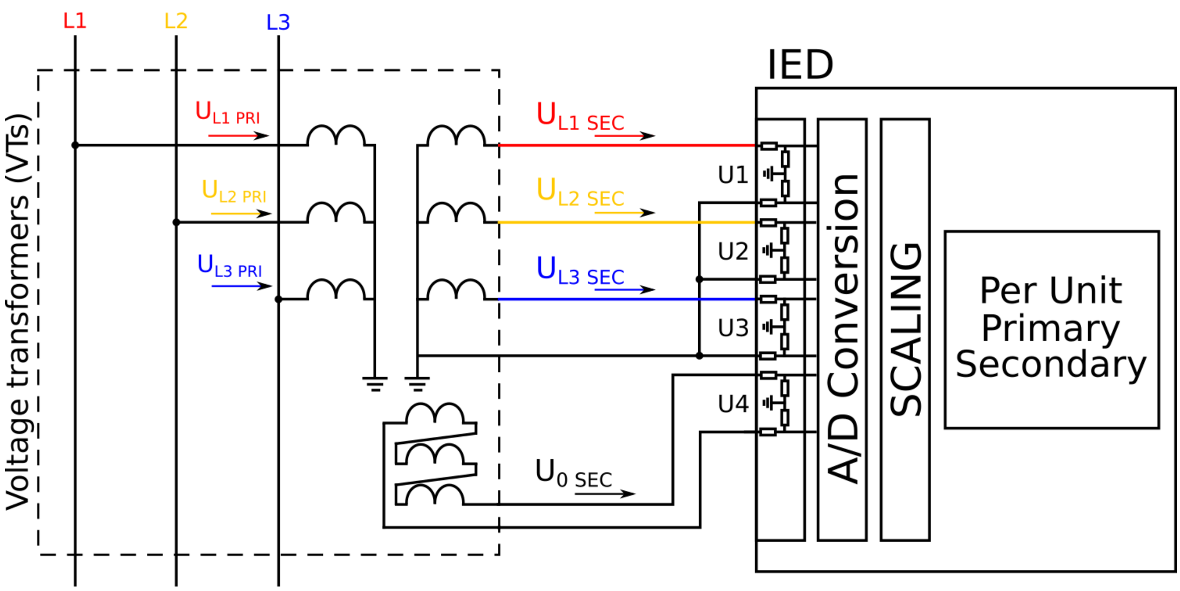
Name	IEC	ANSI	Description
VTS	-	60	Voltage transformer supervision
DR	-	-	Disturbance recorder
MR	-	-	Measurement recorder
VREC	-	-	Measurement value recorder

5.2 Measurements

5.2.1 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. 5.2.1 - 55. 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.

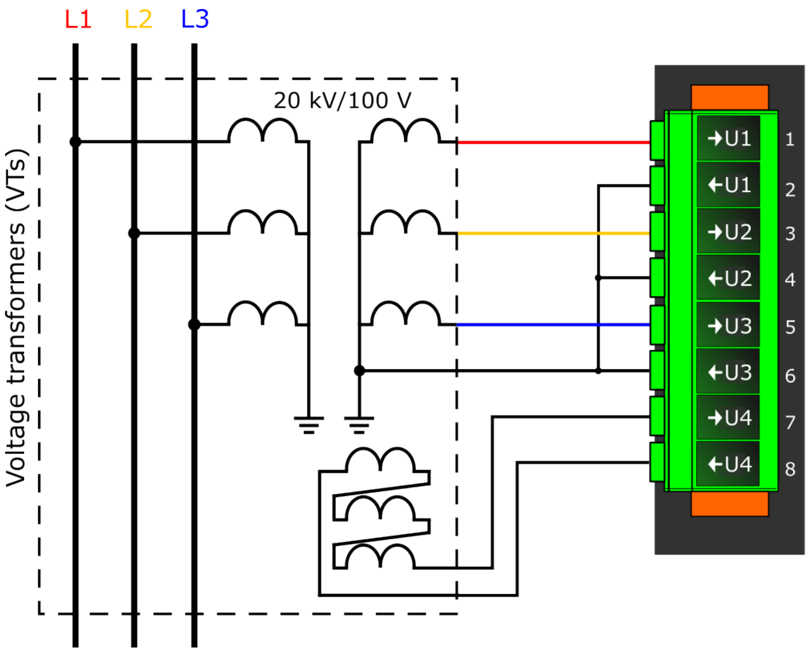
The relay calculates the scaling factors based on the set VT primary, and secondary voltage values. The relay measures secondary voltages, which are the voltage outputs from the VT installed into the application's primary circuit. The voltage can be measured directly from the system (up to 400 V) as 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. 5.2.1 - 56. Connections.



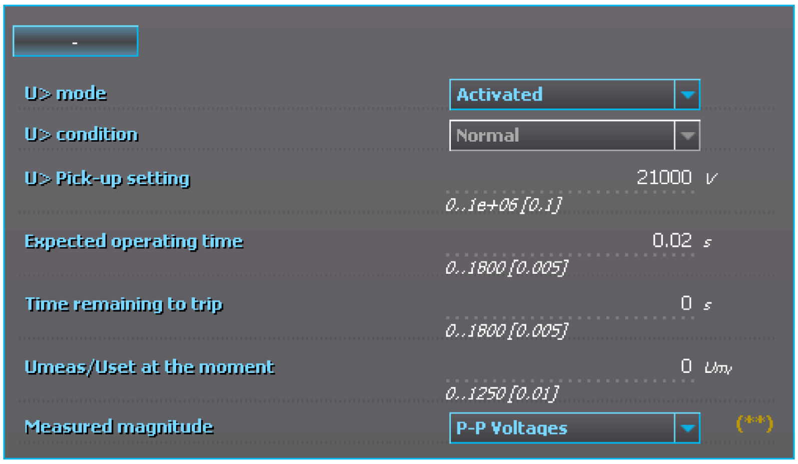
The following table presents the initial data of the connection.

Table. 5.2.1 - 7. 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. 5.2.1 - 57. Selecting the measured magnitude.

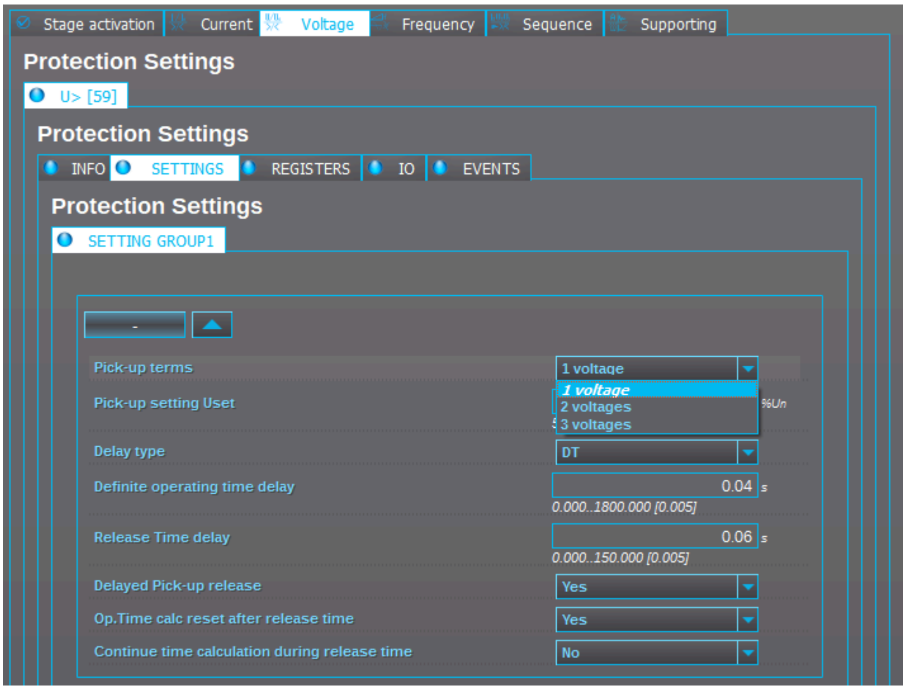


Voltage protection itself is based on the nominal voltage. A 20 000 V nominal voltage equals a 100 % setting in voltage-based protection functions. A 120 % trip setting in the overvoltage stage equals to 24 000 V on the primary level (in this case a 20 % increase equals 4000 V).

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. 5.2.1 - 58. Selecting the operating mode.

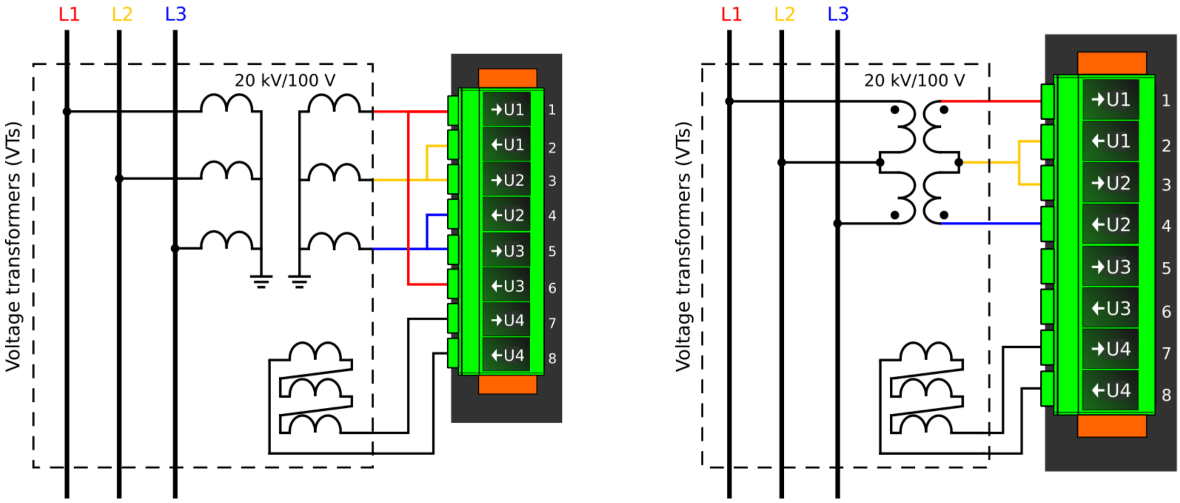


There are several different ways to use all four voltage channels. The voltage measurement modes are the following:

- 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. 5.2.1 - 59. Example connections for voltage line-to-line measurement.

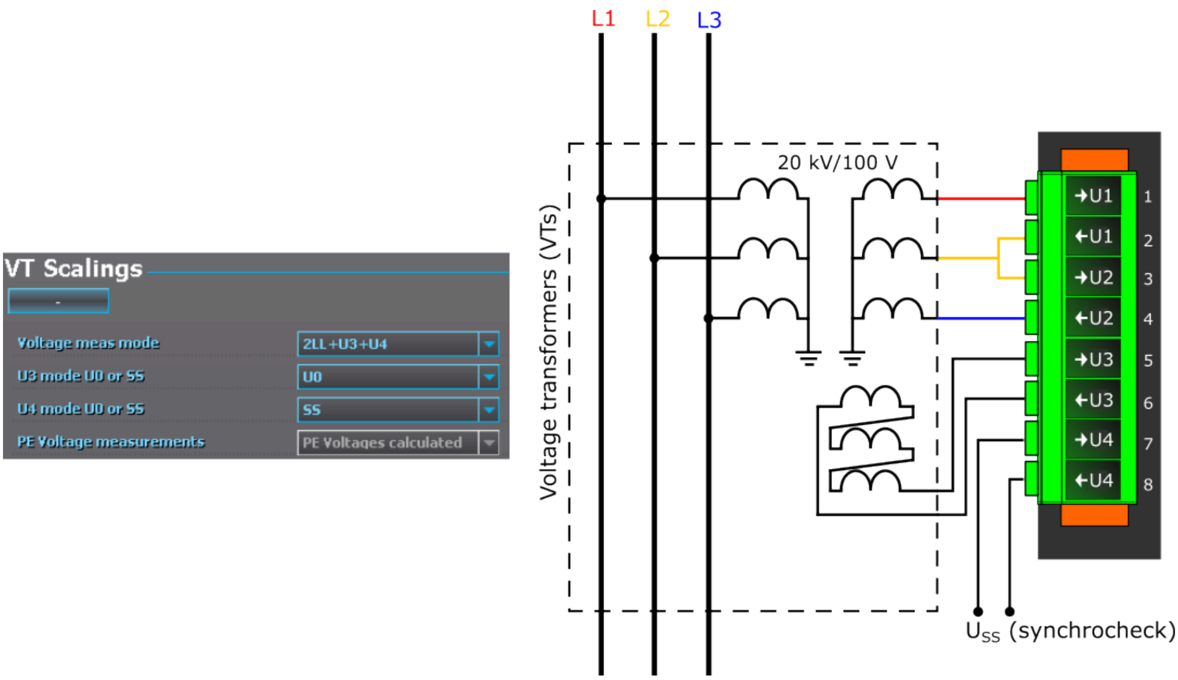


If only two line-to-line voltages are measured, the third one (U_{L31}) is calculated based on the U_{L12} and U_{L23} vectors. When measuring line-to-line voltages, the line-to-neutral voltages can also be calculated as long as the value of U0 is measured and known.

The voltage measurement channel U4 can also be used to measure either the zero sequence voltage (U0) 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 U0 can only be measured by using a single channel.

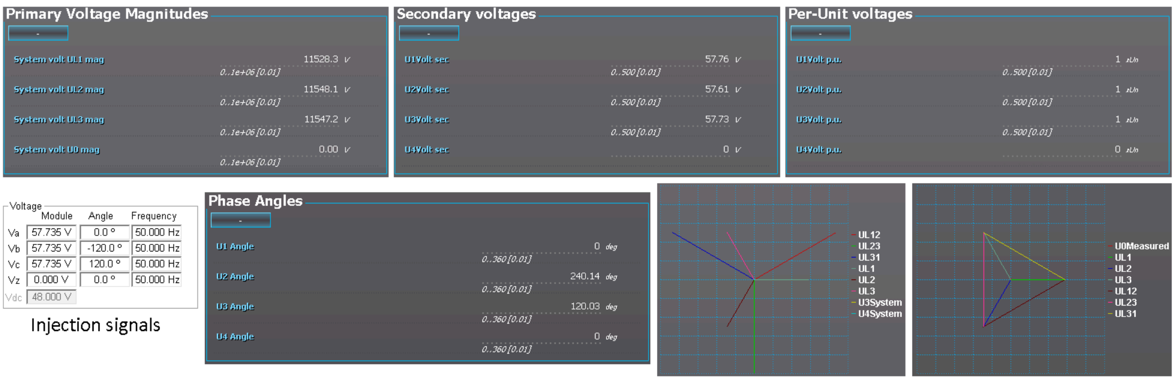
In the image below is an example of 2LL+U0+SS, that is, two line-to-line measurements with the zero sequence voltage and voltage from side 2 for Synchrocheck. Since U0 is available, line-to-neutral voltages can be calculated.

Figure. 5.2.1 - 60. 2LL+U0+SS settings and connections.



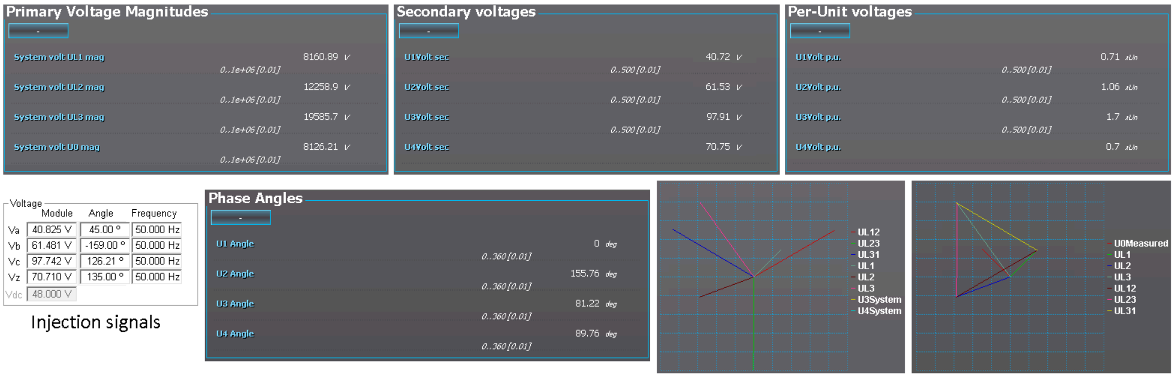
The image collection below presents the relay's behavior when nominal voltage is injected into the relay via secondary test equipment. The measurement mode is 3LN+U4 which means that the relay is measuring line-to-neutral voltages. The VT scaling has been set to 20 000 : 100 V. The U4 channel measures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

Figure. 5.2.1 - 61. Relay behavior when nominal voltage injected.



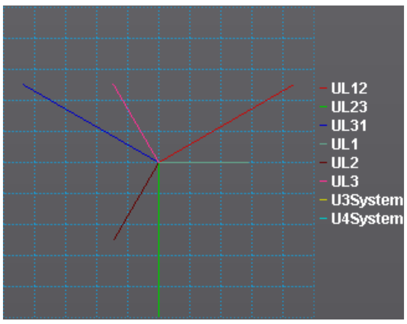
The image collection below presents the relay's behavior when voltage is injected into the relay via secondary test equipment during an earth fault. The measurement mode is 3LN+U4 which means that the relay is measuring line-to-neutral voltages. The VT scaling has been set to 20 000 : 100 V. The U4 channel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

Figure. 5.2.1 - 62. 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 (*Measurement* → *Transformers* → *VT Module*).
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 *Measurement* → *Phasors* and check the "System voltage vectors" diagram. When all connections are correct, the diagram (symmetric feeding) should look like this: 

Settings

Table. 5.2.1 - 8. 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. 5.2.1 - 9. Per-unit voltage measurements.

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

Table. 5.2.1 - 10. 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 31st) measurement from each of the voltage channels.

Table. 5.2.1 - 11. 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. 5.2.1 - 12. Per-unit sequence voltage measurements.

Name	Unit	Range	Step	Description
Positive sequence voltage ("Pos.seq.Volt.p.u.")	× 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.")	× 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.")	× U_n	0.00…500.0	0.01	The measurement (in p.u.) from the calculated zero sequence voltage.

Table. 5.2.1 - 13. 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. 5.2.1 - 14. 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. 5.2.1 - 15. 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. 5.2.1 - 16. 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…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.

Table. 5.2.1 - 17. 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.

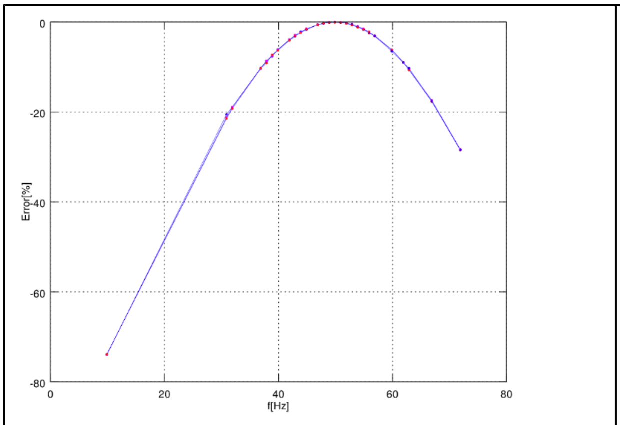
Table. 5.2.1 - 18. Harmonic voltage measurements.

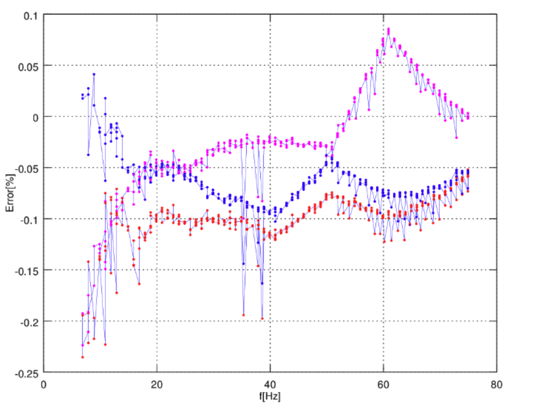
Name	Unit	Range	Step	Default	Description
Harmonics calculation values ("Harm Abs.or Perc.")	-	0: Percent 1: Absolute	-	0: Percent	Defines whether the harmonics are calculated as percentages or absolute values.
Harmonics display	-	0: Per unit 1: Primary V 2: Secondary V	-	0: Per unit	Defines how the harmonics 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.

5.2.2 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. 5.2.2 - 19. Frequency tracking effect (FF changes from 6 Hz to 75 Hz).

<table>
<tr>
<td>


</td>
<td>


</td>
</tr>
<tr>
<td>The measurement error with a fixed 50 Hz sampling frequency when the frequency changes. The constant current is 5 A, the frequency sweep is from 6 Hz to 75 Hz.</td>
<td>The measurement error with frequency tracking when the frequency changes. The constant current is 5 A, the frequency sweep is from 6 Hz to 75 Hz.</td>
</tr>
</table>

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" (*Measurement* → *Frequency* → "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 (*Measurement* → *Frequency*).

Settings

Table. 5.2.2 - 20. 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.
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.

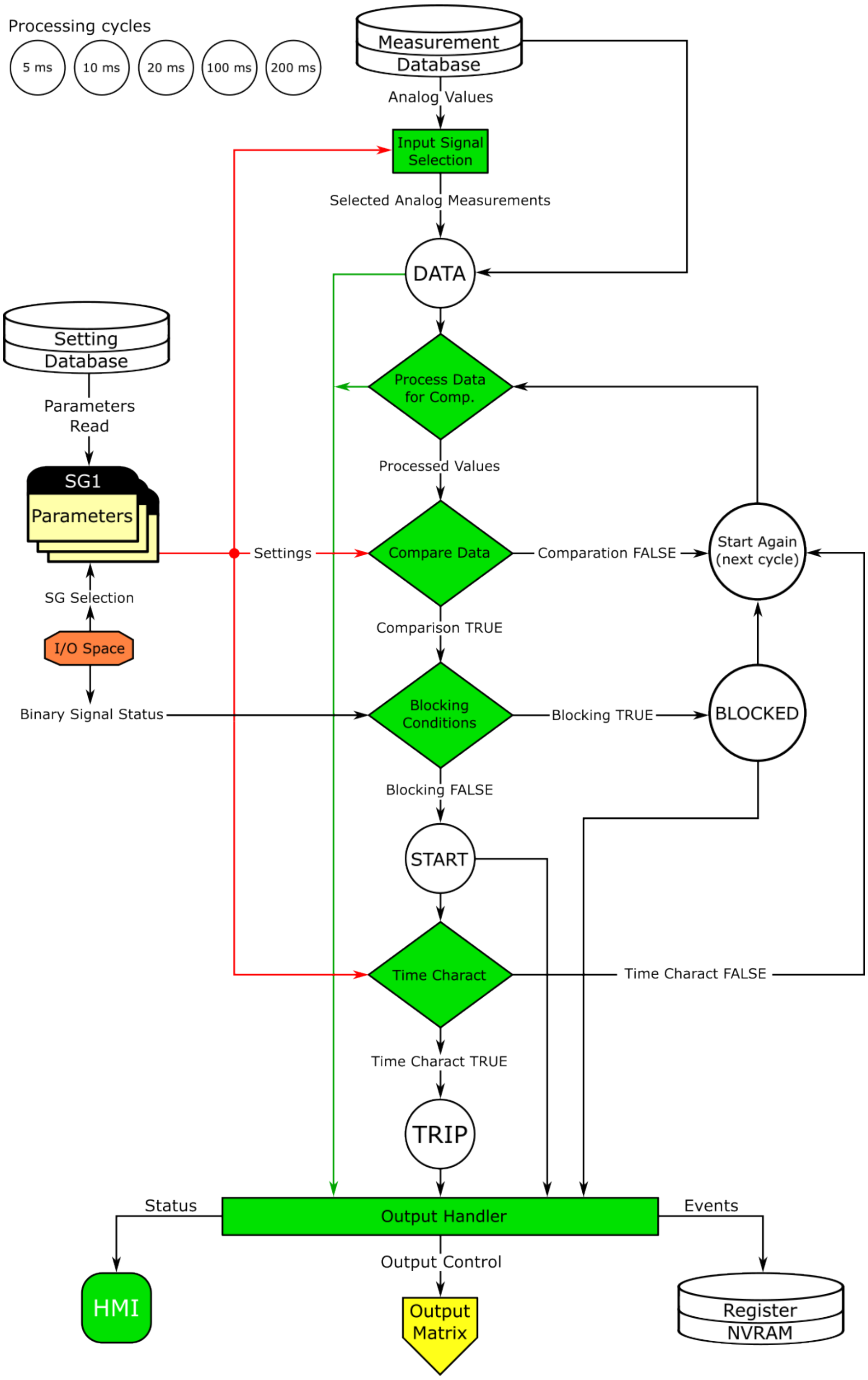
Name	Range	Step	Default	Description
Frequency tracking quality	0: No trackable channels 1: Reference 1 trackable 2: Reference 2 trackable 3: References 1 & 2 trackable 4: Reference 3 trackable 5: Reference 1 & 3 trackable 6: References 2 & 3 trackable 7: All references trackable	-	-	Defines the frequency 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.
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".

Name	Range	Step	Default	Description
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 SS2.meas.frqs	0.000…75.000Hz	0.001Hz	-	Displays frequency used by "system set" channel 1 and 2.
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 Protection functions

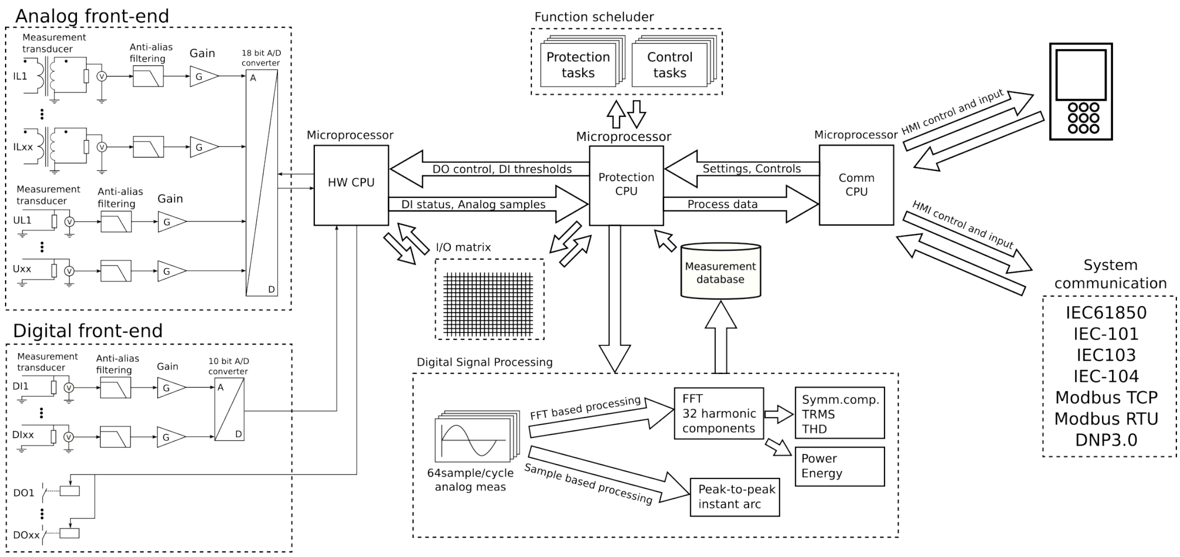
5.3.1 General properties of a protection function

The following flowchart describes the basic structure of any protection function. The basic structure is composed of analog measurement values being compared to the pick-up values and operating time characteristics.



The protection function is run in a completely digital environment with a protection CPU microprocessor which also processes the analog signals transformed into the digital form.

Figure. 5.3.1 - 63. Principle diagram of the protection relay platform.

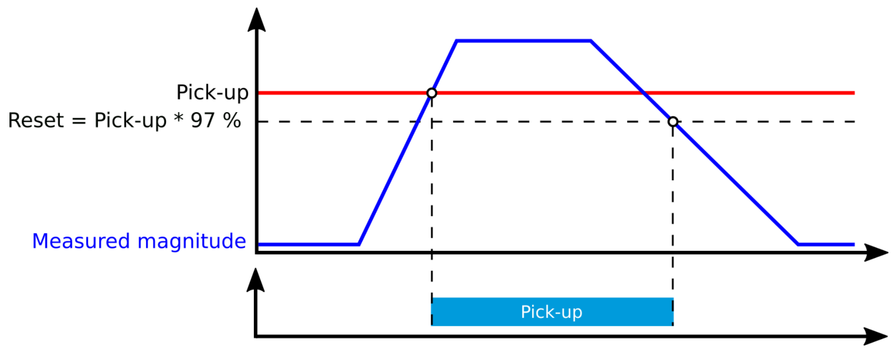


In the following chapters the common functionalities of protection functions are described. If a protection function deviates from this basic structure, the difference is described in the corresponding chapter of the manual.

Pick-up

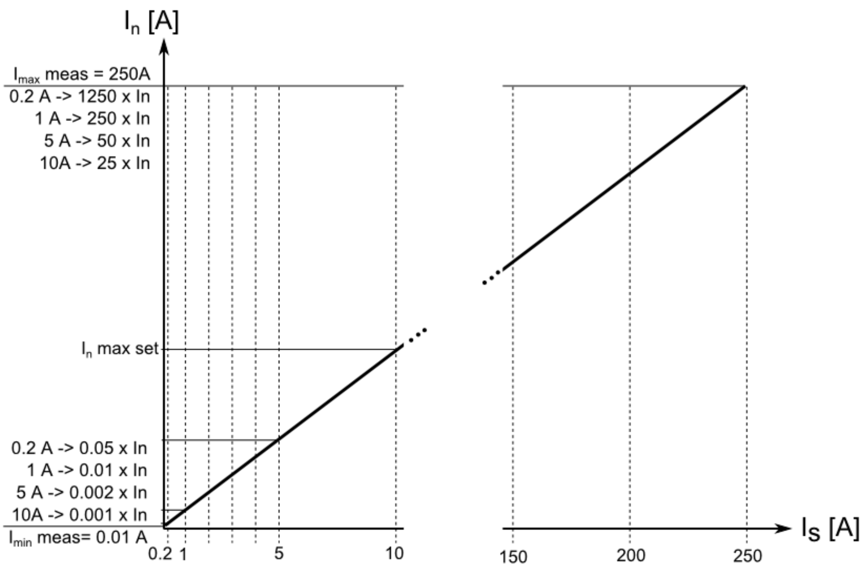
The X_{set} parameter defines the pick-up level of the function, and this in turn defines the maximum or minimum allowed measured magnitude (in per unit, absolute or percentage value) before the function takes action. The function constantly calculates the ratio between the pick-up parameter set by the user and the measured magnitude (X_m). The reset ratio of 97 % is built into the function and is always relative to the X_{set} value. If a function's pick-up characteristics vary from this description, they are defined in the function section in the manual.

Figure. 5.3.1 - 64. Pick up and reset.



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 a blocking condition is not active.

Figure. 5.3.1 - 65. Measurement range in relation to the nominal current.



The I_n magnitude refers to the user set nominal current which can range from 0.2…10 A, typically 0.2 A, 1A or 5 A. With its own current measurement card, the IED will measure secondary currents from 0.001 A up to 250 A. To this relation the pick-up setting in secondary amperes will vary.

Function blocking

The blocking signals are checked in the beginning of each program cycle. A blocking signal is received from the blocking matrix for the function 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 pick-up element activates, a BLOCKED signal is generated and the function will 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 common and global testing mode is activated.

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

Operating time characteristics for trip and reset

The operating timers’ behavior during a function can be set for trip signal and for the release of the function in case the pick-up element is reset before the trip time has been reached. There are three basic operating modes available for the function:

- Instant operation: activates the trip signal with no additional time delay simultaneously with the start signal.
- Definite time operation (DT): activates the trip signal after a user-defined time delay regardless of the measured current as long as the current is above or below the X_{set} value and thus the pick-up element is active (independent time characteristics).

- Inverse definite minimum time (IDMT): activates the trip signal after a time which is in relation to the set pick-up value X_{set} and the measured value X_m (dependent time characteristics).

Both IEC and IEEE/ANSI standard characteristics as well as user settable parameters are available for the IDMT operation. Please note that in the IDMT mode *Definite (Min)* operating time delay is also determines the minimum time for protection tripping (see the figure below). If this function is not desired the parameter should be set to 0 seconds.

Figure. 5.3.1 - 66. Operating time delay: *Definite (Min)* and the minimum for tripping.

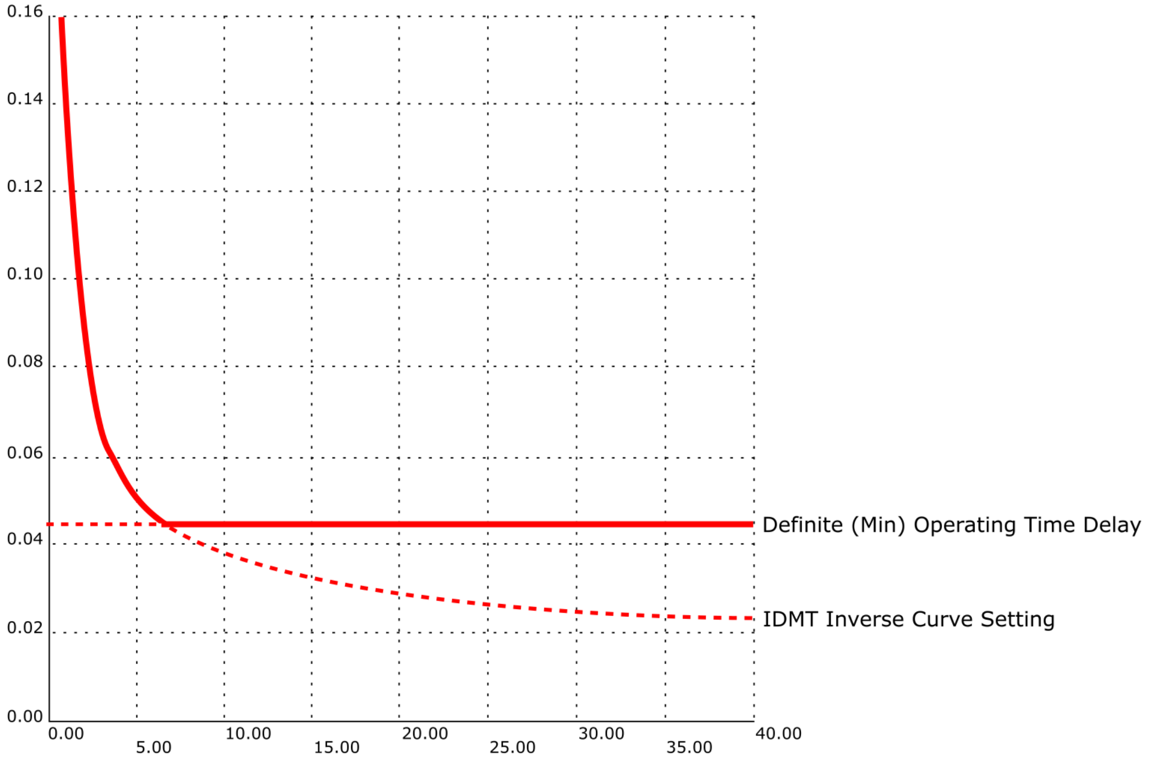


Table. 5.3.1 - 21. Operating time characteristics setting parameters (general).

Name	Range	Step	Default	Description
Delay type	0: DT 1: IDMT	-	0: DT	Selects the delay type for the time counter. The selection is made between dependent (IDMT) and independent (DT) characteristics.
Definite (min) operating time delay	0.000…1800.000s	0.005s	0.040s	When the "Delay type" parameter is set to "DT", this parameter acts as the expected operating time for the protection function. When set to 0 s, the stage operates instantaneously without any additional delay. When the parameter is set to 0.005...1800 s, the stage operates as independent delayed. When the "Delay type" parameter has been set to "IDMT", this parameter can be used to determine the minimum operating time for the protection function. Example of this is presented in the figure above.
Delay curve series	0: IEC 1: IEEE	-	0: IEC	Selects whether the delay curve series for an IDMT operation follows either IEC or IEEE/ANSI standard defined characteristics. This setting is active and visible when the "Delay type" parameter is set to "IDMT".

Name	Range	Step	Default	Description
Delay characteristics IEC	0: NI 1: EI 2: VI 3: LTI 4: Param	-	0: NI	Selects the IEC standard delay characteristics. The options include the following: Normally Inverse ("NI"), Extremely Inverse ("EI"), Very Inverse ("VI") and Long Time Inverse ("LTI") characteristics. Additionally, the "Param" option allows the tuning of the constants A and B which then allows the setting of characteristics following the same formula as the IEC curves mentioned here. This setting is active and visible when the "Delay type" parameter is set to "IDMT" and the "Delay curve series" parameter is set to "IEC".
Delay characteristics IEEE	0: ANSI NI 1: ANSI VI 2: ANSI EI 3: ANSI LTI 4: IEEE MI 5: IEEE VI 6: IEEE EI 7: Param	-	0: ANSI NI	Selects the IEEE and ANSI standard delay characteristics. The options for ANSI include the following: Normal Inverse ("ANSI NI"), Very Inverse ("ANSI VI"), Extremely inverse ("ANSI EI"), Long time inverse ("ANSI LTI") characteristics. IEEE: Moderately Inverse ("IEEE MI"), Very Inverse ("IEEE VI"), Extremely Inverse ("IEEE EI") characteristics. Additionally, the "Param" option allows the tuning of the constants A, B and C which then allows the setting of characteristics following the same formula as the IEEE curves mentioned here. This setting is active and visible when the "Delay type" parameter is set to "IDMT" and the "Delay curve series" parameter is set to "IEEE".
Time dial setting k	0.01…25.00s	0.01s	0.05s	Defines the time dial/multiplier setting for IDMT characteristics. This setting is active and visible when the "Delay type" parameter is set to "IDMT".
A	0.0000…250.0000	0.0001	0.0860	Defines the Constant A for IEC/IEEE characteristics. This setting is active and visible when the "Delay type" parameter is set to "IDMT" and the "Delay characteristic" parameter is set to "Param".
B	0.0000…5.0000	0.0001	0.1850	Defines the Constant B for IEC/IEEE characteristics. This setting is active and visible when the "Delay type" parameter is set to "IDMT" and the "Delay characteristic" parameter is set to "Param".
C	0.0000…250.0000	0.0001	0.0200	Defines the Constant C for IEEE characteristics. This setting is active and visible when the "Delay type" parameter is set to "IDMT" and the "Delay characteristic" parameter is set to "Param".

Figure. 5.3.1 - 67. Inverse operating time formulas for IEC and IEEE standards.

IEC	IEEE/ANSI
$$t = \frac{kA}{\left(\frac{I_m}{I_{set}}\right)^B - 1}$$	$$t = k\left(\frac{A}{\left(\frac{I_m}{I_{set}}\right)^C - 1} + B\right)$$
t = Operating delay (s) k = Time dial setting I_m = Measured maximum current I_{set} = Pick-up setting A = Operating characteristics constant B = Operating characteristics constant	t = Operating delay (s) k = Time dial setting I_m = Measured maximum current I_{set} = Pick-up setting A = Operating characteristics constant B = Operating characteristics constant C = Operating characteristics constant

Standard delays IEC constants

Type	**A**	**B**
Normally Inverse (*NI*)	0,14	0,02
Extremely Inverse (*EI*)	80	2
Very Inverse (*VI*)	13,5	1
Long Time Inverse (*LTI*)	120	1

Standard delays ANSI constants

Type	**A**	**B**	**C**
Normally Inverse (*NI*)	8,934	0,1797	2,094
Very Inverse (*VI*)	3,922	0,0982	2
Extremely Inverse (*EI*)	5,64	0,02434	2
Long Time Inverse (*LTI*)	5,614	2,186	1

Standard delays IEEE constants

Type	**A**	**B**	**C**
Moderately Inverse (*MI*)	0,0515	0,114	0,02
Very Inverse (*VI*)	19,61	0,491	2
Extremely Inverse (*EI*)	28,2	0,1217	2

Non-standard delay characteristics

In addition to the previously mentioned delay characteristics, some functions also have delay characteristics that deviate from the IEC or IEEE standards. These functions are the following:

- overcurrent stages
- residual overcurrent stages
- directional overcurrent stages
- directional residual overcurrent stages.

The setting parameters and their ranges are documented in the chapters of the respective function blocks.

Table. 5.3.1 - 22. Inverse operating time formulas for nonstandard characteristics.

RI-type	RD-type
Used to get time grading with mechanical relays	Mostly used in earth fault protection which grants selective tripping even in non-directional protection
$$t = \frac{k}{0.339 - 0.236 * \frac{I_{set}}{I_m}}$$	$$t = 5.8 - 1.35 * \ln\left(\frac{I_m}{k * I_{set}}\right)$$
t = Operating delay (s) k = Time dial setting I_m = Measured maximum current I_{set} = Pick-up setting	t = Operating delay (s) k = Time dial setting I_m = Measured maximum current I_{set} = Pick-up setting

Table. 5.3.1 - 23. Setting parameters for reset time characteristics.

Name	Range	Step	Default	Description
Delayed pick-up release	0: No 1: Yes	-	1: Yes	Resetting characteristics selection (either time-delayed or instant) after the pick-up element is released. If activated, the START signal is reset after a set release time delay.
Release time delay	0.000…150.000s	0.005s	0.06s	Resetting time. The time allowed between pick-ups if the pick-up has not led into a trip operation. If the "Delayed pick-up release" setting is active, the START signal is held on for the duration of the timer.
Op.Time calculation reset after release time	0: No 1: Yes	-	1: Yes	Operating timer resetting characteristics selection. When active, the operating time counter is reset after a set release time if the pick-up element is not activated during this time. When disabled, the operating time counter is reset directly after the pick-up element is reset.
Continue time calculation during release time	0: No 1: Yes	-	0: No	Time calculation characteristics selection. If activated, the operating time counter continues until a set release time even if the pick-up element is reset.

The behavior of the stages with different release time configurations are presented in the figures below.

Figure. 5.3.1 - 68. No delayed pick-up release.

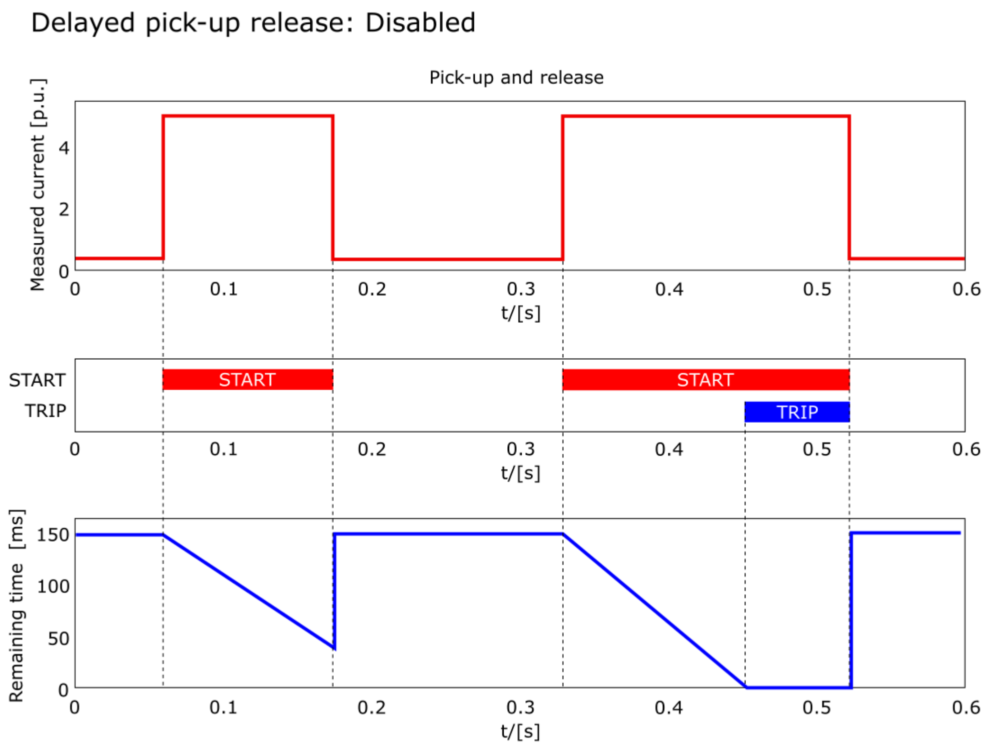


Figure. 5.3.1 - 69. Delayed pick-up release, delay counter is reset at signal drop-off.

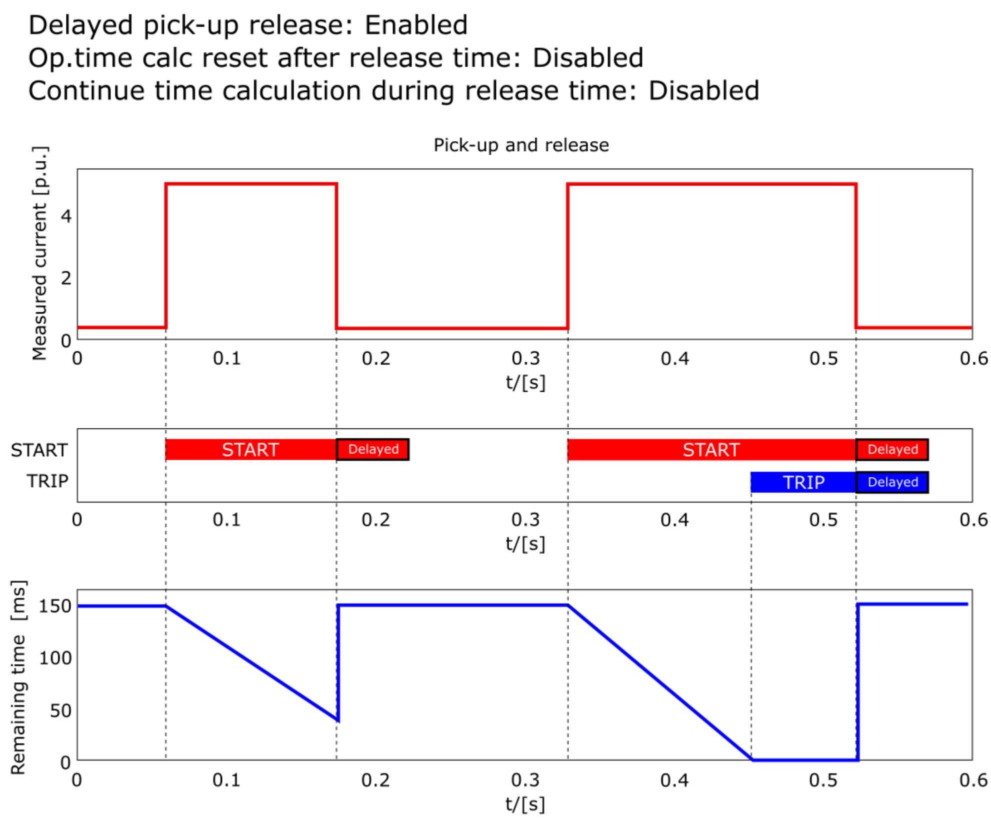


Figure. 5.3.1 - 70. Delayed pick-up release, delay counter value is held during the release time.

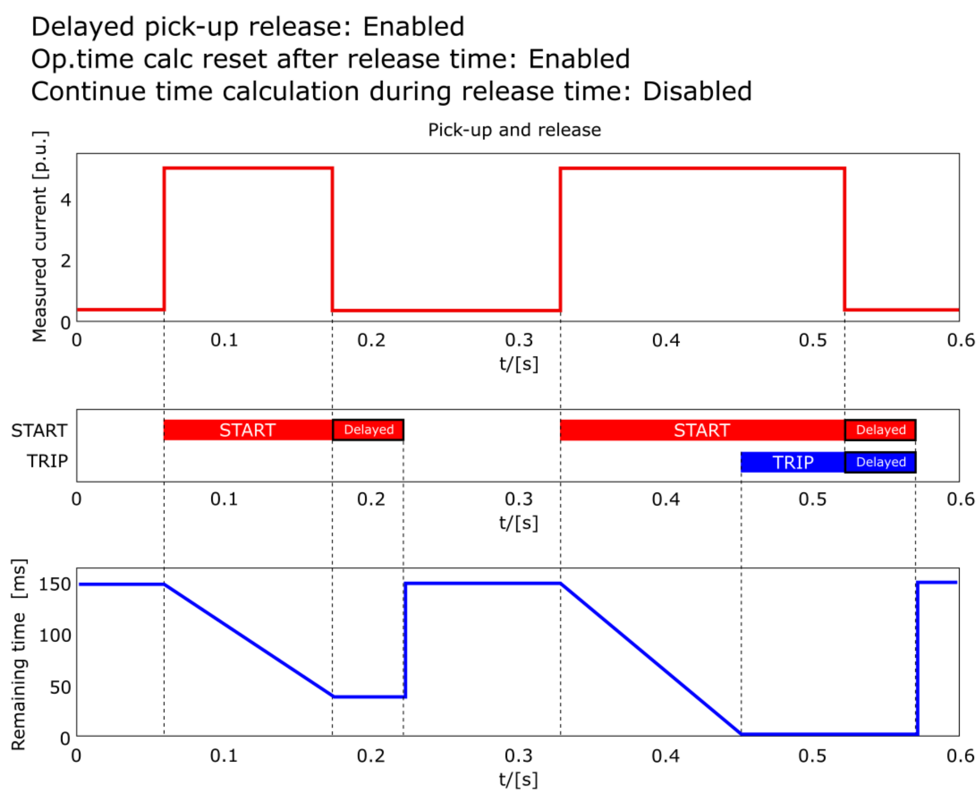
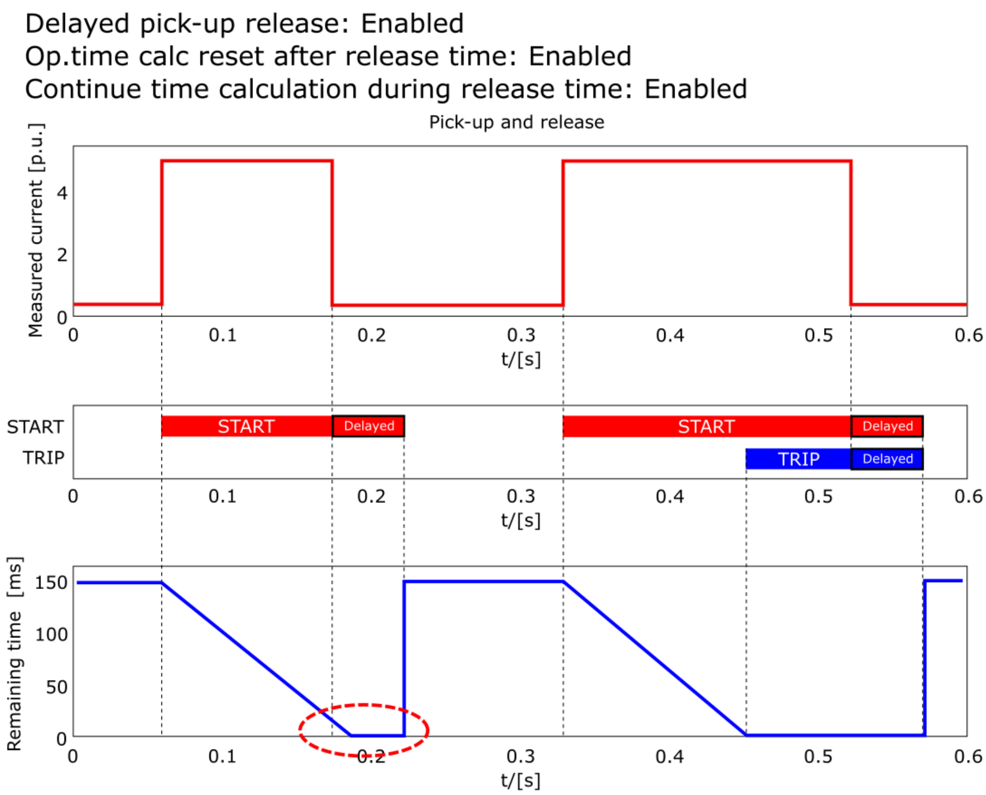


Figure. 5.3.1 - 71. Delayed pick-up release, delay counter value is decreasing during the release time.



The resetting characteristics can be set according to the application. The default setting is delayed 60 ms and the time calculation is held during the release time.

When using the release delay option where the operating time counter is calculating the operating time during the release time, the function will not trip if the input signal is not activated again during the release time counting.

Stage forcing

It is possible to test the logic, event processing and the operation of the relay's protection system by controlling the state of the protection functions manually without injecting any current into the relay with stage forcing. To enable *Stage forcing* set the *Enable stage forcing* to ENABLED in the *General* menu. After this it is possible to control the status of a protection function (Normal, Start, Trip, Blocked etc.) in the *Info* page of the function.

NOTE!

When *Stage forcing* is enabled protection functions will also change state through user input. Injected currents/voltages also affect the behavior of the relay. Regardless, it is recommended to disable *Stage Forcing* after testing has ended.

5.3.2 Circuit breaker failure protection (CBFP; 50BF/52BF)

The circuit breaker failure protection function is used for monitoring the circuit breaker operation after it has received a TRIP signal. The function can also be used to retrip a failing breaker; if the retrip fails, an incomer breaker can be tripped by using the function's CBFP output. The retrip functionality can be disabled if the breaker does not have two trip coils.

The function can be triggered by the following:

- overcurrent (phase and residual)
- digital output monitor
- digital signal
- any combination of the above-mentioned triggers.

In the current-dependent mode the function constantly measures phase current magnitudes and the selected residual current. In the signal-dependent mode any of the device's binary signals (trips, starts, logical signals etc.) can be used to trigger the function. In the digital output-dependent mode the function monitors the status of the selected output relay control signal. 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.

The outputs of the function are CBFP START, RETRIP, CBFP ACT and BLOCKED signals. The circuit breaker failure protection function uses a total of eight (8) separate setting groups which can be selected from one common source. Additionally, the function's operating mode can be changed via setting group selection.

The operational logic consists of the following:

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

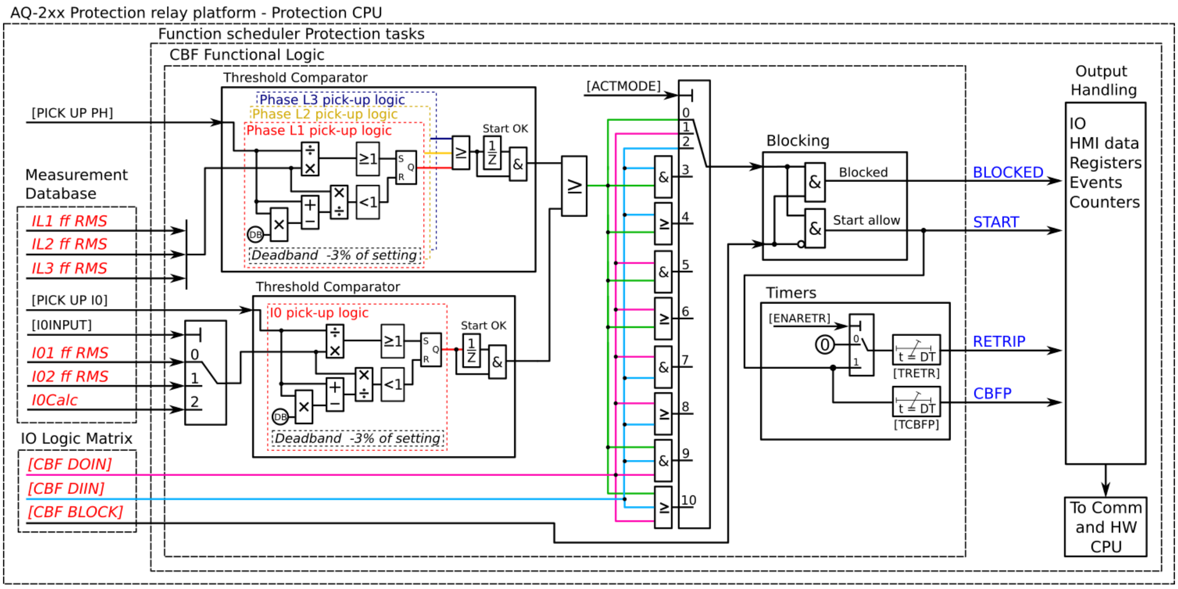
The inputs of the function are the following:

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

The function' output signals 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 two (2) output signals. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counters for RETRIP, CBFP, CBFP START and BLOCKED events.

The following figure presents a simplified function block diagram of the circuit breaker failure protection function.

Figure. 5.3.2 - 72. Simplified function block diagram of the CBFP function.



Measured input

The function block uses analog current measurement values. It always uses the RMS magnitude of the current measurement input. The user can select I01, I02 or the calculated I0 for the residual current measurement. A -20 ms averaged value of the selected magnitude is used for pre-fault data registering.

Table. 5.3.2 - 24. Measurement inputs of the CBFP 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
I01RMS	RMS measurement of residual input I01	5ms
I02RMS	RMS measurement of residual input I02	5ms
I0Calc	Calculated residual current from the phase current inputs	5ms
DOIN	Monitors digital output relay status	5ms
DIIN	Monitors digital input status	5ms

The selection of the used AI channel is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from START or TRIP event.

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. 5.3.2 - 25. CBFP monitoring signal definitions.

Name	Description
Signal in monitor	Defines which TRIP events of the used protection functions trigger the CBFP countdown. For the CBFP function to monitor the signals selected here, the "Operation mode selection" parameter must be set to a mode that includes signals (e.g. "Signals only", "Signals or DO", "Current and signals and DO").
Trip monitor	Defines which output relay of the used protection functions trigger the CBFP countdown. For the CBFP function to monitor the output relays selected here, the "Operation mode selection" parameter must be set to a mode that includes digital outputs (e.g. "DO only", "Current and DO", "Current or signals or DO").

Pick-up

The setting parameters I_{set} and $I0_{set}$ control the pick-up and the activation of the current-dependent CBFP function. They define the minimum allowed measured current before action from the function. The function constantly calculates the ratio between the I_{set} or the $I0_{set}$ and the measured magnitude (I_m) for each of the three phases and the selected residual current input. 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. 5.3.2 - 26. Operating mode and input signals selection.

Name	Range	Step	Default	Description
I0Input	0: Not in use 1: I01 2: I02 3: I0Calc	-	0: Not in use	Selects the residual current monitoring source, which can be either from the two separate residual measurements (I01 and I02) or from the phase current's calculated residual current.
Actmode	0: Current only 1: DO only 2: Signals only 3: Current and DO 4: Current or DO 5: Current and signals 6: Current or signals 7: Signals and DO 8: Signals or DO 9: Current or DO or signals 10: Current and DO and Signals	-	0: Current only	Selects the operating mode. The mode can be dependent on current measurement, binary signal status, output relay status ("DO"), or a combination of the three.

Table. 5.3.2 - 27. Pick-up settings.

Name	Range	Step	Default	Description
I_{set}	0.01…40.00×I_n	0.01×I_n	0.20×I_n	The pick-up threshold for the phase current measurement. This setting limit defines the upper limit for the phase current pick-up element.
$I0_{set}$	0.005...40.000×I_n	0.001×I_n	1.200×I_n	The pick-up threshold for the residual current measurement. This setting limit defines the upper limit for the phase current pick-up element.

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. There is no delay between the activation of the monitored signal and the activation of the pick-up when using binary signals.

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 processes the release time characteristics 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

The operating timers’ behavior during a function can be set depending on the application. The same pick-up signal starts both timers. When retrip is used the time grading should be set as follows: the sum of specific times (i.e. the retrip time, the expected operating time, and the pick-up conditions' release time) is shorter the set CBFP time. This way, when retripping another breaker coil clears the fault, any unnecessary function triggers are avoided.

The following table presents the setting parameters for the function's operating time characteristics.

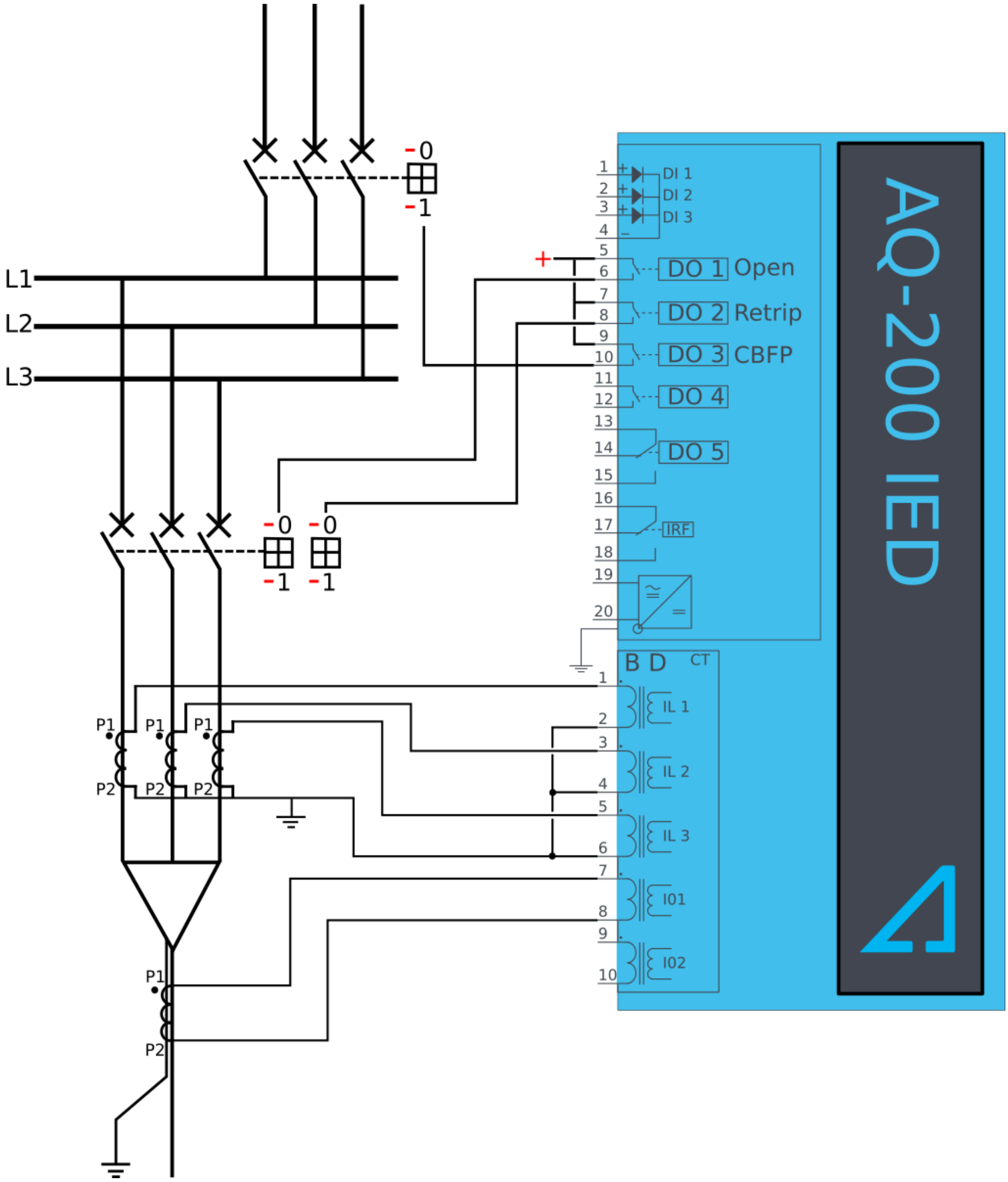
Table. 5.3.2 - 28. Setting parameters for operating time characteristics.

Name	Range	Step	Default	Description
Retrip	0: No 1: Yes	-	1: Yes	Retrip enabled or disabled. When the retrip is disabled, the output will not be visible and the TRetr setting parameter will not be available.
Retrip time delay	0.000…1800.000s	0.005s	0.100s	Retrip start the timer. This setting defines how long the starting condition has to last before a RETRIP signal is activated.
CBFP	0.000…1800.000s	0.005s	0.200s	CBFP starts the timer. This setting defines how long the starting condition has to last before the CBFP signal is activated.

The following figures present some typical cases of the CBFP function.

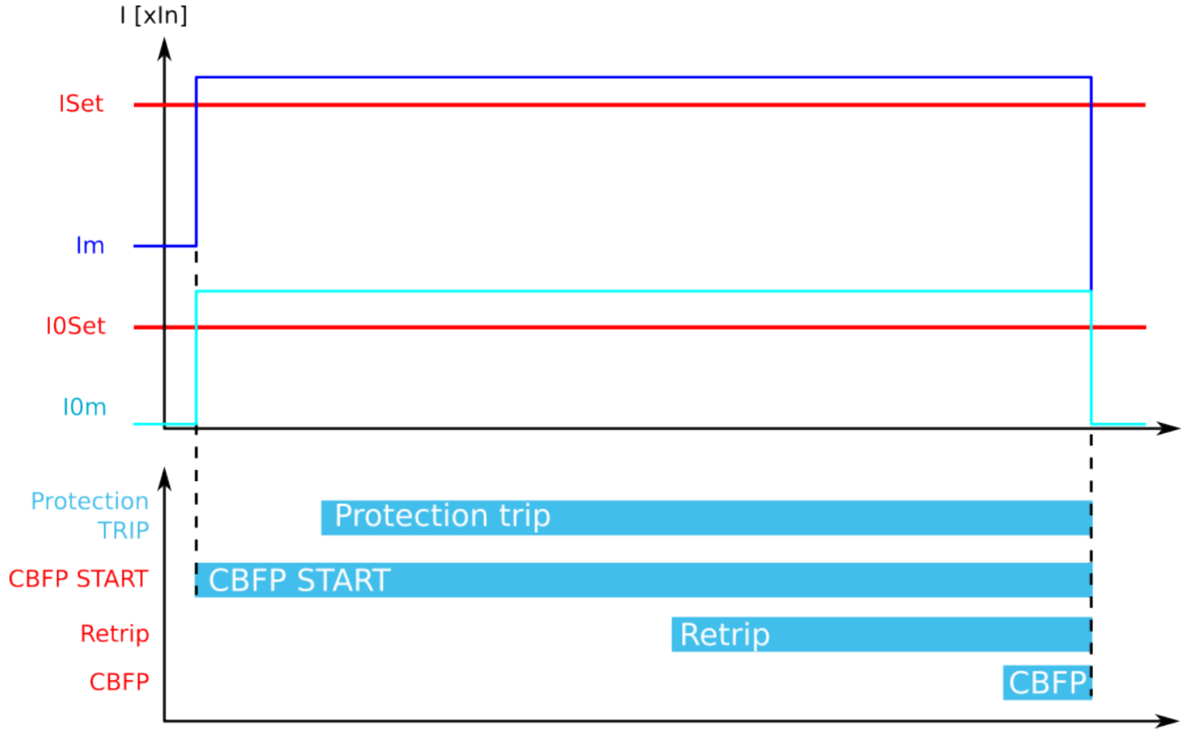
Trip, Retrip and CBFP in the device configuration

Figure. 5.3.2 - 73. Wiring diagram when Trip, Retrip and CBFP are configured to the device.



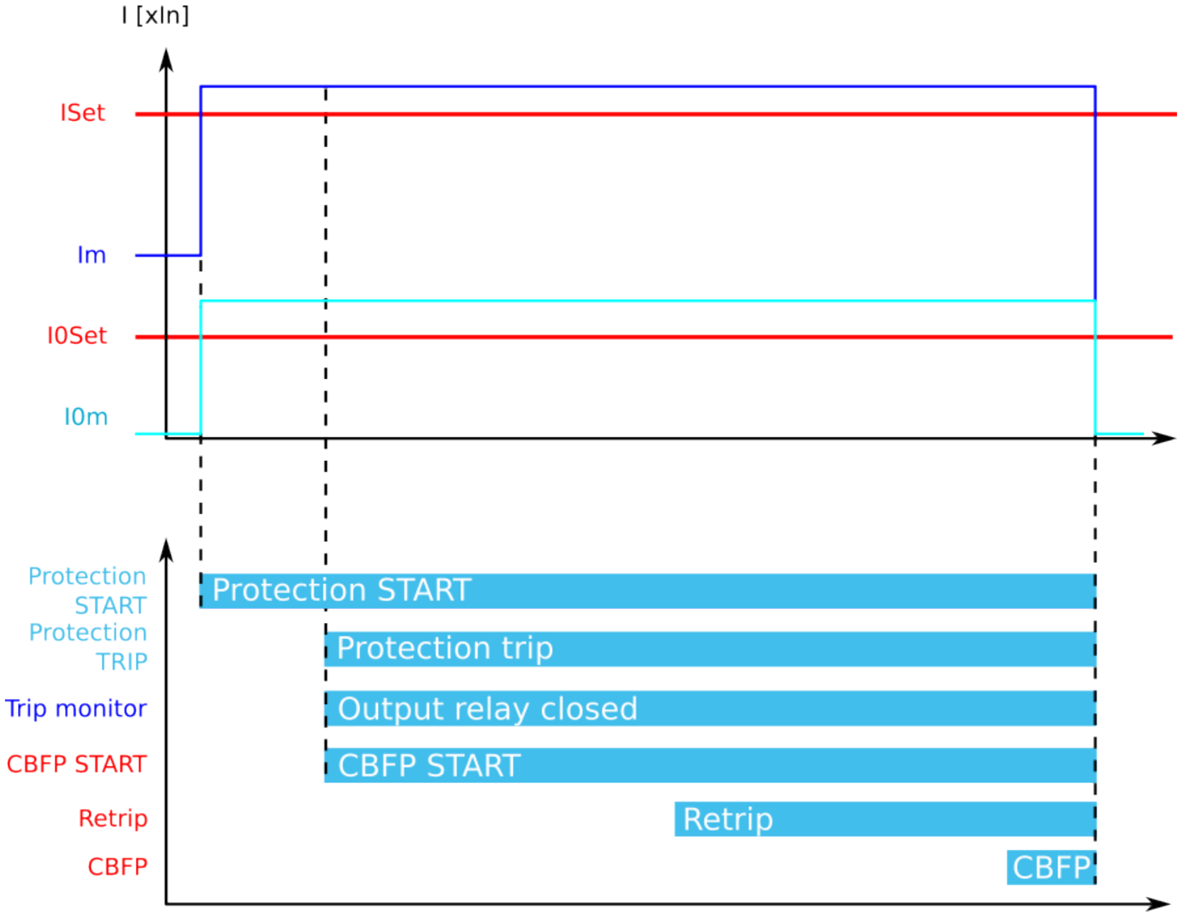
The retrip functionality can be used in applications whose circuit breaker has a retrip or a redundant trip coil available. The TRIP signal is normally wired to the breaker's trip coil from the device's trip output. The retrip is wired from its own device output contact in parallel with the circuit breaker's redundant trip coil. The CBFP signal is normally wired from its device output contact to the incomer breaker. Below are a few operational cases regarding the various applications.

Figure. 5.3.2 - 74. Retrip and CBFP when "Current" is the selected criterion.



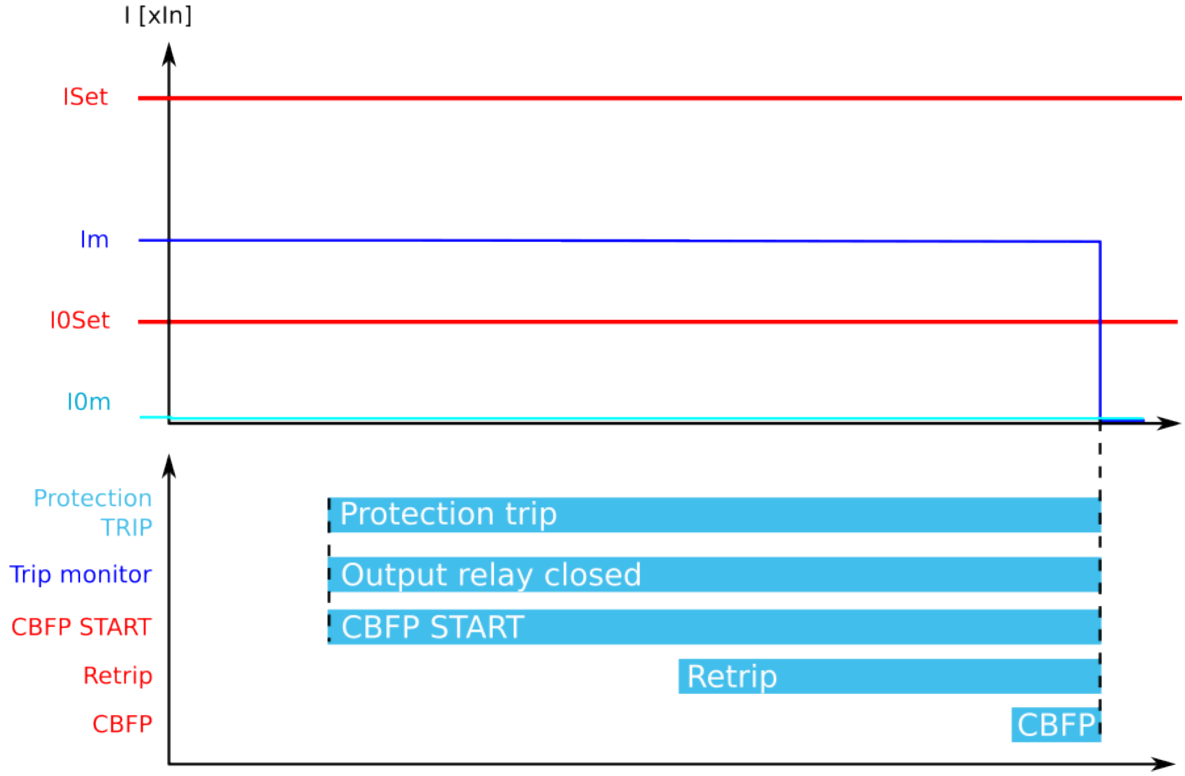
When the current threshold setting of I_{set} and/or $I0_{set}$ is exceeded, the current-based protection is activated and the counters for RETRIP and CBFP start calculating the set operating time. The tripping of the primary protection stage is not monitored in this configuration. Therefore, if the current is not reduced below the setting limit, a RETRIP signal is sent to the redundant trip coil. If the current is not reduced within the set time limit, the function also sends a CBFP signal to the incomer breaker. If the primary protection function clears the fault, both counters (RETRIP and CBFP) are reset as soon as the measured current is below the threshold settings.

Figure. 5.3.2 - 75. Retrip and CBFP when "Current and DO" is the selected criterion.



When the current threshold setting of *Iset* and/or *I0set* is exceeded, the current-based protection is activated. At the same time, the counters for RETRIP and CBFP are halted until the monitored output contact is controlled (that is, until the primary protection operates). When the tripping signal reaches the primary protection stage, the RETRIP and CBFP counters start calculating the set operating time. The tripping of the primary protection stage is constantly monitored in this configuration. If the current is not reduced below the setting limit or the primary stage tripping signal is not reset, a RETRIP signal is sent to the redundant trip coil. If the retripping fails and the current is not reduced below the setting limit or the primary stage tripping signal is not reset, the function also sends a CBFP signal to the incomer breaker. If the primary protection function clears the fault, both counters (RETRIP and CBFP) are reset as soon as the measured current is below the threshold settings or the tripping signal is reset. This configuration allows the CBFP to be controlled with current-based functions alone, and other function trips can be excluded from the CBFP functionality.

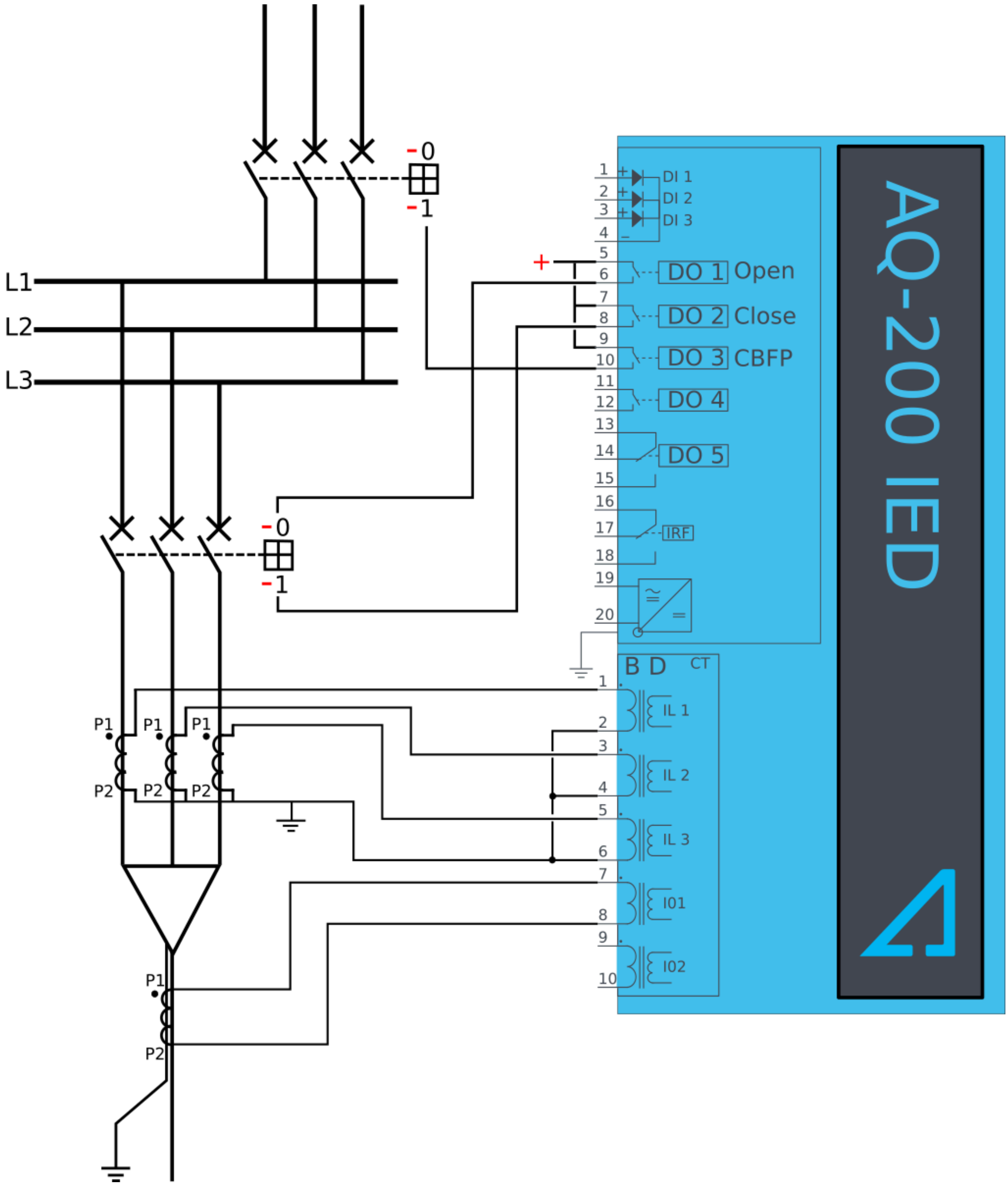
Figure. 5.3.2 - 76. Retrip and CBFP when "Current or DO" is the selected criterion.



When the current threshold setting of I_{set} and/or $I0_{set}$ is exceeded, or the TRIP signal reaches the primary protection stage, the function starts counting down towards the RETRIP and CBFP signals. The tripping of the primary protection stage is constantly monitored in this configuration regardless of the current's status. The pick-up of the CBFP is active unless the current is reduced below the setting limit and the primary stage tripping signal is reset. If either of these conditions is met (i.e. the current is above the limit or the signal is active) for the duration of the set RETRIP time delay, a RETRIP signal is sent to the redundant trip coil. If either of the conditions is active for the duration of the set CBFP time delay, a CBFP signal is sent to the incomer breaker. If the primary protection function clears the fault, both counters (RETRIP and CBFP) are reset as soon as the measured current is below the threshold settings and the tripping signal is reset. This configuration allows the CBFP to be controlled with current-based functions alone, with added security from current monitoring. Other function trips can also be included in the CBFP functionality.

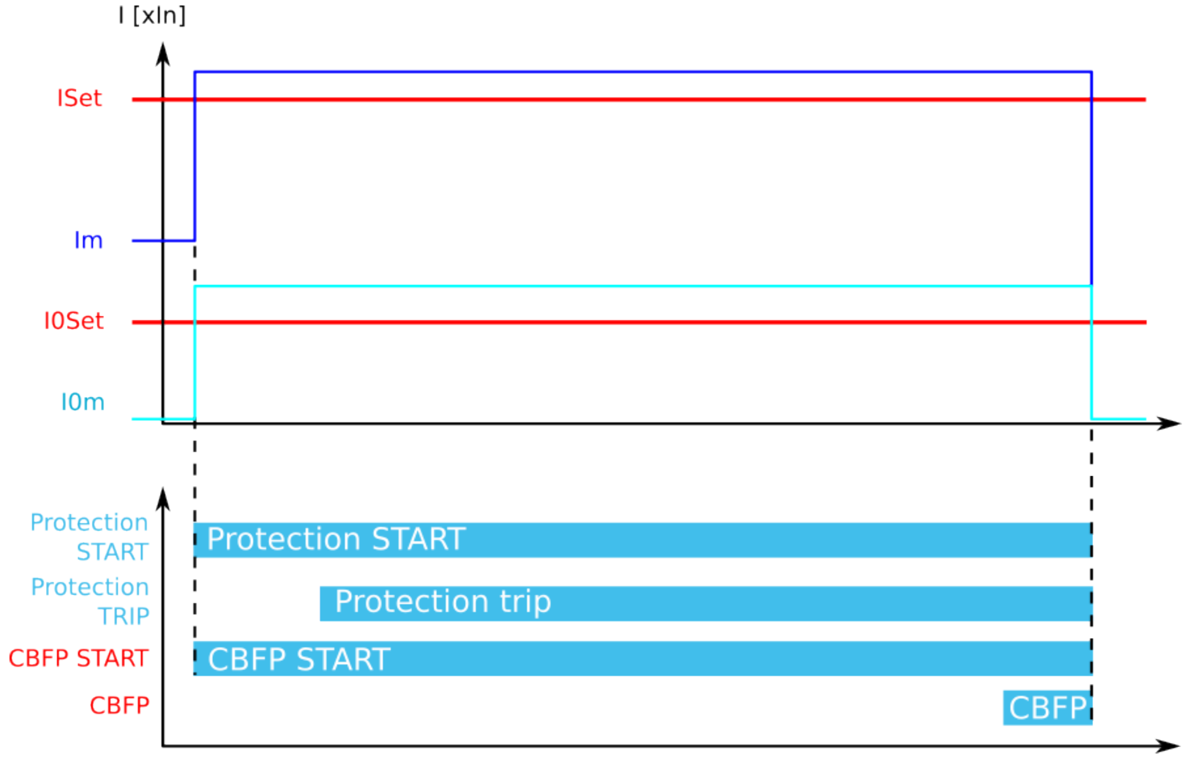
Trip and CBFP in the device configuration

Figure. 5.3.2 - 77. Wiring diagram when Trip and CBFP are configured to the device.



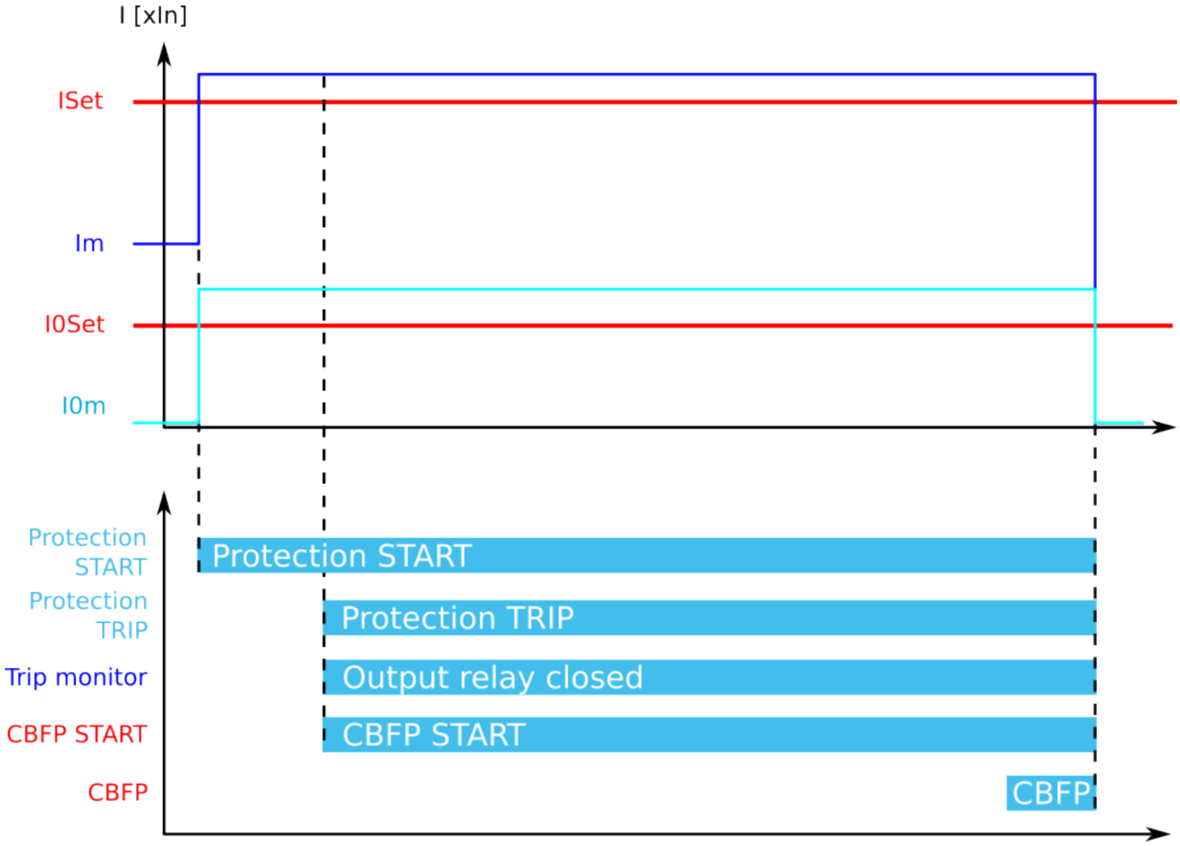
Probably the most common application is when the device's trip output controls the circuit breaker trip coil, while one dedicated CBFP contact controls the CBFP function. Below are a few operational cases regarding the various applications and settings of the CBFP function.

Figure. 5.3.2 - 78. CBFP when "Current" is the selected criterion.



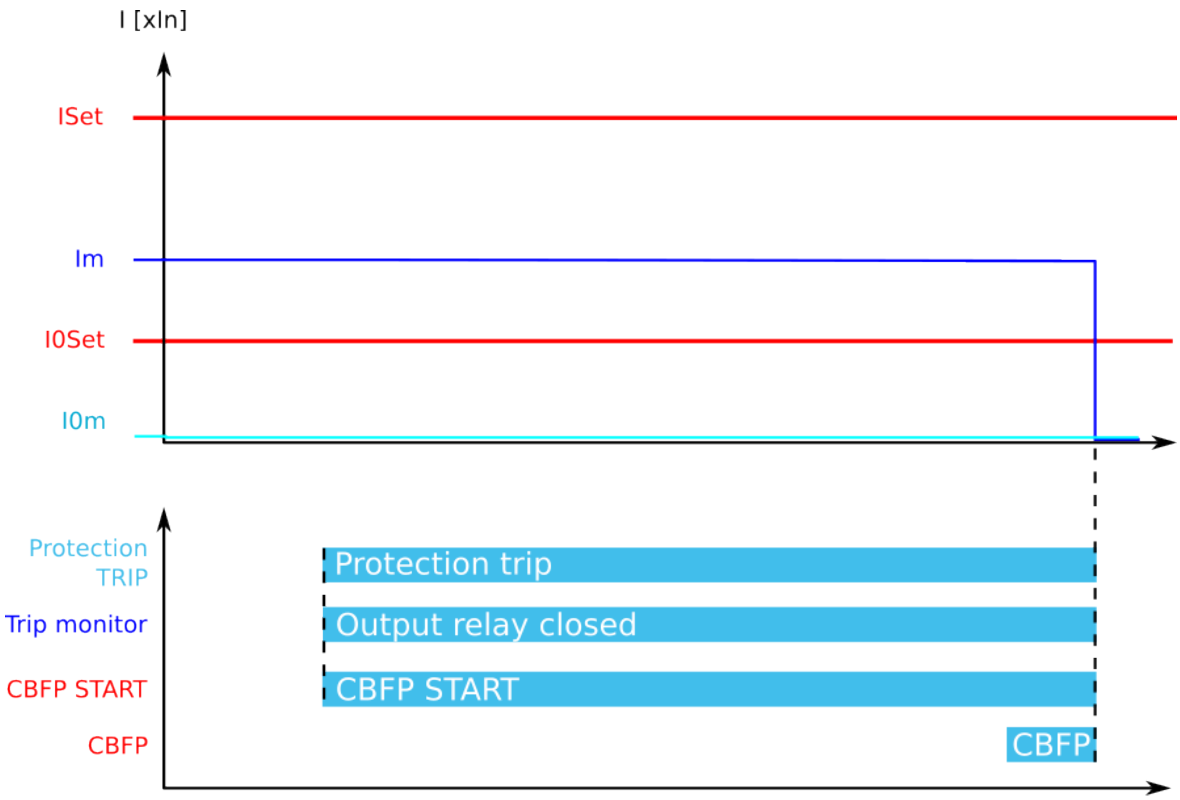
When the current threshold setting of I_{set} and/or $I0_{set}$ is exceeded, the current-based protection is activated and the counter for CBFP starts calculating the set operating time. The tripping of the primary protection stage is not monitored in this configuration. Therefore, if the current is not reduced below the setting limit, a CBFP signal is sent to the incomer breaker. If the primary protection function clears the fault, the counter for CBFP resets as soon as the measured current is below the threshold settings.

Figure. 5.3.2 - 79. CBFP when "Current and DO" is the selected criterion.



When the current threshold setting of I_{set} and/or $I0_{set}$ is exceeded, the current-based protection is activated. At the same time, the counter for CBFP is halted until the monitored output contact is controlled (that is, until the primary protection operates). When the tripping signal reaches the primary protection stage, the CBFP counter starts calculating the set operating time. The tripping of the primary protection stage is constantly monitored in this configuration. If the current is not reduced below the setting limit or the primary stage tripping signal is not reset, a CBFP signal is sent to the incomer breaker. The time delay counter for CBFP is reset as soon as the measured current is below the threshold settings or the tripping signal is reset. This configuration allows the CBFP to be controlled by current-based functions alone, and other function trips can be excluded from the CBFP functionality.

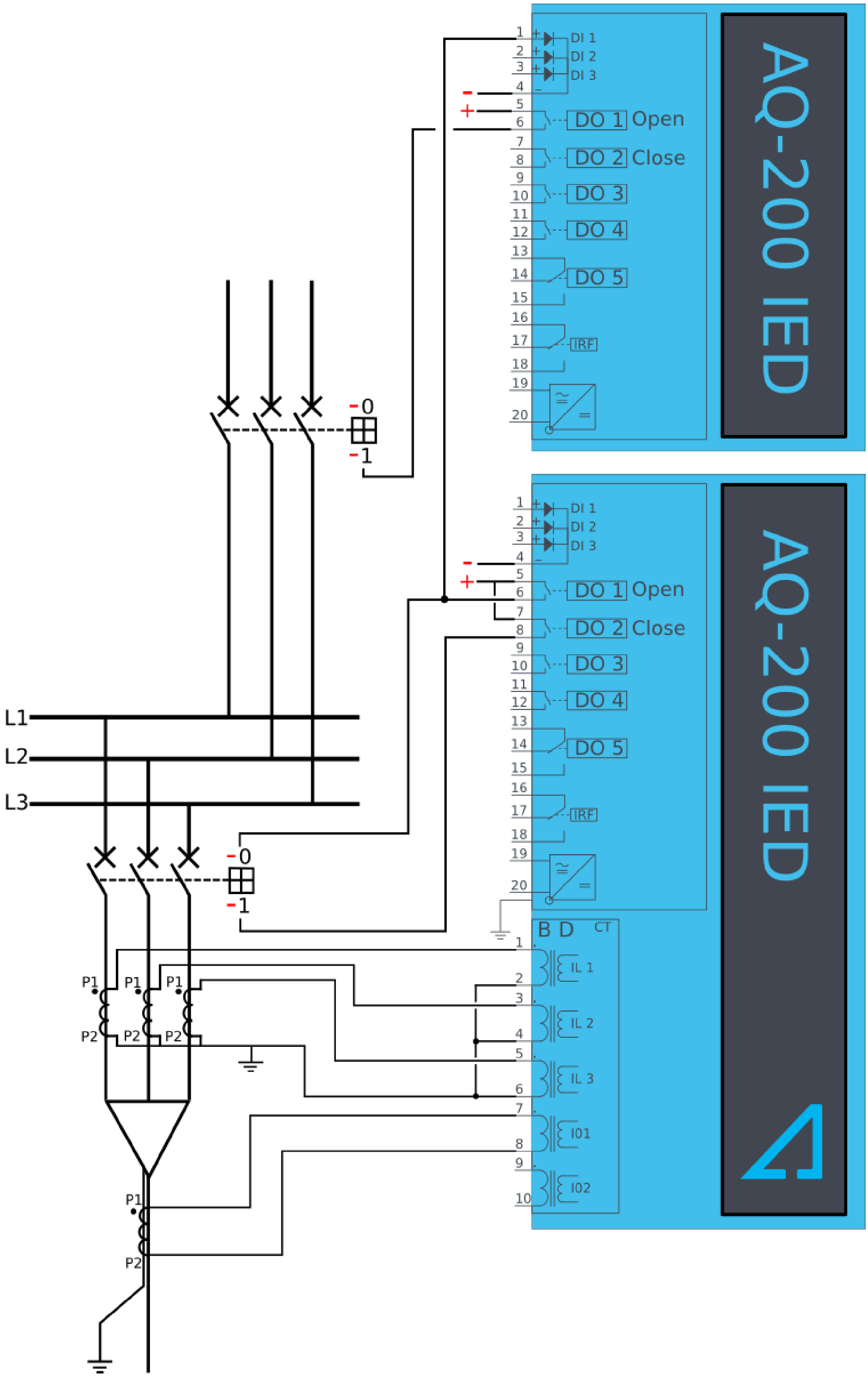
Figure. 5.3.2 - 80. CBFP when "Current or DO" is the selected criterion.



When the current threshold setting of I_{set} and/or $I0_{set}$ is exceeded, or the TRIP signal reaches the primary protection stage, the function starts counting down towards the CBFP signal. The tripping of the primary protection stage is constantly monitored in this configuration regardless of the current's status. The pick-up of the CBFP is active unless the current is reduced below the setting limit and the primary stage tripping signal is reset. If either of these conditions is met (i.e. the current is above the limit or the signal is active) for the duration of the set CBFP time delay, a CBFP signal is sent to the incomer breaker. The time delay counter for CBFP is reset as soon as the measured current is below the threshold settings and the tripping signal is reset. This configuration allows the CBFP to be controlled by current-based functions alone, with added security from current monitoring. Other function trips can also be included to the CBFP functionality.

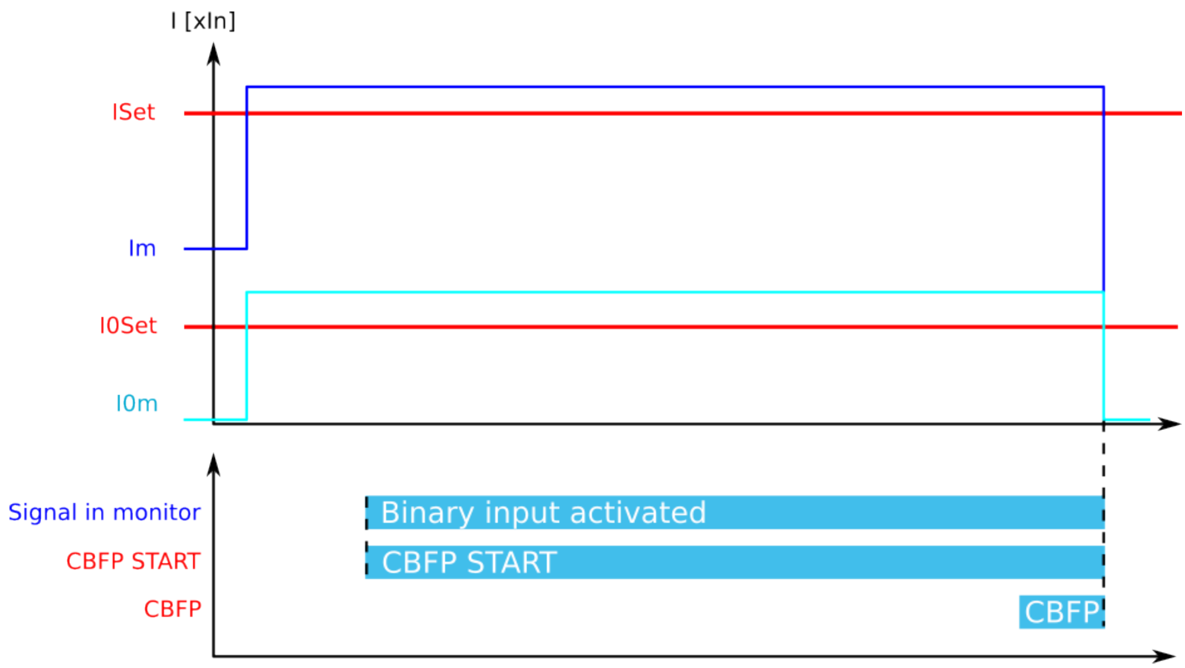
Device configuration as a dedicated CBFP unit

Figure. 5.3.2 - 81. Wiring diagram when the device is configured as a dedicated CBFP unit.



Some applications require a dedicated circuit breaker protection unit. When the CBFP function is configured to operate with a digital input signal, it can be used in these applications. When a device is used for this purpose, the tripping signal is wired to the device's digital input and the device's own TRIP signal is used only for the CBFP purpose. In this application's incomer the RETRIP and CBFP signals are also available with different sets of requirements. The RETRIP signal can be used for tripping the section's feeder breaker and the CBFP signal for tripping the incomer. The following example does not use retripping and the CBFP signal is used as the incomer trip from the outgoing breaker trip signal. The TRIP signal can also be transported between different devices by using GOOSE messages.

Figure. 5.3.2 - 82. Dedicated CBFP operation from digital input signal.



In this mode the CBFP operates only from a digital input signal. Both current and output relay monitoring can be used. The counter for the CBFP signal begins when the digital input is activated. If the counter is active until the CBFP counter is used, the device issues a CBFP command to the incomer breaker. In this application the device tripping signals from all outgoing feeders can be connected to one, dedicated CBFP device which operates either on current-based protection or on all possible faults' CBFP protection.

Events and registers

The circuit breaker failure protection function (abbreviated "CBF" in event block names) generates events and registers from the status changes in RETRIP, in CBFP-activated and CBFP-blocked signals, as well as in internal pick-up comparators. 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 - 29. Event codes.

Event number	Event channel	Event block name	Event code	Description
2816	44	CBF1	0	Start ON
2817	44	CBF1	1	Start OFF
2818	44	CBF1	2	Retrip ON
2819	44	CBF1	3	Retrip OFF

Event number	Event channel	Event block name	Event code	Description
2820	44	CBF1	4	CBFP ON
2821	44	CBF1	5	CBFP OFF
2822	44	CBF1	6	Block ON
2823	44	CBF1	7	Block OFF
2824	44	CBF1	8	DO monitor ON
2825	44	CBF1	9	DO monitor OFF
2826	44	CBF1	10	Signal ON
2827	44	CBF1	11	Signal OFF
2828	44	CBF1	12	Phase current ON
2829	44	CBF1	13	Phase current OFF
2830	44	CBF1	14	Res current ON
2831	44	CBF1	15	Res current 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. 5.3.2 - 30. Register content.

Date and time	Event code	Trigger current	Time to RETRact	Time to CBFPact	F type	S type	Used SG
dd.mm.yyyy hh:mm:ss.mss	2816-2831 Descr.	Phase and residual currents on trigger time	Time remaining before RETR is active	Time remaining before CBFP is active	Monitored current status code	Activate start triggers	Setting group 1...8 active

5.3.3 Overvoltage protection (U>; 59)

The overvoltage function is used for instant and time-delayed overvoltage protection. Each device with a voltage protection module has four (4) available stages of the function (U>, U>>, U>>>, U>>>>). The function constantly measures phase voltage magnitudes or line-to-line magnitudes. Overvoltage protection is based on line-to-line RMS measurement or to line-to-neutral RMS measurement (as the user selects). If the protection is based on line-to-line voltage, overvoltage protection is not affected by earth faults in isolated or compensated networks. 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.

The outputs of the function are the START, TRIP and BLOCKED signals. The overvoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode. In time-delayed mode the operation can be selected between definite time (DT) mode and inverse definite minimum time (IDMT).

The operational logic consists of the following:

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

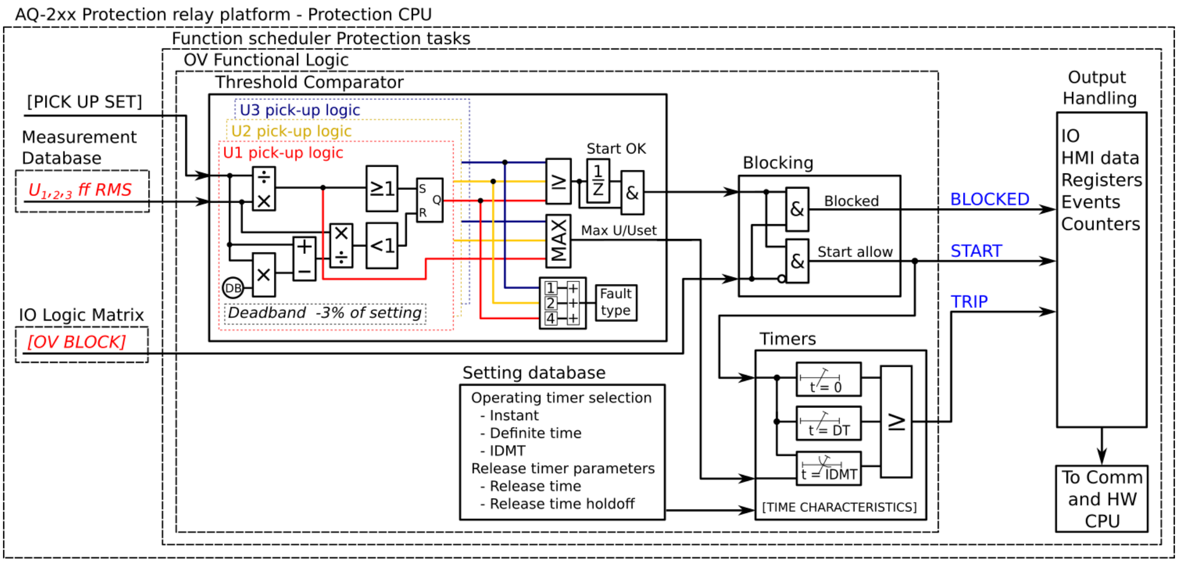
The inputs for the function are the following:

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

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signals. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the overvoltage function.

Figure. 5.3.3 - 83. Simplified function block diagram of the U> function.



Measured input

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

Table. 5.3.3 - 31. Measurement input of the U> function.

Signal	Description	Time base
UL12RMS	RMS measurement of voltage UL12/V	5ms
UL23RMS	RMS measurement of voltage UL23/V	5ms
UL31RMS	RMS measurement of voltage UL31/V	5ms
UL1RMS	RMS measurement of voltage UL1/V	5ms
UL2RMS	RMS measurement of voltage UL2/V	5ms
UL3RMS	RMS measurement of voltage UL3/V	5ms

Table. 5.3.3 - 32. Measured magnitude selection settings.

Name	Description	Range	Step	Default
Measured magnitude	Selection of phase-to-phase or phase-to-earth voltages. Additionally, the U3 or U4 input can be assigned as the voltage channel to be supervised.	0: P-P voltages 1: P-E voltages 2: U3 input (2LL-U3SS) 3: U4 input (SS)	-	0: P-P voltages

The selection of the AI channel in use is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from START or TRIP event.

Figure. 5.3.3 - 84. Selectable measurement magnitudes with 3LN+U4 VT connection.

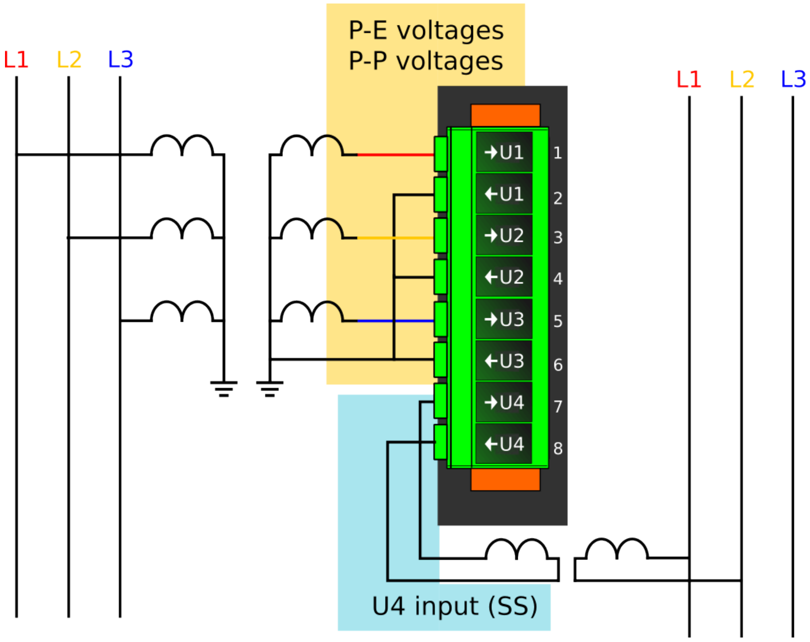


Figure. 5.3.3 - 85. Selectable measurement magnitudes with 3LL+U4 VT connection (P-E voltages not available without residual voltage).

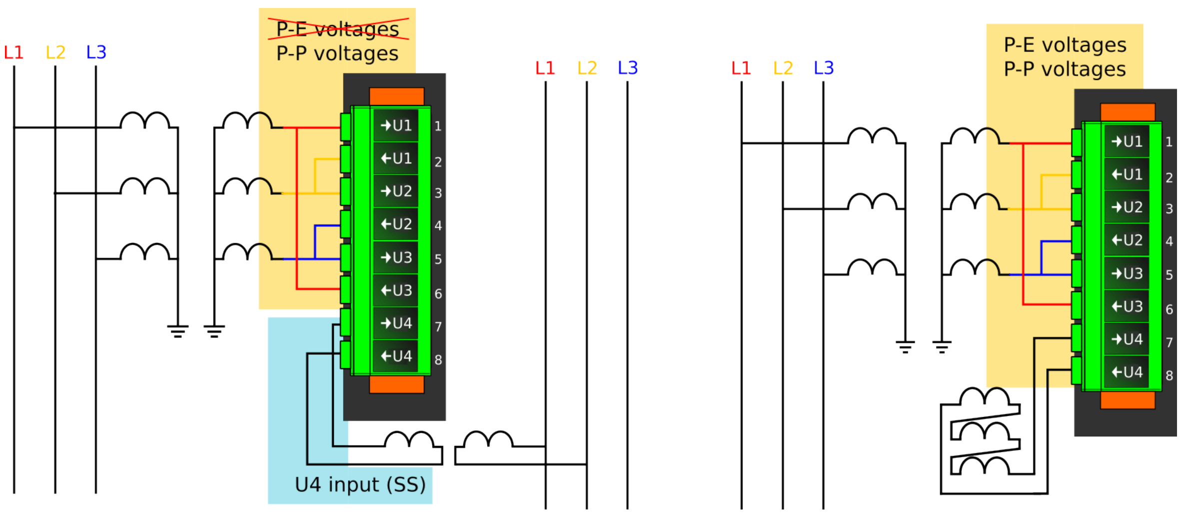
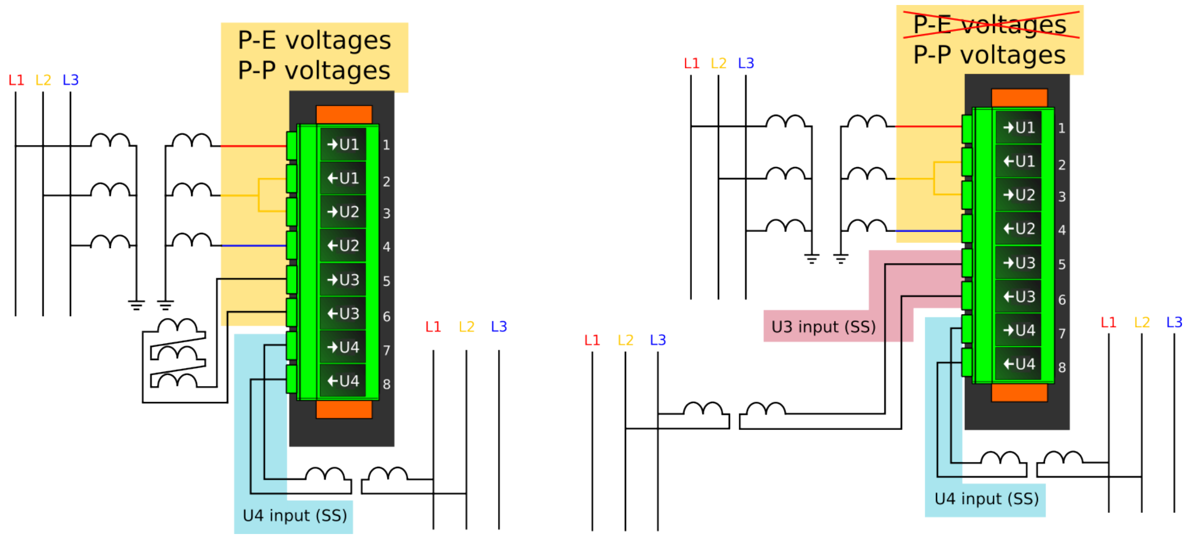


Figure. 5.3.3 - 86. Selectable measurement magnitudes with 2LL+U3+U4 VT connection (P-E voltages not available without residual voltage).



P-P Voltages and *P-E Voltages* selections follow phase-to-neutral or phase-to-phase voltages in the first three voltage channels (or two first voltage channels in the 2LL+U3+U4 mode). *U4 input* selection follows the voltage in Channel 4. *U3Input* selection only follows the voltage in Channel 3 if the 2LL+U3+U4 mode is in use.

Pick-up

The U_{set} setting parameter controls the pick-up of the U> 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. The setting value is common for all measured amplitudes, and when the U_m exceeds the U_{set} value (in single, dual or all voltages) it triggers the pick-up operation of the function.

Table. 5.3.3 - 33. Pick-up settings.

Name	Description	Range	Step	Default
Operation mode	Pick-up criteria selection	0: 1 voltage 1: 2 voltages 2: 3 voltages	-	0: 1 voltage
U_{set}	Pick-up setting	50.00…150.00%U_n	0.01%U_n	105%U_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.

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. 5.3.3 - 34. Information displayed by the function.

Name	Range	Step	Description
U< pick-up setting	0.0...1 000 000.0V	0.1V	The primary voltage required for tripping. The displayed pick-up voltage level depends on the pick-up setting and the voltage transformer settings.

Name	Range	Step	Description
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs. When IDMT mode is used, the expected operating time depends on the measured voltage value. If the measured voltage changes during a fault, the expected operating time changes accordingly.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.
$U_{A(B)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_A or U_{AB} voltage and the pick-up value.
$U_{B(c)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_B or U_{BC} voltage and the pick-up value.
$U_{C(A)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_C or U_{CA} voltage and the pick-up value.
U_{meas}/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between the measured voltage and the pick-up value.

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 voltage 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 trip and reset

The operating timers' behavior during a 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. There are three basic operating modes available for the function:

- Instant operation: gives the TRIP signal with no additional time delay simultaneously with the START signal.
- Definite time operation (DT): gives the TRIP signal after a user-defined time delay regardless of the measured voltage as long as the voltage is above the U_{set} value and thus the pick-up element is active (independent time characteristics).

- Inverse definite minimum time (IDMT): gives the TRIP signal after a time which is in relation to the set pick-up voltage U_{set} and the measured voltage U_m (dependent time characteristics).

The IDMT function follows this formula:

$$t = \frac{k}{\left(\frac{Um}{Us}\right)^a - 1}$$

Where:

- t = operating time
- k = time dial setting
- U_m = measured voltage
- U_s = pick-up setting
- a = IDMT Multiplier setting

The following table presents the setting parameters for the function's time characteristics.

Table. 5.3.3 - 35. Setting parameters for operating time characteristics.

Name	Range	Step	Default	Description
Delay type	1: DT 2: IDMT	-	1: DT	Selection of the delay type time counter. The selection possibilities are dependent (IDMT, Inverse Definite Minimum Time) and independent (DT, Definite Time) characteristics.
Definite operating time delay	0.000…800.000s	0.005s	0.040s	Definite time operating delay. The setting is active and visible when DT is the selected delay type. When set to 0.000 s, the stage operates as instant stage without added delay. When the parameter is set to 0.005...1800 s, the stage operates as independent delayed.
Time dial setting k	0.01…60.00s	0.01s	0.05s	This setting is active and visible when IDMT is the selected delay type. Time dial/multiplier setting for IDMT characteristics.
IDMT Multiplier	0.01…25.00s	0.01s	1.00s	This setting is active and visible when IDMT is the selected delay type. IDMT time multiplier in the U_m/U_{set} power.

Table. 5.3.3 - 36. Setting parameters for reset time characteristics.

Name	Range	Step	Default	Description
Release time delay	0.000…150.000s	0.005s	0.06s	Resetting time. The time allowed between pick-ups if the pick-up has not led to a trip operation. During this time the START signal is held on for the timers if the delayed pick-up release is active.
Delayed pick-up release	1: No 2: Yes	-	1: Yes	Resetting characteristics selection either as time-delayed or as instant after the pick-up element is released. If activated the START signal is reset after the set release time delay.
Time calc reset after release time	1: No 2: Yes	-	2: Yes	Operating timer resetting characteristics selection. When active, the operating time counter is reset after a set release time if the pick-up element is not activated during this time. When disabled, the operating time counter is reset directly after the pick-up element is reset.

Name	Range	Step	Default	Description
Continue time calculation during release time	1: No 2: Yes	-	1: No	Time calculation characteristics selection. If activated, the operating time counter is continuing until a set release time has passed even if the pick-up element is reset.

The user can reset characteristics through the application. The default setting is a 60 ms delay; the time calculation is held during the release time.

In the release delay option the operating time counter calculates the operating time during the release. When using this option the function does not trip if the input signal is not re-activated while the release time count is on-going.

Events and registers

The overvoltage function (abbreviated "OV" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers four (4) independent stages; the events are segregated for each stage operation.

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

Table. 5.3.3 - 37. Event codes.

Event number	Event channel	Event block name	Event code	Description
5440	85	OV1	0	Start ON
5441	85	OV1	1	Start OFF
5442	85	OV1	2	Trip ON
5443	85	OV1	3	Trip OFF
5444	85	OV1	4	Block ON
5445	85	OV1	5	Block OFF
5504	86	OV2	0	Start ON
5505	86	OV2	1	Start OFF
5506	86	OV2	2	Trip ON
5507	86	OV2	3	Trip OFF
5508	86	OV2	4	Block ON
5509	86	OV2	5	Block OFF
5568	87	OV3	0	Start ON
5569	87	OV3	1	Start OFF
5570	87	OV3	2	Trip ON
5571	87	OV3	3	Trip OFF
5572	87	OV3	4	Block ON
5573	87	OV3	5	Block OFF
5632	88	OV4	0	Start ON
5633	88	OV4	1	Start OFF
5634	88	OV4	2	Trip ON

Event number	Event channel	Event block name	Event code	Description
5635	88	OV4	3	Trip OFF
5636	88	OV4	4	Block ON
5637	88	OV4	5	Block OFF

The function registers its operation into the last twelve (12) time-stamped registers; this information is available for all provided instances separately. The register of the function records the ON event process data for START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.3.3 - 38. Register content.

Date and time	Event code	Fault type	Trigger voltage	Fault voltage	Pre-fault voltage	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	5440-5637 Descr.	L1-E… L1-L2-L3	Start average voltage	Trip -20ms averages	Start -200ms averages	0 s...1800s	Setting group 1...8 active

5.3.4 Undervoltage protection (U<; 27)

The undervoltage function is used for instant and time-delayed undervoltage protection. Each device with a voltage protection module has four (4) available stages of the function (U>, U>>, U>>>, U>>>>). The function constantly measures phase voltage magnitudes or line-to-line voltage magnitudes. Undervoltage protection is based on line-to-line voltages or to line-to-neutral voltages (as the user selects). If the protection is based on line-to-line voltage, undervoltage protection is not affected by earth faults in isolated or compensated networks. Undervoltage protection has two blocking stages: internal blocking (based on voltage measurement and low voltage), or external blocking (e.g. during voltage transformer fuse failure). 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.

The outputs of the function are the START, TRIP and BLOCKED signals. The undervoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode. In time-delayed mode the operation can be selected between definite time (DT) mode and inverse definite minimum time (IDMT).

The operational logic consists of the following:

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

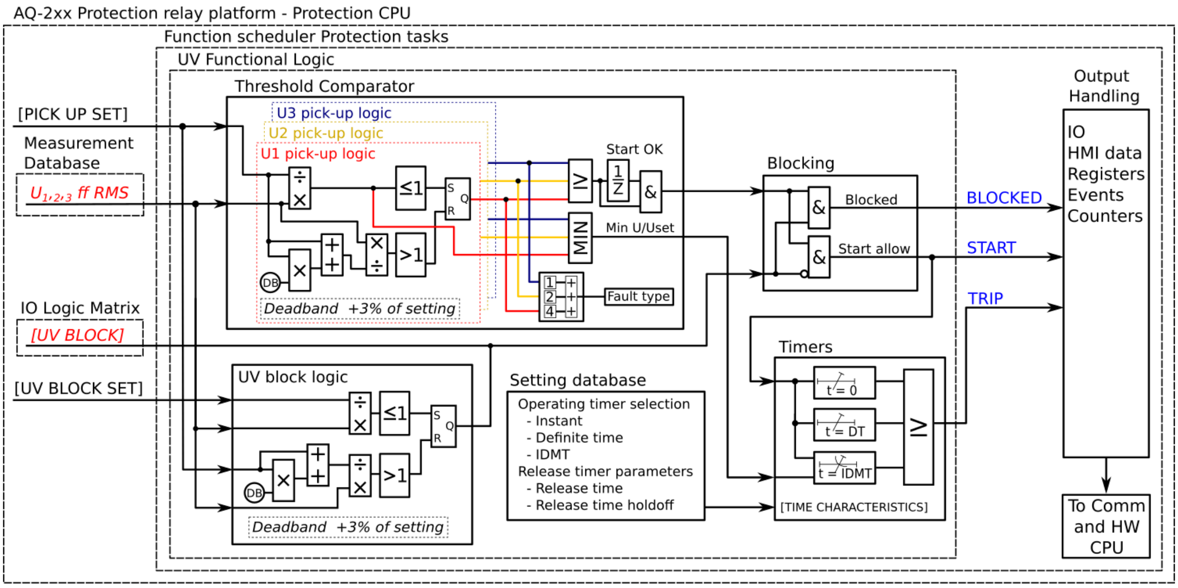
The inputs for the function are the following:

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

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signals. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the undervoltage function.

Figure. 5.3.4 - 87. Simplified function block diagram of the U< function.



Measured input

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

Table. 5.3.4 - 39. Measurement inputs of the U< function.

Signal	Description	Time base
U_{L12}RMS	RMS measurement of voltage U_{L12}/V	5ms
U_{L23}RMS	RMS measurement of voltage U_{L23}/V	5ms
U_{L31}RMS	RMS measurement of voltage U_{L31}/V	5ms
U_{L1}RMS	RMS measurement of voltage U_{L1}/V	5ms
U_{L2}RMS	RMS measurement of voltage U_{L2}/V	5ms
U_{L3}RMS	RMS measurement of voltage U_{L3}/V	5ms

Table. 5.3.4 - 40. Measured magnitude selection settings.

Name	Description	Range	Step	Default
Measured magnitude	Selection of P-P or P-E voltages. Additionally, the U3 or U4 input can be assigned as the voltage channel to be supervised.	0: P-P voltages 1: P-E voltages 2: U3 input (2LL-U3SS) 3: U4 input (SS)	-	0: P-P voltages

The selection of the AI channel in use is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from START or TRIP event.

Figure. 5.3.4 - 88. Selectable measurement magnitudes with 3LN+U4 VT connection.

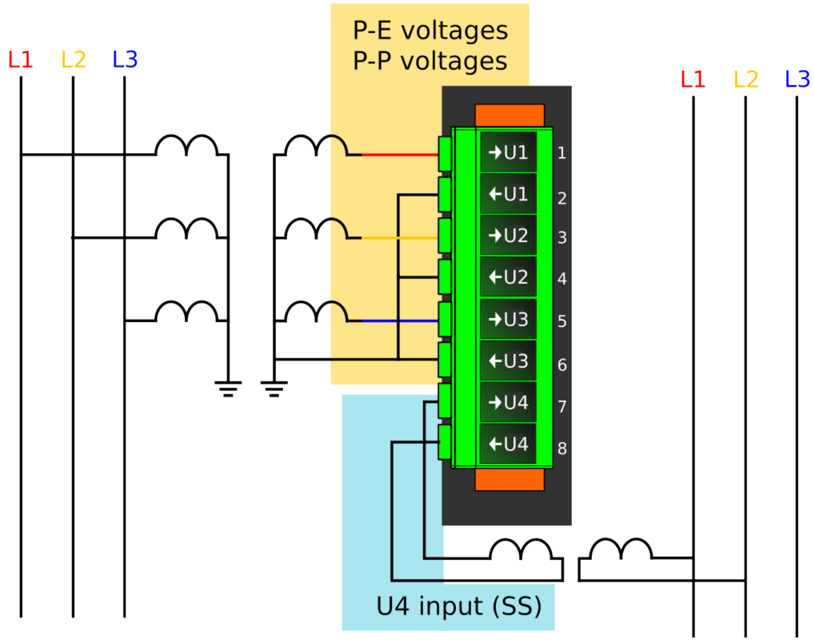


Figure. 5.3.4 - 89. Selectable measurement magnitudes with 3LL+U4 VT connection (P-E voltages not available without residual voltage).

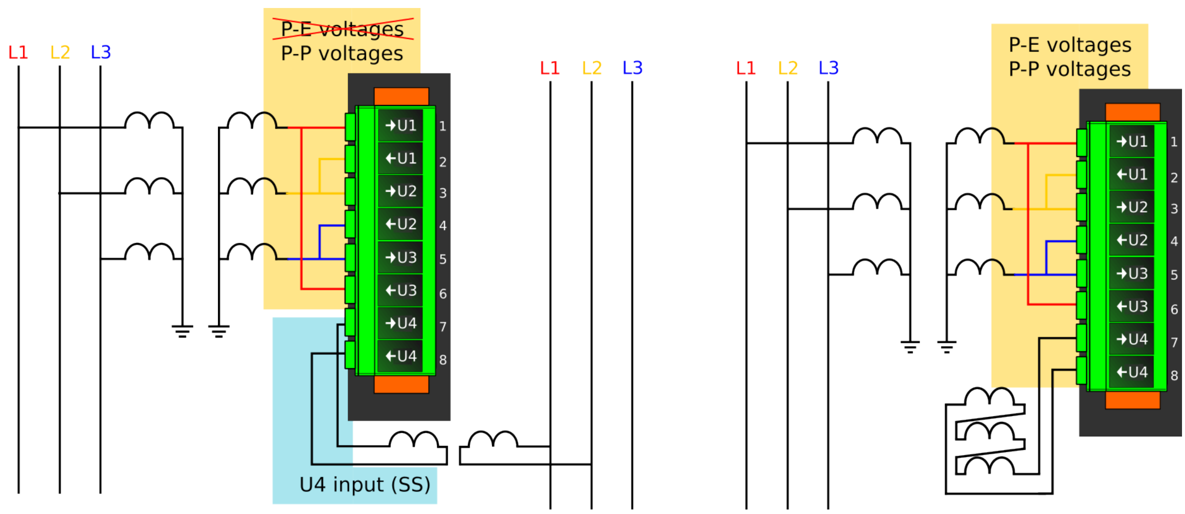
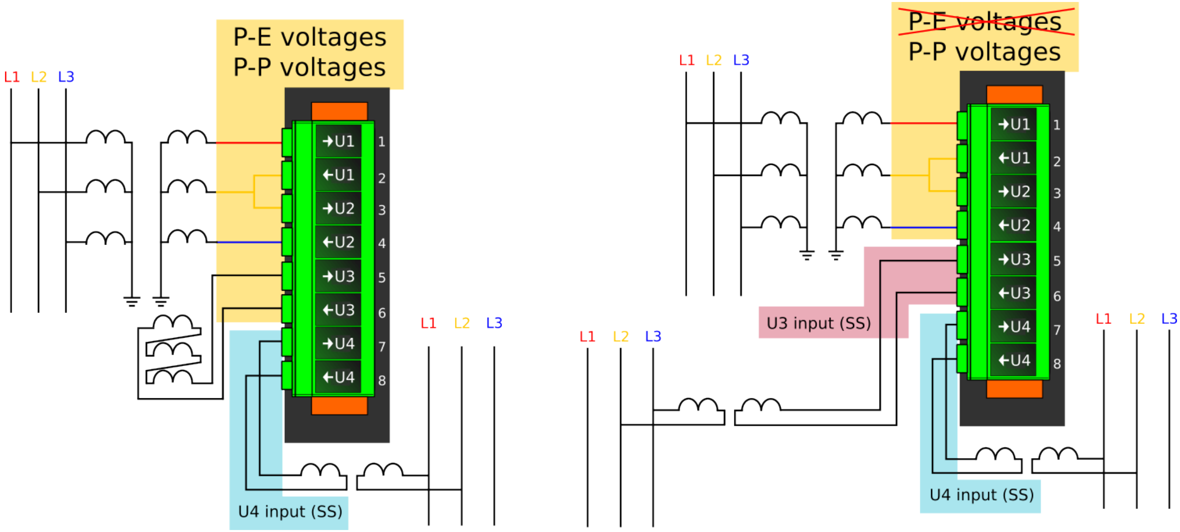


Figure. 5.3.4 - 90. Selectable measurement magnitudes with 2LL+U4 VT connection (P-E voltages not available without residual voltage).



P-P Voltages and *P-E Voltages* selections follow phase-to-neutral or phase-to-phase voltages in the first three voltage channels (or two first voltage channels in the 2LL+U3+U4 mode). *U4 input* selection follows the voltage in Channel 4. *U3Input* selection only follows the voltage in Channel 3 if the 2LL+U3+U4 mode is in use.

Pick-up

The U_{set} setting parameter controls the pick-up of the U< function. This 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, and when the U_m exceeds the U_{set} value (in single, dual or all voltages) it triggers the pick-up operation of the function.

Table. 5.3.4 - 41. Pick-up settings.

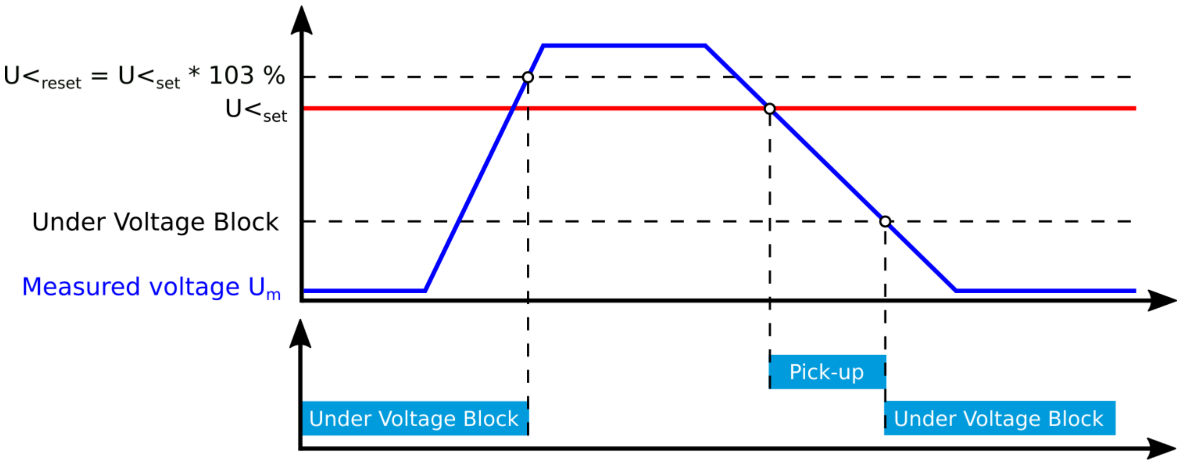
Name	Description	Range	Step	Default
U_{set}	Pick-up setting	0.00…120.00%U_n	0.01%U_n	60%U_n
U Block setting	Block setting. If set to zero, blocking is not in use. The operation is explained in the next chapter.	0.00…100.00%U_n	0.01%U_n	10%U_n

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.

Using *Block setting* to prevent nuisance trips

It is recommended to use the *Block setting* parameter to prevent the relay from tripping in a situation where the network is de-energized. When the measured voltage drops below the set value, the relay does not give a tripping signal. If the measured voltage has dropped below the *Block setting* parameter, the blocking continues until all of the line voltages have increased above the U< pick-up setting. Please see the image below for a visualization of this function. If the block level is set to zero (0), blocking is not in use.

Figure. 5.3.4 - 91. Example of the block setting operation.



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. 5.3.4 - 42. Information displayed by the function.

Name	Range	Step	Description
U< pick-up setting	0.0...1 000 000.0V	0.1V	The primary voltage required for tripping. The displayed pick-up voltage level depends on the pick-up setting and the voltage transformer settings.
U< block setting	0.0...1 000 000.0V	0.1V	The primary voltage level required for trip blocking. If the measured voltage is below this value, the network is considered de-energized and the function will not trip. To deactivate the blocking the measured voltage must exceed the pick-up setting value.
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs. When IDMT mode is used, the expected operating time depends on the measured voltage value. If the measured voltage changes during a fault, the expected operating time changes accordingly.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.
$U_{A(B)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_A or U_{AB} voltage and the pick-up value.
$U_{B(c)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_B or U_{BC} voltage and the pick-up value.
$U_{C(A)}$ meas/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between U_C or U_{CA} voltage and the pick-up value.
U_{meas}/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between the lowest measured phase or line voltage and the pick-up value.

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 voltage 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 trip and reset

The operating timers' behavior during a 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. There are three basic operating modes available for the function:

- Instant operation: gives the TRIP signal with no additional time delay simultaneously with the START signal.
- Definite time operation (DT): gives the TRIP signal after a user-defined time delay regardless of the measured voltage as long as the voltage is above the U_{set} value and thus the pick-up element is active (independent time characteristics).
- Inverse definite minimum time (IDMT): gives the TRIP signal after a time which is in relation to the set pick-up voltage U_{set} and the measured voltage U_m (dependent time characteristics).

The IDMT function follows this formula:

$$t = \frac{k}{1 - \left(\frac{Um}{Us}\right)^{a}}$$

Where:

- t = operating time
- k = time dial setting
- U_m = measured voltage
- U_s = pick-up setting
- a = IDMT multiplier setting

The following table presents the setting parameters for the function's time characteristics.

Table. 5.3.4 - 43. Setting parameters for operating time characteristics.

Name	Range	Step	Default	Description
Delay type	1: DT 2: IDMT	-	1: DT	Selection of the delay type time counter. The selection possibilities are dependent (IDMT, Inverse Definite Minimum Time) and independent (DT, Definite Time) characteristics.
Definite operating time delay	0.000…1800.000s	0.005s	0.040s	Definite time operating delay. This setting is active and visible when DT is the selected delay type. When set to 0.000 s, the stage operates as instant stage without added delay. When the parameter is set to 0.005...1800 s, the stage operates as independent delayed.
Time dial setting k	0.01…60.00s	0.01s	0.05s	This setting is active and visible when IDMT is the selected delay type. Time dial/multiplier setting for IDMT characteristics.
IDMT Multiplier	0.01…25.00s	0.01s	1.00s	This setting is active and visible when IDMT is the selected delay type. IDMT time multiplier in the U_m/U_{set} power.

Table. 5.3.4 - 44. Setting parameters for reset time characteristics.

Name	Range	Step	Default	Description
Release time delay	0.000…150.000s	0.005s	0.06s	Resetting time. The time allowed between pick-ups if the pick-up has not led to a trip operation. During this time the START signal is held on for the timers if the delayed pick-up release is active.
Delayed pick-up release	1: No 2: Yes	-	2: Yes	Resetting characteristics selection, either time-delayed or instant after the pick-up element is released. If activated, the START signal is reset after a set release time delay.
Time calc reset after release time	1: No 2: Yes	-	2: Yes	Operating timer resetting characteristics selection. When actived, the operating time counter is reset after a set release time if the pick-up element is not activated during this time. When disabled, the operating time counter is reset directly after the pick-up element reset.
Continue time calculation during release time	1: No 2: Yes	-	1: No	Time calculation characteristics selection. If activated, the operating time counter continues until a set release time even when the pick-up element is reset.

The user can reset characteristics through the application. The default setting is a 60 ms delay; the time calculation is held during the release time.

In the release delay option the operating time counter calculates the operating time during the release. When using this option the function does not trip if the input signal is not re-activated while the release time count is on-going.

Events and registers

The undervoltage function (abbreviated "UV" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers four (4) independent stages; the events are segregated for each stage operation.

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

Table. 5.3.4 - 45. Event codes.

Event number	Event channel	Event block name	Event code	Description
5696	89	UV1	0	Start ON

Event number	Event channel	Event block name	Event code	Description
5697	89	UV1	1	Start OFF
5698	89	UV1	2	Trip ON
5699	89	UV1	3	Trip OFF
5700	89	UV1	4	Block ON
5701	89	UV1	5	Block OFF
5702	89	UV1	6	Undervoltage Block ON
5703	89	UV1	7	Undervoltage Block OFF
5760	90	UV2	0	Start ON
5761	90	UV2	1	Start OFF
5762	90	UV2	2	Trip ON
5763	90	UV2	3	Trip OFF
5764	90	UV2	4	Block ON
5765	90	UV2	5	Block OFF
5766	90	UV2	6	Undervoltage Block ON
5767	90	UV2	7	Undervoltage Block OFF
5824	91	UV3	0	Start ON
5825	91	UV3	1	Start OFF
5826	91	UV3	2	Trip ON
5827	91	UV3	3	Trip OFF
5828	91	UV3	4	Block ON
5829	91	UV3	5	Block OFF
5830	91	UV3	6	Undervoltage Block ON
5831	91	UV3	7	Undervoltage Block OFF
5888	92	UV4	0	Start ON
5889	92	UV4	1	Start OFF
5890	92	UV4	2	Trip ON
5891	92	UV4	3	Trip OFF
5892	92	UV4	4	Block ON
5893	92	UV4	5	Block OFF
5894	92	UV4	6	Undervoltage Block ON
5895	92	UV4	7	Undervoltage Block OFF

The function registers its operation into the last twelve (12) time-stamped registers; this information is available for all provided instances separately. The register of the function records the ON event process data for START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.3.4 - 46. Register content.

Date and time	Event code	Fault type	Pre-trig voltage	Fault voltage	Pre-fault voltage	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	5696-5895 Descr.	A…A-B-C	Start average voltage	Trip -20ms averages	Start -200ms averages	0 ms...1800s	Setting group 1...8 active

5.3.5 Neutral overvoltage protection (U0>; 59N)

The neutral overvoltage function is used for non-directional instant and time-delayed earth fault protection. Each device with a voltage protection module has four (4) available stages of the function (U0>, U0>>, U0>>>, U0>>>>). The function constantly measures phase-to-earth voltage magnitudes and calculates the zero sequence component. Neutral overvoltage protection is scaled to line-to-line RMS level. When the line-to-line voltage of a system is 100 V in the secondary side, the earth fault is 100 % of the U_n and the calculated zero sequence voltage reaches 100/√3 V = 57.74 V.

Below is the formula for symmetric component calculation (and therefore to zero sequence voltage calculation).

$$U0 = 1/3(U_{L1} + U_{L2} + U_{L3})$$

$$U_{L1\ldots3} = \text{Line to neutral voltages}$$

Below are some examples of zero sequence calculation.

Figure. 5.3.5 - 92. Normal situation.

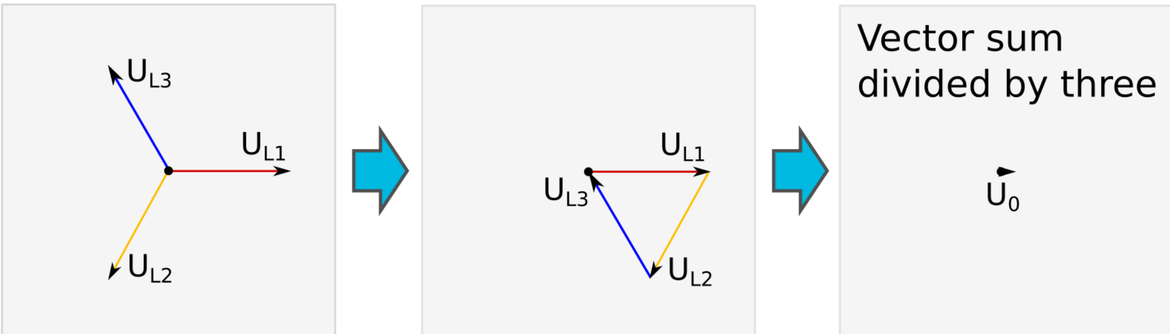


Figure. 5.3.5 - 93. Earth fault in isolated network.

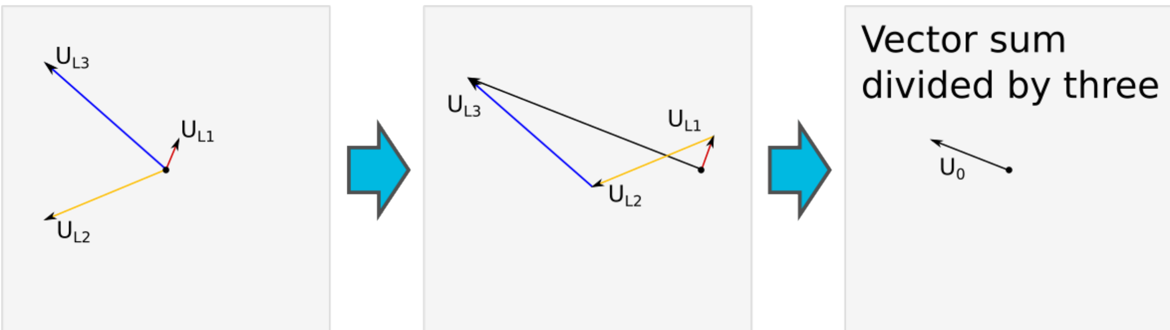
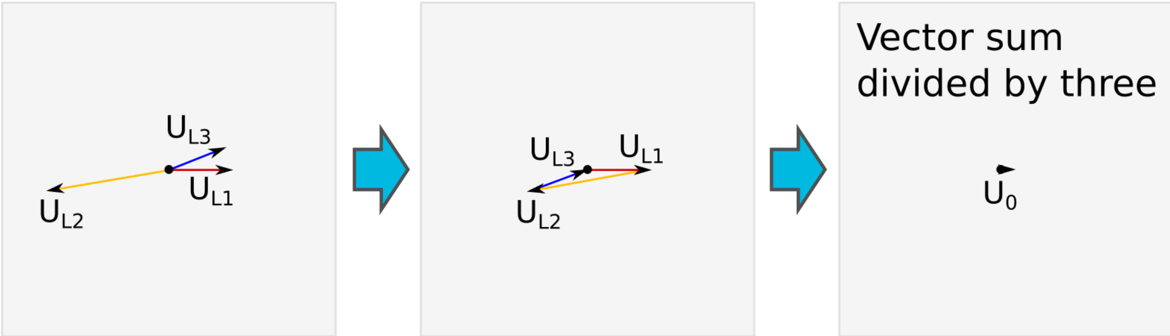


Figure. 5.3.5 - 94. Close-distance short-circuit between phases 1 and 3.



The monitored voltage magnitudes are equal to RMS values. 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.

The outputs of the function are the START, TRIP and BLOCKED signals. The neutral overvoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode. In the time-delayed mode the operation can be selected for definite time (DT) or for inverse definite minimum time (IDMT); the IDMT operation supports both IEC and ANSI standard time delays as well as custom parameters.

The operational logic consists of the following:

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

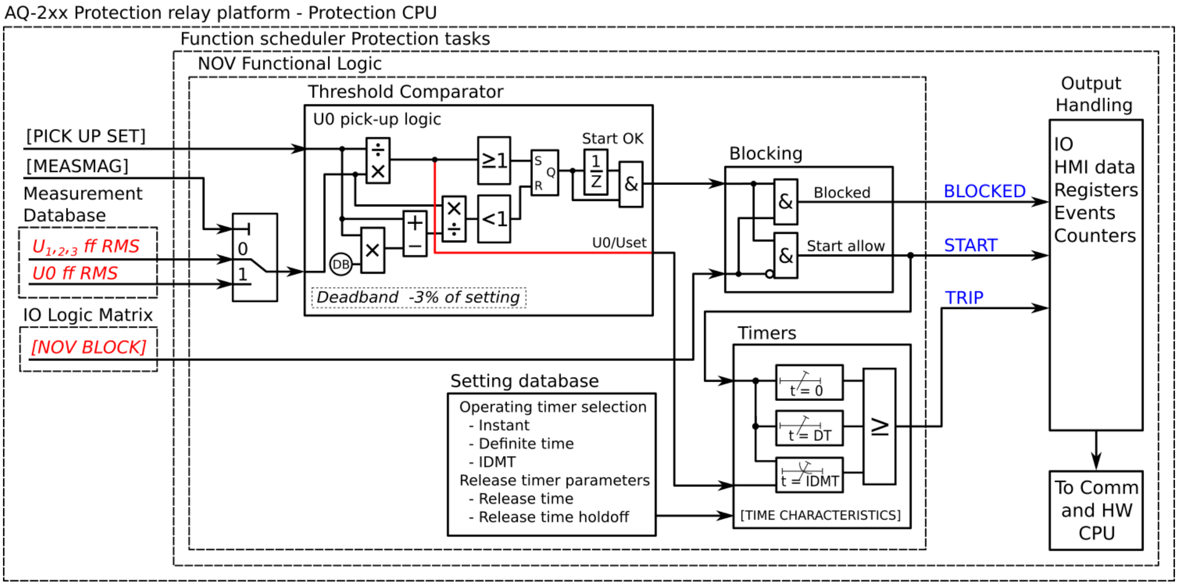
The inputs for the function are the following:

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

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signals. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a cumulative counter for the START, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the neutral overvoltage function.

Figure. 5.3.5 - 95. Simplified function block diagram of the U0> function.



Measured input

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

Table. 5.3.5 - 47. Measurement inputs of the U0> function.

Signal	Description	Time base
U0RMS	RMS measurement of voltage U0/V	5ms
U_{L1}RMS	RMS measurement of voltage U_{L1}/V	5ms
U_{L2}RMS	RMS measurement of voltage U_{L2}/V	5ms
U_{L3}RMS	RMS measurement of voltage U_{L3}/V	5ms

The selection of the AI channel currently in use is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from a START or TRIP event.

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 neutral voltage. The reset ratio of 97 % is built into the function and is always relative to the U_{set} value. The setting value is common for all measured amplitudes, and when the U_m exceeds the U_{set} value it triggers the pick-up operation of the function.

Table. 5.3.5 - 48. Pick-up settings.

Name	Description	Range	Step	Default
Pick-up setting U0set>	Pick-up setting	1.00…99.00%U_n	0.01%U_n	20.00%U_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.

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.

Name	Range	Step	Default	Description
U0> Measuring now	0: No U0 avail! 1: U0Calc 2: U3 Input 3: U4 Input	-	0: Select	Displays which voltage channel is used by the function. If no voltage channel has been selected the function defaults to calculated residual voltage if line-to-neutral voltages have been connected to device. If no channel is set to "U0" mode and line-to-line voltages are connected, no residual voltage is available and "No U0 avail!" will be displayed.
U0> Pick-up setting	0.0...1 000 000.0V	0.1V	-	Primary voltage required for tripping. The displayed pick-up voltage level depends on the chosen U0 measurement input selection, on the pick-up settings and on the voltage transformer settings.
Expected operating time	0.000...1800.000s	0.005s	-	Displays the expected operating time when a fault occurs. When IDMT mode is used, the expected operating time depends on the measured voltage value. If the measured voltage changes during a fault, the expected operating time changes accordingly.
Time remaining to trip	-1800.000...1800.000s	0.005s	-	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.
U_{meas}/U_{set} at the moment	0.00...1250.00	0.01	-	The ratio between the measured or calculated neutral voltage and the pick-up value.

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 voltage 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 trip and reset

The operating timers’ behavior during a 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. There are three basic operating modes available for the function:

- Instant operation: gives the TRIP signal with no additional time delay simultaneously with the START signal.

- Definite time operation (DT): gives the TRIP signal after a user-defined time delay regardless of the measured or calculated voltage as long as the voltage is above the U_{set} value and thus the pick-up element is active (independent time characteristics).
- Inverse definite minimum time (IDMT): gives the TRIP signal after a time which is in relation to the set pick-up voltage U_{set} and the measured voltage U_m (dependent time characteristics).

The IDMT function follows this formula:

$$t = \frac{k}{\left(\frac{Um}{Us}\right)^{a} - 1}$$

Where:

- t = operating time
- k = time dial setting
- U_m = measured voltage
- U_S = pick-up setting
- a = IDMT multiplier setting

The following table presents the setting parameters for the function's time characteristics.

Table. 5.3.5 - 49. Setting parameters for operating time characteristics.

Name	Range	Step	Default	Description
Delay type	1: DT 2: IDMT	-	1: DT	Selection of the delay type time counter. The selection possibilities are dependent (IDMT, Inverse Definite Minimum Time) and independent (DT, Definite Time) characteristics.
Definite operating time delay	0.000…1800.000s	0.005s	0.040s	Definite time operating delay. The setting is active and visible when DT is the selected delay type. When set to 0.000 s, the stage operates as instant without added delay. When the parameter is set to 0.005...1800 s, the stage operates as independent delayed.
Time dial setting k	0.01…60.00s	0.01s	0.05s	The setting is active and visible when IDMT is the selected delay type. Time dial/multiplier setting for IDMT characteristics.
IDMT Multiplier	0.01…25.00s	0.01s	1.00s	The setting is active and visible when IDMT is the selected delay type. IDMT time multiplier in the U_m/U_{set} power.

Table. 5.3.5 - 50. Setting parameters for reset time characteristics.

Name	Range	Step	Default	Description
Release time delay	0.000…150.000s	0.005s	0.06s	Resetting time. Time allowed between pick-ups if the pick-up has not led to a trip operation. During this time the START signal is held on for the timers if the delayed pick-up release is active.
Delayed pick-up release	1: No 2: Yes	-	2: Yes	Resetting characteristics selection either as time-delayed or as instant after the pick-up element is released. If activated, the START signal is reset after a set release time delay.
Time calc reset after release time	1: No 2: Yes	-	2: Yes	Operating timer resetting characteristics selection. When active, the operating time counter is reset after a set release time if the pick-up element is not activated during this time. When disabled, the operating time counter is reset directly after the pick-up element reset.

Name	Range	Step	Default	Description
Continue time calculation during release time	1: No 2: Yes	-	1: No	Time calculation characteristics selection. If activated, the operating time counter continues until a set release time has passed even if the pick-up element is reset.

The user can reset characteristics through the application. The default setting is a 60 ms delay; the time calculation is held during the release time.

In the release delay option the operating time counter calculates the operating time during the release. When using this option the function does not trip if the input signal is not re-activated while the release time count is on-going.

Events and registers

The neutral overvoltage function (abbreviated "NOV" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers four (4) independent stages; the events are segregated for each stage operation.

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

Table. 5.3.5 - 51. Event codes.

Event number	Event channel	Event block name	Event code	Description
5952	93	NOV1	0	Start ON
5953	93	NOV1	1	Start OFF
5954	93	NOV1	2	Trip ON
5955	93	NOV1	3	Trip OFF
5956	93	NOV1	4	Block ON
5957	93	NOV1	5	Block OFF
6016	94	NOV2	0	Start ON
6017	94	NOV2	1	Start OFF
6018	94	NOV2	2	Trip ON
6019	94	NOV2	3	Trip OFF
6020	94	NOV2	4	Block ON
6021	94	NOV2	5	Block OFF
6080	95	NOV3	0	Start ON
6081	95	NOV3	1	Start OFF
6082	95	NOV3	2	Trip ON
6083	95	NOV3	3	Trip OFF
6084	95	NOV3	4	Block ON
6085	95	NOV3	5	Block OFF
6144	96	NOV4	0	Start ON
6145	96	NOV4	1	Start OFF
6146	96	NOV4	2	Trip ON

Event number	Event channel	Event block name	Event code	Description
6147	96	NOV4	3	Trip OFF
6148	96	NOV4	4	Block ON
6149	96	NOV4	5	Block OFF

The function registers its operation into the last twelve (12) time-stamped registers; this information is available for all provided instances separately. The register of the function records the ON event process data for START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.3.5 - 52. Register content.

Date and time	Event code	Fault type	Trigger voltage	Fault voltage	Pre-fault voltage	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	5952-6149 Descr.	L1-G…L1-L2-L3	Start average voltage	Trip -20ms averages	Start -200ms averages	0 ms...1800s	Setting group 1...8 active

5.3.6 Sequence voltage protection (U1/U2>/<; 47/27P/59PN)

The sequence voltage function is used for instant and time-delayed voltage protection. It has positive and negative sequence protection for both overvoltage and undervoltage (the user selects the needed function). Each device with a voltage protection module has four (4) available stages of the function. The function constantly measures the RMS value of phase-to-earth voltage magnitudes, or line-to-line and neutral voltage magnitudes to calculate the positive or negative sequence voltage. The user can select the voltage used. Sequence voltage is based on the system's line-to-line voltage level. Protection stages can be set to protect against both undervoltage and overvoltage. 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.

Positive sequence voltage calculation

Below is the formula for symmetric component calculation (and therefore to positive sequence voltage calculation).

$$U1 = {}^{1}/_{3}\,(U_{L1} + aU_{L2} + a^2U_{L3})$$

$$a = 1\angle 120°$$

$$a^2 = 1\angle 240°$$

$$U_{L1\ldots 3} = \mathit{Line\ to\ neutral\ voltages}$$

In what follows are three examples of positive sequence calculation (positive sequence component vector).

Figure. 5.3.6 - 96. Normal situation.

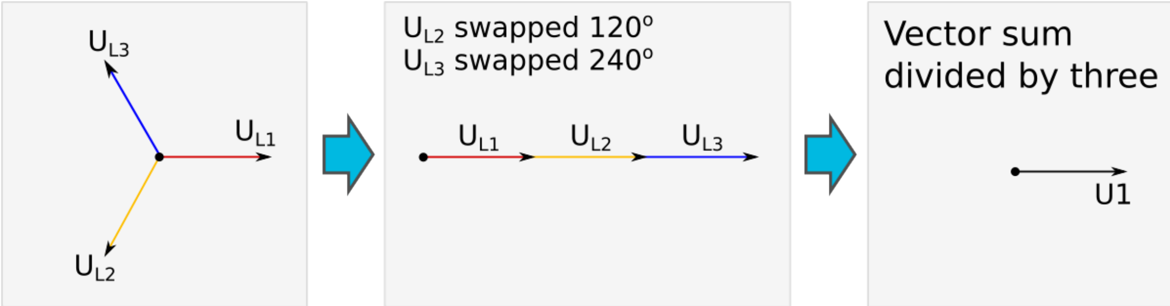


Figure. 5.3.6 - 97. Earth fault in an isolated network.

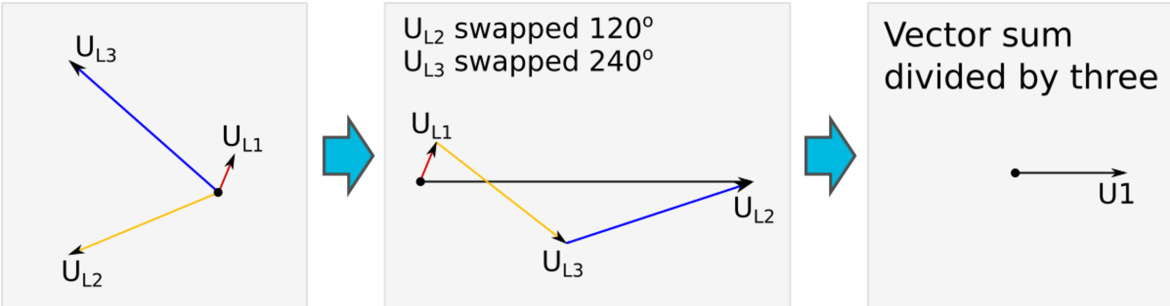
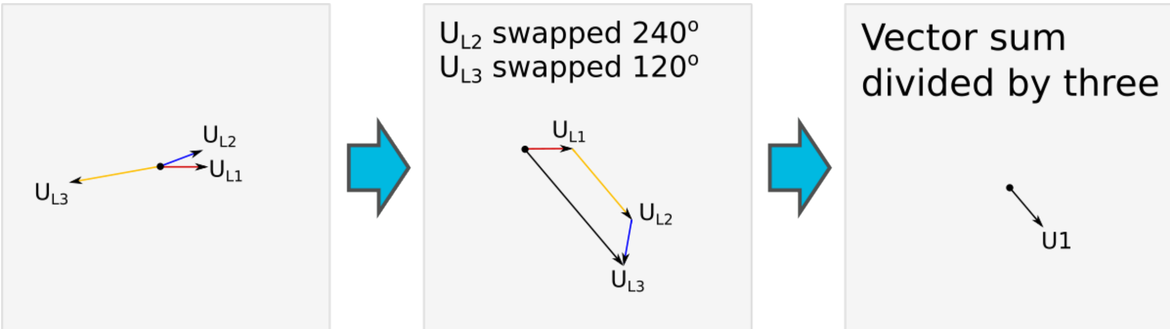


Figure. 5.3.6 - 98. Close-distance short-circuit between phases 1 and 3.



Negative sequence voltage calculation

Below is the formula for symmetric component calculation (and therefore to negative sequence voltage calculation).

$$U2 = {}^{1}/_{3}\,(U_{L1} + a^2 U_{L2} + aU_{L3})$$

$$a = 1\angle 120°$$

$$a^2 = 1\angle 240°$$

$$U_{L1\ldots3} = Line\ to\ neutral\ voltages$$

In what follows are three examples of negative sequence calculation (negative sequence component vector).

Figure. 5.3.6 - 99. Normal situation.

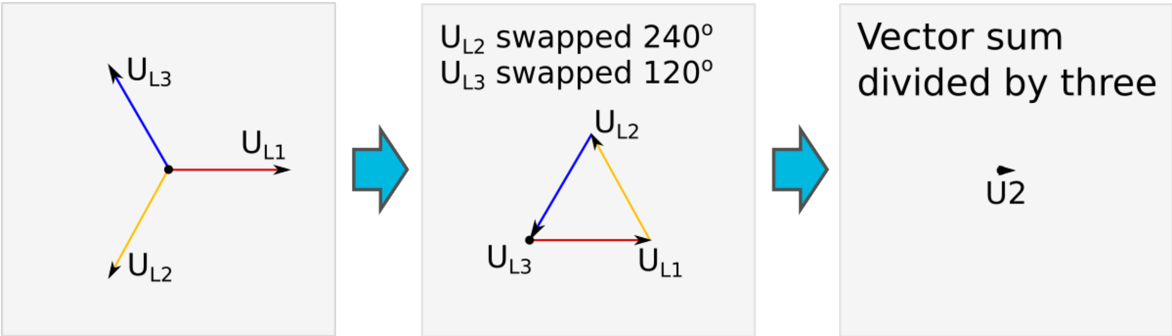


Figure. 5.3.6 - 100. Earth fault in isolated network.

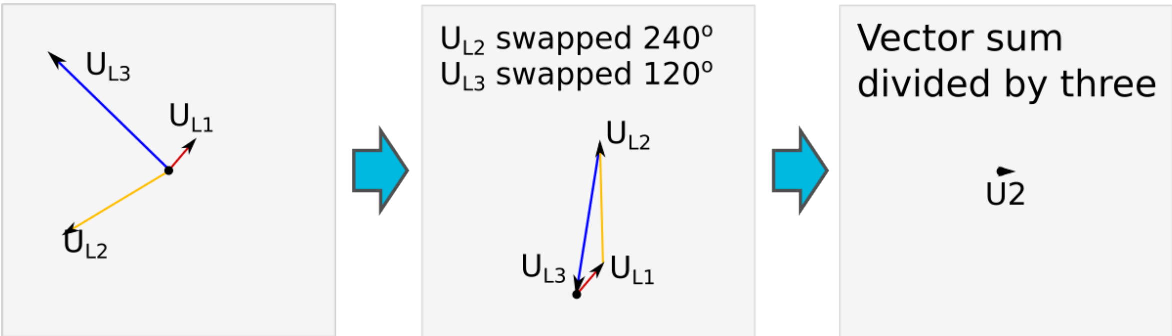
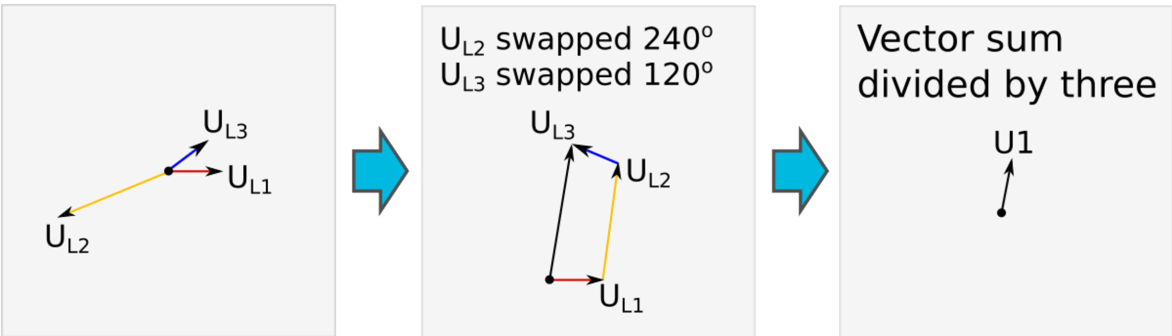


Figure. 5.3.6 - 101. Close-distance short-circuit between phases 1 and 3.



The sequence voltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode. In time-delayed mode the operation can be selected between definite time (DT) mode and inverse definite minimum time (IDMT).

The operational logic consists of the following:

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

The inputs for the function are the following:

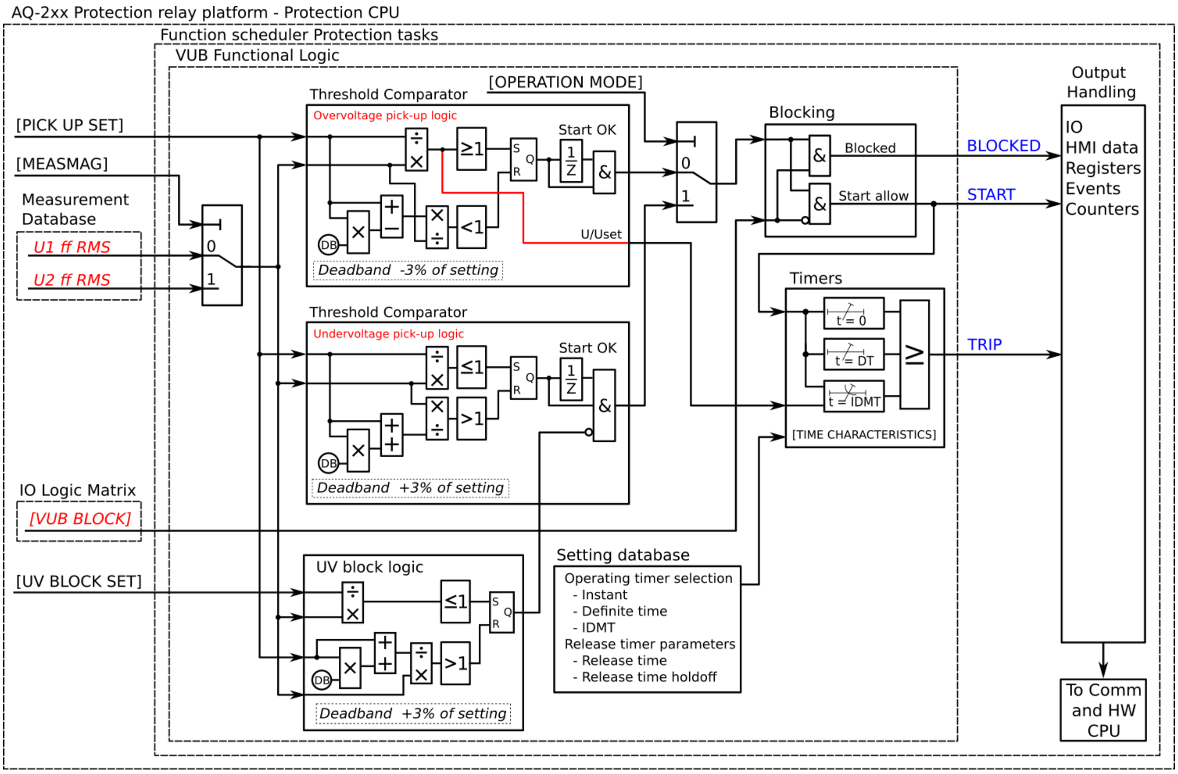
- operating mode selections
- setting parameters

- digital inputs and logic signals
- measured and pre-processed voltage magnitudes.

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signal. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also a resettable cumulative counter for the START, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the sequence voltage function.

Figure. 5.3.6 - 102. Simplified function block diagram of the U1/U2>/< function.



Measured input

The function block uses analog voltage measurement values and always uses RMS values. A -20 ms averaged value of the selected magnitude is used for pre-fault data registering.

Table. 5.3.6 - 53. Measurement inputs of the U1/U2>/< function.

Signal	Description	Time base
U_1RMS	RMS measurement of voltage U_1/V	5ms
U_2RMS	RMS measurement of voltage U_2/V	5ms
U_3RMS	RMS measurement of voltage U_3/V	5ms

Table. 5.3.6 - 54. Measured magnitude selection.

Name	Description	Range	Default
Measured magnitude	Selects which calculated voltage is supervised.	1: U1 Positive sequence voltage 2: U2 Negative sequence voltage	1: U1 Positive sequence voltage

In RMS values the pre-fault condition is presented with 20 ms averaged history value from -20 ms of START or TRIP event.

Pick-up

The U_{set} setting parameter controls the pick-up of the U1/U2>/< function. This defines the maximum or minimum allowed calculated U1 or U2 voltage before action from the function. The function constantly calculates the ratio between the U_{set} and the calculated U1 or U2 magnitude (U_C). The monitored voltage is chosen in the *Info* page with the parameter *Measured magnitude*. The reset ratio of 97 % in overvoltage applications is built into the function and is always relative to the U_{set} value. The reset ratio of 103 % in undervoltage applications is built into the function and is always relative to the U_{set} value. When the U_C goes above or below the U_{set} value it triggers the pick-up operation of the function.

Table. 5.3.6 - 55. Pick-up settings.

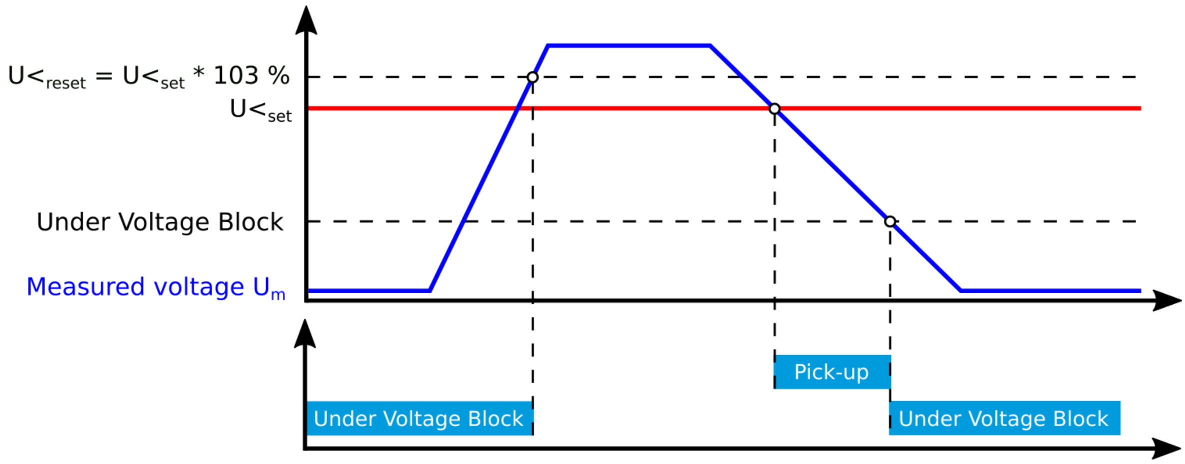
Name	Description	Range	Step	Default
Pick-up terms	Selects whether the function picks-up when the monitored voltage is under or over the set pick-up value.	Over > Under<	-	Over>
U_{set}	Pick-up setting	5.00…150.00%U_n	0.01%U_n	105%U_n
U_{blk}	Undervoltage blocking (visible when the pick-up term is Under<)	0.00…80.00%U_n	0.01%U_n	5%U_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.

Using *Block setting* to prevent nuisance trips

It is recommended to use the *Under block setting* U_{blk} parameter when Under< is the chosen tripping condition to prevent the relay from tripping in a situation where the network is de-energized. When the measured voltage drops below the set value, the relay does not give a tripping signal. If the measured voltage has dropped below the *Under block setting* U_{blk} parameter, the blocking continues until all of the line voltages have increased above the U< pick-up setting. Please see the image below for a visualization of this function. If the block level is set to zero (0), blocking is not in use.

Figure. 5.3.6 - 103. Example of the block setting operation.



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. 5.3.6 - 56. Information displayed by the function.

Name	Range	Step	Description
U1/2 >/< Pick-up setting	0.0...1 000 000.0V	0.1V	The primary voltage required for tripping. The displayed pick-up voltage level depends on the pick-up setting and the voltage transformer settings.
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs. When IDMT mode is used, the expected operating time depends on the measured voltage value. If the measured voltage changes during a fault, the expected operating time changes accordingly.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.
U_{meas}/U_{set} at the moment	0.00...1250.00U_m/U_{set}	0.01U_m/U_{set}	The ratio between the measured voltage and the pick-up value.

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 voltage 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 trip and reset

The operating timers' behavior during a 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. There are three basic operating modes available for the function:

- Instant operation: gives the TRIP signal with no additional time delay simultaneously with the START signal.
- Definite time operation (DT): gives the TRIP signal after a user-defined time delay regardless of the measured or calculated voltage as long as the voltage is above the U_{set} value and thus the pick-up element is active (independent time characteristics).
- Inverse definite minimum time (IDMT): gives the TRIP signal after a time which is in relation to the set pick-up voltage U_{set} and the measured voltage U_m (dependent time characteristics).

The IDMT function follows one of the following formulas:

Overvoltage

$$t = \frac{k}{\left(\frac{Um}{Us}\right)^a - 1}$$

Undervoltage

$$t = \frac{k}{1 - \left(\frac{Um}{Us}\right)^a}$$

Where:

- t = operating time
- k = time dial setting
- U_m = measured voltage
- U_s = pick-up setting
- a = IDMT multiplier setting

The following table presents the setting parameters for the function's time characteristics.

Table. 5.3.6 - 57. Setting parameters for operating time characteristics.

Name	Range	Step	Default	Description
Delay type	1: DT 2: IDMT	-	1: DT	Selection of the delay type time counter. The selection possibilities are dependent (IDMT, Inverse Definite Minimum Time) and independent (DT, Definite Time) characteristics.
Definite operating time delay	0.000…1800.000s	0.005s	0.040s	Definite time operating delay. The setting is active and visible when DT is the selected delay type. When set to 0.000 s, the stage operates as instant without added delay. When the parameter is set to 0.005...1800 s, the stage operates as independent delayed.
Time dial setting k	0.01…60.00s	0.01s	0.05s	The setting is active and visible when IDMT is the selected delay type. Time dial/multiplier setting for IDMT characteristics.
IDMT Multiplier	0.01…25.00s	0.01s	1.00s	The setting is active and visible when IDMT is the selected delay type. IDMT time multiplier in the U_m/U_{set} power.

Table. 5.3.6 - 58. Setting parameters for reset time characteristics.

Name	Range	Step	Default	Description
Release time delay	0.000…150.000s	0.005s	0.06s	Resetting time. Time allowed between pick-ups if the pick-up has not led to a trip operation. During this time the START signal is held on for the timers if the delayed pick-up release is active.
Delayed pick-up release	1: No 2: Yes	-	2: Yes	Resetting characteristics selection either as time-delayed or as instant after the pick-up element is released. If activated, the START signal is reset after a set release time delay.
Time calc reset after release time	1: No 2: Yes	-	2: Yes	Operating timer resetting characteristics selection. When active, the operating time counter is reset after a set release time if the pick-up element is not activated during this time. When disabled, the operating time counter is reset directly after the pick-up element reset.
Continue time calculation during release time	1: No 2: Yes	-	1: No	Time calculation characteristics selection. If activated, the operating time counter continues until a set release time has passed even if the pick-up element is reset.

The user can reset characteristics through the application. The default setting is a 60 ms delay; the time calculation is held during the release time.

In the release delay option the operating time counter calculates the operating time during the release. When using this option the function does not trip if the input signal is not re-activated while the release time count is on-going.

Events and registers

The sequence voltage function (abbreviated "VUB" in event block names) generates events and registers from the status changes in START, TRIP and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers four (4) independent stages; the events are segregated for each stage operation.

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

Table. 5.3.6 - 59. Event codes.

Event number	Event channel	Event block name	Event code	Description
8320	130	VUB1	0	Start ON
8321	130	VUB1	1	Start OFF
8322	130	VUB1	2	Trip ON
8323	130	VUB1	3	Trip OFF
8324	130	VUB1	4	Block ON
8325	130	VUB1	5	Block OFF
8384	131	VUB2	0	Start ON
8385	131	VUB2	1	Start OFF
8386	131	VUB2	2	Trip ON
8387	131	VUB2	3	Trip OFF
8388	131	VUB2	4	Block ON
8389	131	VUB2	5	Block OFF
8448	132	VUB3	0	Start ON

Event number	Event channel	Event block name	Event code	Description
8449	132	VUB3	1	Start OFF
8450	132	VUB3	2	Trip ON
8451	132	VUB3	3	Trip OFF
8452	132	VUB3	4	Block ON
8453	132	VUB3	5	Block OFF
8512	133	VUB4	0	Start ON
8513	133	VUB4	1	Start OFF
8514	133	VUB4	2	Trip ON
8515	133	VUB4	3	Trip OFF
8516	133	VUB4	4	Block ON
8517	133	VUB4	5	Block OFF

The function registers its operation into the last twelve (12) time-stamped registers; this information is available for all provided instances separately. The register of the function records the ON event process data for START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.3.6 - 60. Register content.

Date and time	Event code	Trigger voltage	Fault voltage	Pre-fault voltage	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	8320 - 8517 Descr.	Start average voltage	Trip -20ms averages	Start -200ms averages	0 ms...1800s	Setting group 1...8 active

5.3.7 Overfrequency and underfrequency protection (f>/<; 81O/81U)

The frequency protection function can be used both in overfrequency and in underfrequency situations, and it has four (4) stages for both. Frequency protection can be applied to protect feeder, bus, transformer, motor and generator applications. The difference between the generated power and the load demand can cause the frequency to drop below or rise above the allowed level. When the consumption is larger than the generated power, the frequency may drop. When more power is generated than is consumed, overfrequency can occur.

In generator applications too big a load or a malfunction in the power controller can cause the frequency to decrease. Underfrequency causes damage to turbine wings through vibration as well as heating due to increased iron losses, dropped cooling efficieny and over-magnetization in step-up transformers. Overfrequency protection prevents the generator from running too fast which can cause damage to the generator turbine.

Underfrequency and overfrequency protection can be used as an indicator of an accidental island operation in distributed generation and in some consumers (as it is unlikely that the consumed and generated power are the same). Overfrequency is also often used to control power generation to keep the system's frequency consistent.

Each stage can be activated and deactivated individually. After the f>/< mode has been activated (*Protection → Stage activation → Frequency stages*), the user can activate and deactivate the individual stages at will (*Protection → Frequency → Frequency protection f >/< → INFO → Stage operational setup*).

The outputs of the function are the START, TRIP and BLOCKED signals. The frequency protection function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode.

The operational logic consists of the following:

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

The inputs for the function are the following:

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

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signal. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

The following figures present simplified function block diagrams of the frequency function.

Figure. 5.3.7 - 104. Simplified function block diagram of the f> function.

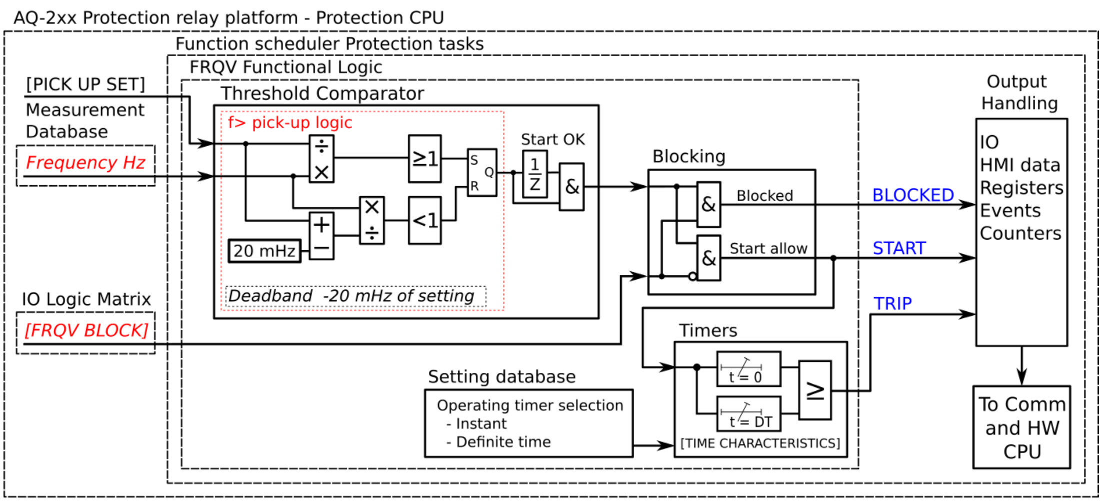
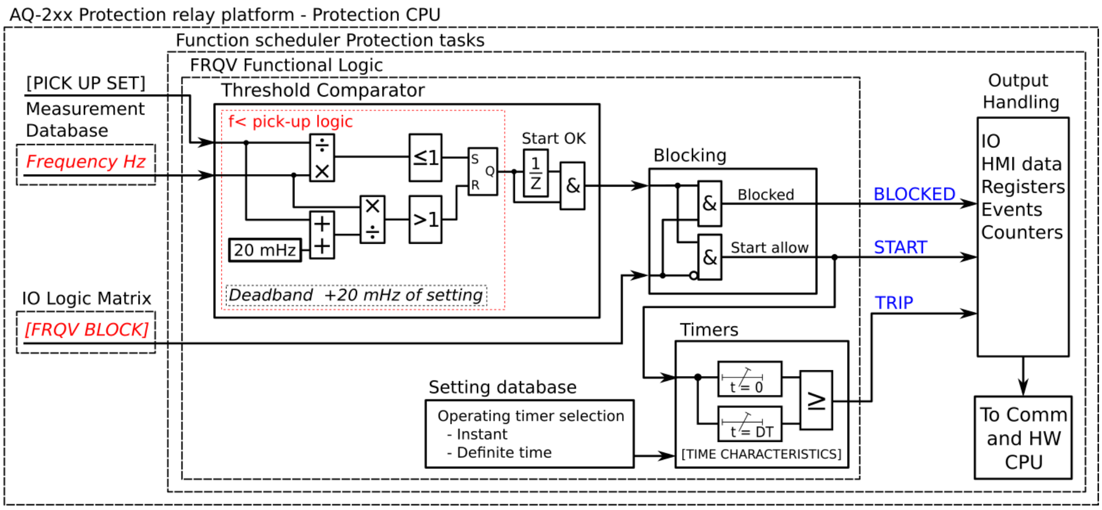


Figure. 5.3.7 - 105. Simplified function block diagram of the f< function.



Measured input

The frequency protection function compares the measured frequency to the pick-up setting (given in Hz). The source of the measured frequency depends on the user-defined tracking reference which can be chosen from the *Frequency* tab of the *Measurement* menu.

Table. 5.3.7 - 61. Measurement inputs of the f>/< function.

Signals	Description	Time base
VT1 U1, U2, U3	L-N voltages of the first voltage transformer	5ms
VT2 U1, U2, U3	L-N voltages of the second voltage transformer	5ms

Pick-up and time delay

The f_{set}>, f_{set}>>, etc.setting parameters control the pick-up of each stage of the f>/< function. They define the maximum or minimum allowed measured frequency before action from the function. The function constantly calculates the ratio between the pick-up setting and the measured frequency. The reset ratio of 20mHz is built into the function and is always relative to the pick-up value.

Table. 5.3.7 - 62. Pick-up settings.

Name	Description	Range	Step	Default
f> used in setting group f>> used in setting group f>>> used in setting group f>>>> used in setting group f< used in setting group f<< used in setting group f<<< used in setting group f<<<< used in setting group	Enables or disables the protection stage in the setting group.	0: No 1: Yes	-	0: No
fset> fset>> fset>>> fset>>>>	Pick-up setting	10.00…80.00Hz	0.01Hz	51Hz

Name	Description	Range	Step	Default
fset< fset<< fset<<< fset<<<<	Pick-up setting	5.00…75.00Hz	0.01Hz	49Hz
f> operating time f>> operating time f>>> operating time f>>>> operating time f< operating time f<< operating time f<<< operating time f<<<< operating time	Operation time	0.000...1800.00s	0.005s	0.1s

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.

Operating time characteristics for trip and reset

This function supports definite time delay (DT). For detailed information on this delay types please refer to the chapter "General properties of a protection function" and its section "Operating time characteristics for trip and reset".

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. 5.3.7 - 63. Information displayed by the function.

Name	Range	Step	Description
f>/< condition	0: Normal 1: Start 2: Trip 3: Blocked	-	Displays the status of the protection function.
f meas/f set	0.000..20.000f_m/f_{set}	0.001f_m/f_{set}	The ratio between the measured frequency and the pick-up value.
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.

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 frequency values.

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.

Events and registers

The frequency function (abbreviated "FRQV" in event block names) generates events and registers from the status changes in START, TRIP and BLOCKED. 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 - 64. Event codes.

Event number	Event channel	Event block name	Event code	Description
6336	99	FRQV1	0	f> Start ON
6337	99	FRQV1	1	f> Start OFF
6338	99	FRQV1	2	f> Trip ON
6339	99	FRQV1	3	f> Trip OFF
6340	99	FRQV1	4	f>> Start ON
6341	99	FRQV1	5	f>> Start OFF
6342	99	FRQV1	6	f>> Trip ON
6343	99	FRQV1	7	f>> Trip OFF
6344	99	FRQV1	8	f>>> Start ON
6345	99	FRQV1	9	f>>> Start OFF
6346	99	FRQV1	10	f>>> Trip ON
6347	99	FRQV1	11	f>>> Trip OFF
6348	99	FRQV1	12	f>>>> Start ON
6349	99	FRQV1	13	f>>>> Start OFF
6350	99	FRQV1	14	f>>>> Trip ON
6351	99	FRQV1	15	f>>>> Trip OFF
6352	99	FRQV1	16	f< Start ON
6353	99	FRQV1	17	f< Start OFF
6354	99	FRQV1	18	f< Trip ON
6355	99	FRQV1	19	f< Trip OFF
6356	99	FRQV1	20	f<< Start ON
6357	99	FRQV1	21	f<< Start OFF
6358	99	FRQV1	22	f<< Trip ON
6359	99	FRQV1	23	f<< Trip OFF
6360	99	FRQV1	24	f<<< Start ON
6361	99	FRQV1	25	f<<< Start OFF
6362	99	FRQV1	26	f<<< Trip ON

Event number	Event channel	Event block name	Event code	Description
6363	99	FRQV1	27	f<<< Trip OFF
6364	99	FRQV1	28	f<<<< Start ON
6365	99	FRQV1	29	f<<<< Start OFF
6366	99	FRQV1	30	f<<<< Trip ON
6367	99	FRQV1	31	f<<<< Trip OFF
6368	99	FRQV1	32	f> Block ON
6369	99	FRQV1	33	f> Block OFF
6370	99	FRQV1	34	f>> Block ON
6371	99	FRQV1	35	f>> Block OFF
6372	99	FRQV1	36	f>>> Block ON
6373	99	FRQV1	37	f>>> Block OFF
6374	99	FRQV1	38	f>>>> Block ON
6375	99	FRQV1	39	f>>>> Block OFF
6376	99	FRQV1	40	f< Block ON
6377	99	FRQV1	41	f< Block OFF
6378	99	FRQV1	42	f<< Block ON
6379	99	FRQV1	43	f<< Block OFF
6380	99	FRQV1	44	f<<< Block ON
6381	99	FRQV1	45	f<<< Block OFF
6382	99	FRQV1	46	f<<<< Block ON
6383	99	FRQV1	47	f<<<< Block 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. 5.3.7 - 65. Register content.

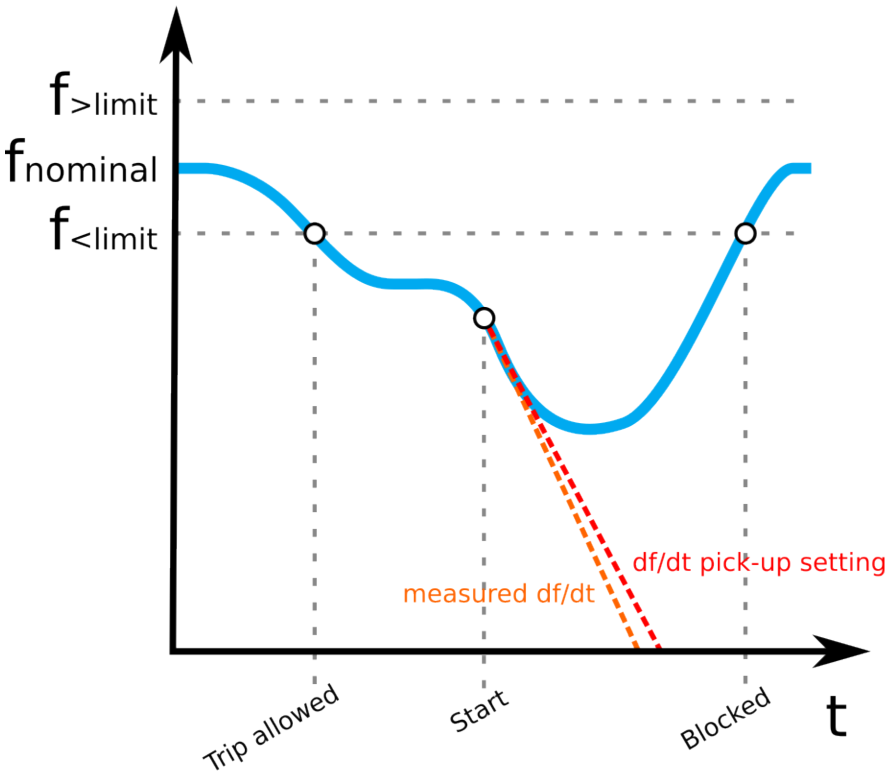
Date and time	Event code	f Pre-trig (Hz)	f Fault (Hz)	Used SG
dd.mm.yyyy hh:mm:ss.mss	6336-6383 Descr.	Start –20ms averages	Fault frequency	Setting group 1...8 active

5.3.8 Rate-of-change of frequency (df/dt>/<; 81R)

The rate-of-change of frequency function is used to detect fast drops or increases in frequency. If the load changes fast this function detects and clears the frequency-based faults faster than conventional underfrequency and overfrequency protections. One of the most common causes for the frequency to deviate from its nominal value is an unbalance between the generated power and the load demand. If the unbalance is big the frequency changes rapidly.

The rate-of-change of frequency protection can also be applied to detect a loss of mains situation. Loss of mains is a situation where a part of the network (incorporating generation) loses its connection with the rest of the system (i.e. becomes an islanded network). A generator that is not disconnected from the network can cause safety hazards. A generator can also be automatically reconnected to the network, which can cause damage to the generator and the network.

Figure. 5.3.8 - 106. Operation of the df/dt>/< function when the frequency starts but doesn't trip.



The figure above presents an example of the df/dt>/< function's operation when the frequency is decreasing. If the $f<_{limit}$ and/or $f>_{limit}$ is activated, the function does not trip no matter how fast the measured frequency changes if it's over the $f<_{limit}$ or under $f>_{limit}$. As can be seen in the figure above, when the frequency decreases under the $f<_{limit}$,tripping is allowed although the change of frequency is not yet fast enough for the function to trip. Later the frequency makes a fast dip and as a result the change of frequency is faster than the set pick-up value which then causes the relay to operate.

Each stage can be activated and deactivated individually. After the f>/< mode has been activated (*Protection → Stage activation → Frequency stages*), the user can activate and deactivate the individual stages at will (*Protection → Frequency → Frequency protection f >/< → INFO → Stage operational setup*).

The outputs of the function are the START, TRIP and BLOCKED signals. The frequency protection function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode.

The operational logic consists of the following:

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

The inputs for the function are the following:

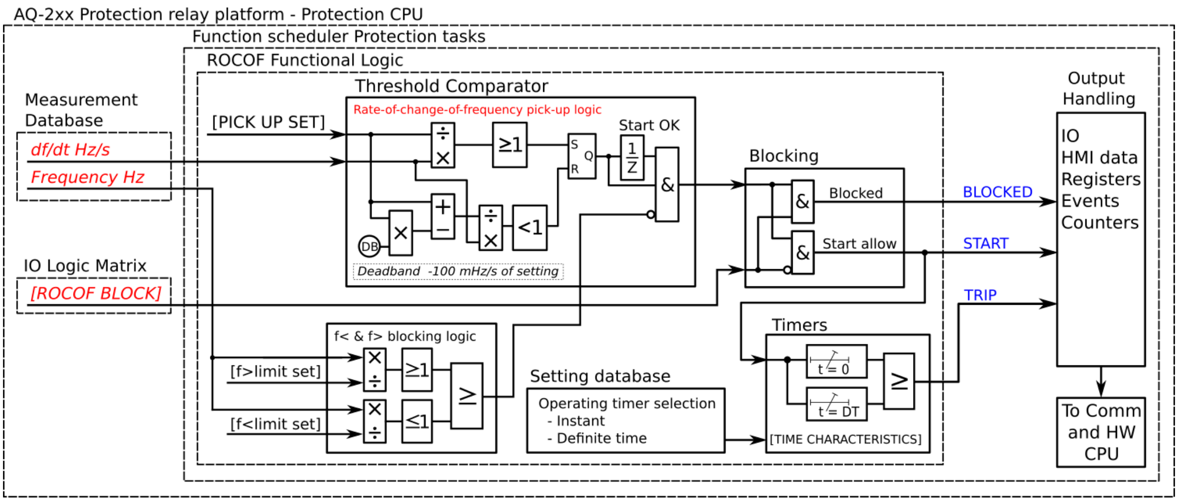
- operating mode selections
- setting parameters
- digital inputs and logic signals

- measured and pre-processed frequency magnitudes.

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signals. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the df/dt>/< function.

Figure. 5.3.8 - 107. Simplified function block diagram of the df/dt>/< function.



Measured input

The rate-of-change of frequency protection function compares the measured df/dt>/< ratio to the pick-up setting (given in Hz/s). The source of the measured frequency depends on the factory-defined tracking reference which can be checked from the *Frequency* tab of the *Measurement* menu.

Table. 5.3.8 - 66. Measurement inputs of the df/dt>/< function.

Signals	Description	Time base
VT1 U1, U2, U3	L-N voltages of the first voltage transformer	5ms
VT2 U1, U2, U3	L-N voltages of the second voltage transformer	5ms

Pick-up and time delay

The df/dt>/< (1) pick-up, df/dt>/< (2) pick-up, etc. setting parameters control the pick-up of each stage of the df/dt>/< function. They define the maximum or minimum allowed change of frequency before action from the function. The function constantly calculates the ratio between the pick-up setting and the measured df/dt>/<. The reset ratio of +/- 100 mHz/s is built into the function and is always relative to the pick-up value. The f>/< limit value is used to block the funtion from operating near the nominal frequency.

Table. 5.3.8 - 67. Pick-up settings.

Name	Description	Range	Step	Default
Max allowed df/dt rate	If df/dt rate exceeds this setting, the function is blocked.	0.10...50.00Hz/s	0.10Hz/s	20Hz/s

Name	Description	Range	Step	Default
df/dt>/< (1…8) used in setting group	Enables the protection stage in setting group.	0: No 1: Yes	-	0: No
df/dt>/< (1…8) operating mode	Defines the operation mode of the protection stage. In "Rising" mode df/dt function can trip only from increasing frequency. In "Falling" mode df/dt function can trip only from decreasing frequency. "Both" allows df/dt to trip from both.	0: Rising 1: Falling 2: Both	-	0: Rising
df/dt>/< (1…8) frequency limit	Displays if frequency limits are used or not.	0: Not used 1: Use f limit	-	0: Not used
df/dt>/< (1…8) pick-up	Pick-up setting.	0.01…10.00Hz/s	0.01Hz/s	0.2Hz/s
df/dt>/< (1…8) f< limit	Underfrequency limit. Tripping is permitted when measured frequency is under this value. This parameter is visible only when operation mode is set to "Falling" or "Both".	7.00…65.00Hz/s	0.01Hz/s	49.95Hz/s
df/dt>/< (1…8) f> limit	Overfrequency limit. Tripping is permitted if measured frequency is above this value. This parameter is visible only when operation mode is set to "Rising" or "Both".	10.00…70.00Hz/s	0.01Hz/s	51Hz/s
df/dt>/< (1…8) operating time	Operation time delay.	0.000...1800.000s	0.005s	0.1s

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.

Operating time characteristics for trip and reset

This function supports definite time delay (DT). For detailed information on this delay types please refer to the chapter "General properties of a protection function" and its section "Operating time characteristics for trip and reset".

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. 5.3.8 - 68. Information displayed by the function.

Name	Range	Step	Description
Measured df/dt	0.000...20.000Hz/s	0.001Hz/s	Rate-of-change-of-frequency at the moment.
df/dt >/< (1...8) condition	0: Normal 1: Start 2: Trip 3: Blocked	-	Displays the status of the protection function.
df/dt >/< (1...8) df/dt meas / df/dt set	0.000...20.000p.u.	0.005p.u.	The ratio between the rate-of-change-of-frequency and the pick-up value.
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.

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 frequency values.

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.

Events and registers

The rate-of-change of frequency function (abbreviated "DFT" in event block names) generates events and registers from the status changes in START, TRIP and BLOCKED. 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 - 69. Event codes.

Event number	Event channel	Event block name	Event code	Description
6592	103	DFT1	0	df/dt>/< (1) Start ON
6593	103	DFT1	1	df/dt>/< (1) Start OFF
6594	103	DFT1	2	df/dt>/< (1) Trip ON
6595	103	DFT1	3	df/dt>/< (1) Trip OFF
6596	103	DFT1	4	df/dt>/< (2) Start ON
6597	103	DFT1	5	df/dt>/< (2) Start OFF
6598	103	DFT1	6	df/dt>/< (2) Trip ON
6599	103	DFT1	7	df/dt>/< (2) Trip OFF
6600	103	DFT1	8	df/dt>/< (3) Start ON
6601	103	DFT1	9	df/dt>/< (3) Start OFF
6602	103	DFT1	10	df/dt>/< (3) Trip ON
6603	103	DFT1	11	df/dt>/< (3) Trip OFF
6604	103	DFT1	12	df/dt>/< (4) Start ON
6605	103	DFT1	13	df/dt>/< (4) Start OFF
6606	103	DFT1	14	df/dt>/< (4) Trip ON
6607	103	DFT1	15	df/dt>/< (4) Trip OFF
6608	103	DFT1	16	df/dt>/< (5) Start ON

Event number	Event channel	Event block name	Event code	Description
6609	103	DFT1	17	df/dt>/< (5) Start OFF
6610	103	DFT1	18	df/dt>/< (5) Trip ON
6611	103	DFT1	19	df/dt>/< (5) Trip OFF
6612	103	DFT1	20	df/dt>/< (6) Start ON
6613	103	DFT1	21	df/dt>/< (6) Start OFF
6614	103	DFT1	22	df/dt>/< (6) Trip ON
6615	103	DFT1	23	df/dt>/< (6) Trip OFF
6616	103	DFT1	24	df/dt>/< (7) Start ON
6617	103	DFT1	25	df/dt>/< (7) Start OFF
6618	103	DFT1	26	df/dt>/< (7) Trip ON
6619	103	DFT1	27	df/dt>/< (7) Trip OFF
6620	103	DFT1	28	df/dt>/< (8) Start ON
6621	103	DFT1	29	df/dt>/< (8) Start OFF
6622	103	DFT1	30	df/dt>/< (8) Trip ON
6623	103	DFT1	31	df/dt>/< (8) Trip OFF
6624	103	DFT1	32	df/dt>/< (1) Block ON
6625	103	DFT1	33	df/dt>/< (1) Block OFF
6626	103	DFT1	34	df/dt>/< (2) Block ON
6627	103	DFT1	35	df/dt>/< (2) Block OFF
6628	103	DFT1	36	df/dt>/< (3) Block ON
6629	103	DFT1	37	df/dt>/< (3) Block OFF
6630	103	DFT1	38	df/dt>/< (4) Block ON
6631	103	DFT1	39	df/dt>/< (4) Block OFF
6632	103	DFT1	40	df/dt>/< (5) Block ON
6633	103	DFT1	41	df/dt>/< (5) Block OFF
6634	103	DFT1	42	df/dt>/< (6) Block ON
6635	103	DFT1	43	df/dt>/< (6) Block OFF
6636	103	DFT1	44	df/dt>/< (7) Block ON
6637	103	DFT1	45	df/dt>/< (7) Block OFF
6638	103	DFT1	46	df/dt>/< (8) Block ON
6639	103	DFT1	47	df/dt>/< (8) Block 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.

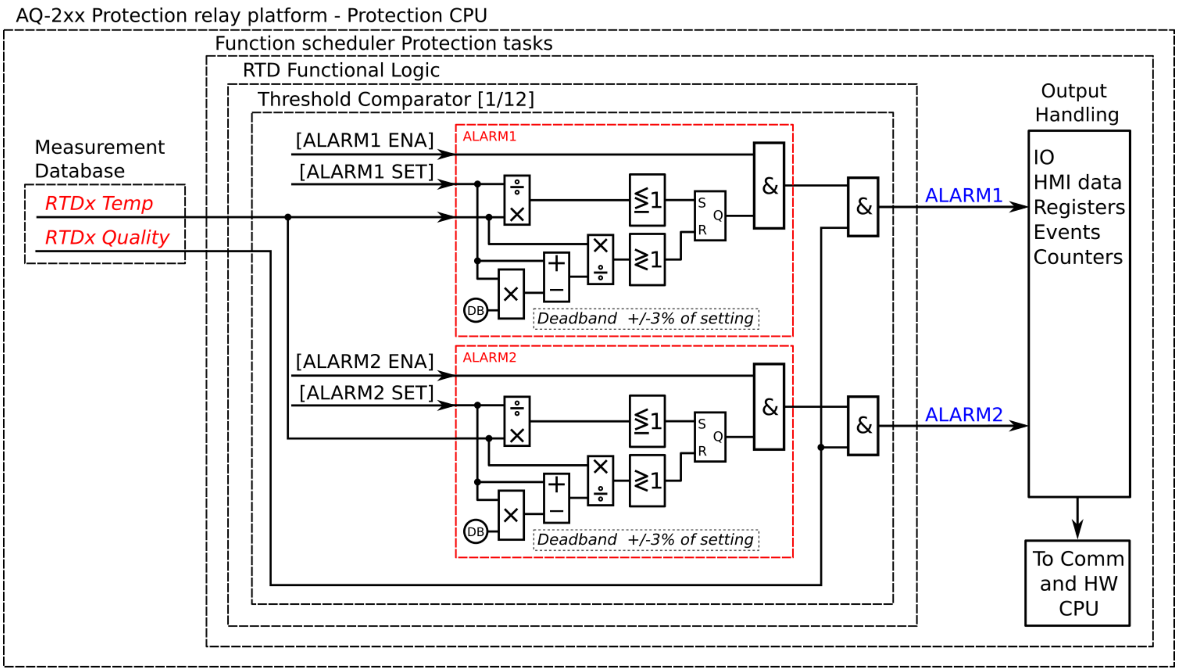
Table. 5.3.8 - 70. Register content.

Date and time	Event code	df/dt>/< Pre-trig (Hz/s)	f Pre-trig (Hz)	df/dt>/< Fault (Hz/s)	f Fault (Hz)	Used SG
dd.mm.yyyy hh:mm:ss.mss	6592-6639 Descr.	Start –20ms averages	Start –20ms averages	Fault df/dt>/<	Fault frequency	Setting groups 1...8 active

5.3.9 Resistance temperature detectors

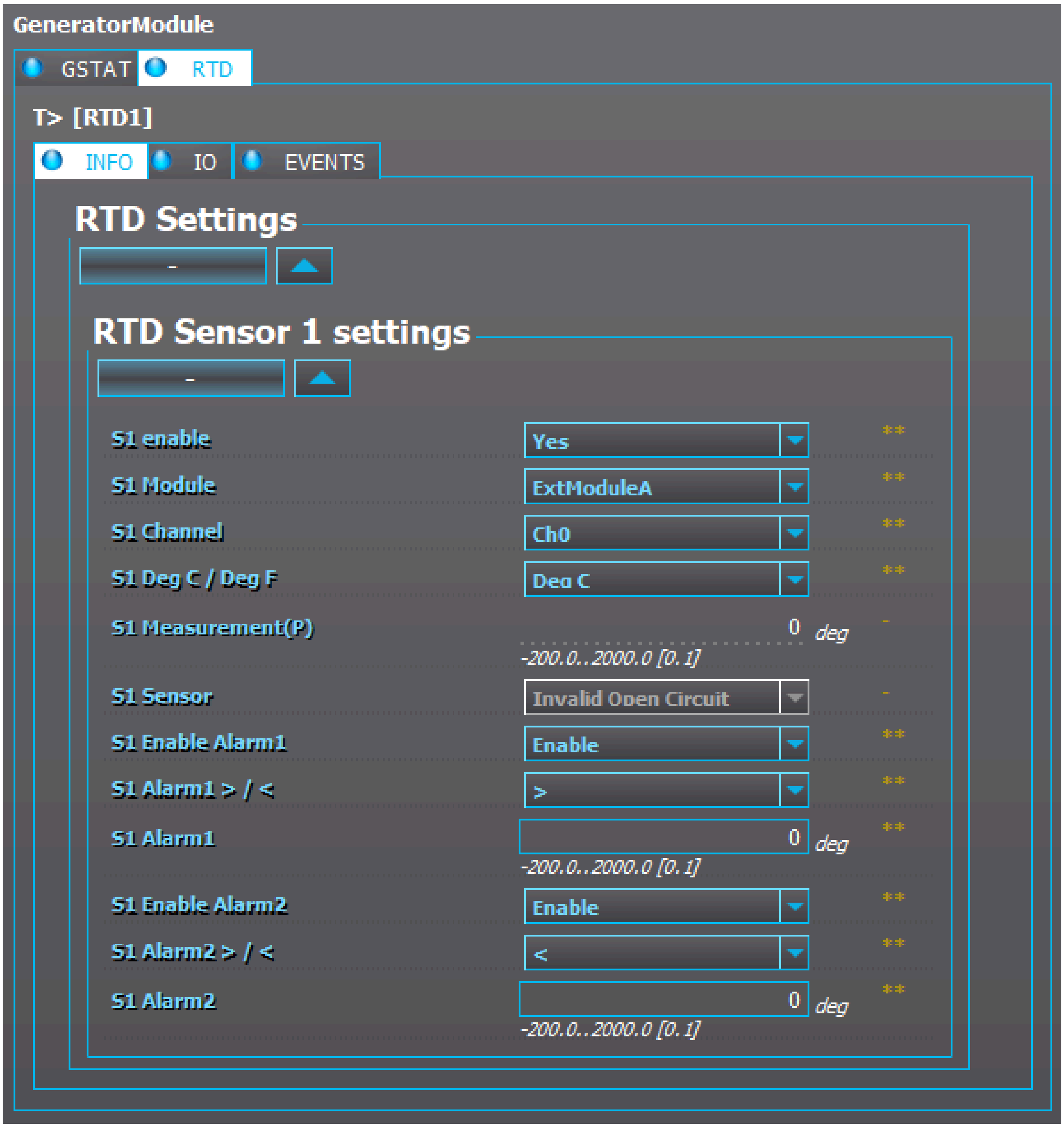
Resistance temperature detectors (or RTDs) can be used to measure both temperatures of motors/generators and ambient temperatures. Typically an RTD is a thermocouple or of type PT100. Up to three (3) separate RTD modules based on an external Modbus are supported; each can hold up to eight (8) measurement elements. Up to two (2) separate RTD option cards are supported by this function. Sixteen (16) individual element monitors can be set for this alarm function, and each of those can be set to alarm two (2) separate alarms from one selected input. The user can set alarms and measurements to be either in degrees Celsius or Fahrenheit.

The following figure shows the principal structure of the resistance temperature detection function.



Setting up an RTD measurement, the user first needs to set the measurement module to scan the wanted RTD elements. A multitude of Modbus-based modules are supported. Communication requires bitrate, databits, parity, stopbits and Modbus I/O protocol to be set; this is done at *Communication → Connections*. Once communication is set, the wanted channels are selected at *Communication → Protocols → ModbusIO*. Then the user selects the measurement module from the three (3) available modules (A, B and C), as well as the poll address. Additionally, both the module type and the polled channels need to be set. When using a thermocouple module, the thermo element type also needs to be set for each of the measurement channels. Once these settings are done the RTDs are ready for other functions.

Figure. 5.3.9 - 108. RTD alarm setup.



Function can be set to monitor the measurement data from previously set RTD channels. A single channel can be set to have several alarms if the user sets the channel to multiple sensor inputs. In each sensor setting the user can select the monitored module and channel, as well as the monitoring and alarm setting units (°C or °F). The alarms can be enabled, given a setting value (in degrees), and be set to trigger either above or below the setting value. There are sixteen (16) available sensor inputs in the function. An active alarm requires a valid channel measurement. It can be invalid if communication is not working or if a sensor is broken.

Settings

Table. 5.3.9 - 71. Function settings for Channel x (Sx).

Name	Range	Step	Default	Description
S1...S16 enable	0: No 1: Yes	-	0: No	Enables/disables the selecion of sensor measurements and alarms.

Name	Range	Step	Default	Description
S1...S16 module	0: InternalRTD1 1: InternalRTD2 2: ExtModuleA 3: ExtModuleB 4: ExtModuleC	-	0: InternalRTD1	Selects the measurement module. Internal RTD modules are option cards installed to the relay. External modules are Modbus based external devices.
S1...S16 channel	0: Channel 0 1: Channel 1 3: Channel 2 4: Channel 3 5: Channel 4 6: Channel 5 7: Channel 6 8: Channel 7	-	0: Channel 0	Selects the measurement channel in the selected module.
S1...S16 Deg C/Dec F	0: Deg C 1: Deg F	-	0: Deg C	Selects the measurement temperature scale (Celsius or Fahrenheit).
S1...S16 Measurement	-	-	-	Displays the measurement value in the selected temperature scale.
S1...S16 Sensor	0: Ok 1: Invalid	-	-	Displays the measured sensor's data validity. If the sensor reading has any problems, the sensor data is set to "Invalid" and the alarms are not activated.
S1...S16 Enable alarm 1	0: Disable 1: Enable	-	0: Disable	Enables/disables the selection of Alarm 1 for the measurement channel x.
S1...S16 Alarm1 >/<	0: > 1: <	-	0: >	Selects whether the alarm activates when measurement is above or below the pick-up setting value.
S1...S16 Alarm1	-101.0…2000.0deg	0.1deg	0.0deg	Sets the pick-up value for Alarm 1. The alarm is activated if the measurement goes above or below this setting mode (depends on the selected mode in "Sx Alarm1 >/<").
S1...S16 sensor	0: Ok 1: Invalid	-	-	Displays the measured sensor's data validity. If the sensor reading has any problems, the sensor data is set to "Invalid" and the alarms are not activated.
S1...S16 Enable alarm 2	0: Disable 1: Enable	-	0: Disable	Enables/disables the selection of Alarm 2 for the measurement channel x.
S1...S16 Alarm2 >/<	0: > 1: <	-	0: >	Selects whether the measurement is above or below the setting value.
S1...S16 Alarm2	-101.0…2000.0deg	0.1deg	0.0deg	Sets the value for Alarm 2. The alarm is activated if the measurement goes above or below this setting mode (depends on the selected mode in "Sx Alarm2 >/<").

When the RTDs have been set, the values can be read to SCADA (or some other control system). The alarms can also be used for direct output control as well as in logics.

Events

The resistance temperature detector function (abbreviated "RTD" in event block names) generates events and registers from the status changes in ALARM and MEAS INVALID. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers sixteen (16) independent stages; the events are segregated for each stage operation.

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

Table. 5.3.9 - 72. Event codes.

Event number	Event channel	Event block name	Event code	Description
4416	69	RTD1	0	S1 Alarm1 ON
4417	69	RTD1	1	S1 Alarm1 OFF
4418	69	RTD1	2	S1 Alarm2 ON
4419	69	RTD1	3	S1 Alarm2 OFF
4420	69	RTD1	4	S2 Alarm1 ON
4421	69	RTD1	5	S2 Alarm1 OFF
4422	69	RTD1	6	S2 Alarm2 ON
4423	69	RTD1	7	S2 Alarm2 OFF
4424	69	RTD1	8	S3 Alarm1 ON
4425	69	RTD1	9	S3 Alarm1 OFF
4426	69	RTD1	10	S3 Alarm2 ON
4427	69	RTD1	11	S3 Alarm2 OFF
4428	69	RTD1	12	S4 Alarm1 ON
4429	69	RTD1	13	S4 Alarm1 OFF
4430	69	RTD1	14	S4 Alarm2 ON
4431	69	RTD1	15	S4 Alarm2 OFF
4432	69	RTD1	16	S5 Alarm1 ON
4433	69	RTD1	17	S5 Alarm1 OFF
4434	69	RTD1	18	S5 Alarm2 ON
4435	69	RTD1	19	S5 Alarm2 OFF
4436	69	RTD1	20	S6 Alarm1 ON
4437	69	RTD1	21	S6 Alarm1 OFF
4438	69	RTD1	22	S6 Alarm2 ON
4439	69	RTD1	23	S6 Alarm2 OFF
4440	69	RTD1	24	S7 Alarm1 ON
4441	69	RTD1	25	S7 Alarm1 OFF
4442	69	RTD1	26	S7 Alarm2 ON
4443	69	RTD1	27	S7 Alarm2 OFF
4444	69	RTD1	28	S8 Alarm1 ON
4445	69	RTD1	29	S8 Alarm1 OFF
4446	69	RTD1	30	S8 Alarm2 ON
4447	69	RTD1	31	S8 Alarm2 OFF
4448	69	RTD1	32	S9 Alarm1 ON
4449	69	RTD1	33	S9 Alarm1 OFF
4450	69	RTD1	34	S9 Alarm2 ON
4451	69	RTD1	35	S9 Alarm2 OFF
4452	69	RTD1	36	S10 Alarm1 ON

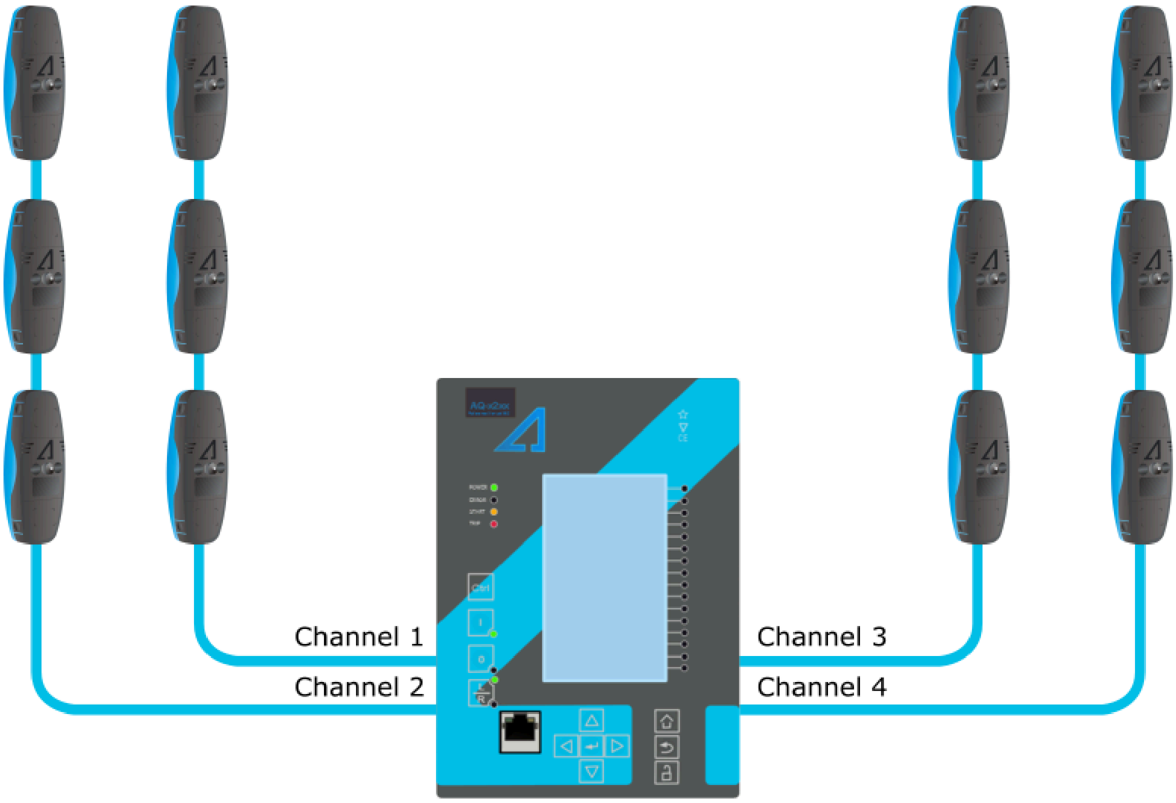
Event number	Event channel	Event block name	Event code	Description
4453	69	RTD1	37	S10 Alarm1 OFF
4454	69	RTD1	38	S10 Alarm2 ON
4455	69	RTD1	39	S10 Alarm2 OFF
4456	69	RTD1	40	S11 Alarm1 ON
4457	69	RTD1	41	S11 Alarm1 OFF
4458	69	RTD1	42	S11 Alarm2 ON
4459	69	RTD1	43	S11 Alarm2 OFF
4460	69	RTD1	44	S12 Alarm1 ON
4461	69	RTD1	45	S12 Alarm1 OFF
4462	69	RTD1	46	S12 Alarm2 ON
4463	69	RTD1	47	S12 Alarm2 OFF
4464	69	RTD1	48	S13 Alarm1 ON
4465	69	RTD1	49	S13 Alarm1 OFF
4466	69	RTD1	50	S13 Alarm2 ON
4467	69	RTD1	51	S13 Alarm2 OFF
4468	69	RTD1	52	S14 Alarm1 ON
4469	69	RTD1	53	S14 Alarm1 OFF
4470	69	RTD1	54	S14 Alarm2 ON
4471	69	RTD1	55	S14 Alarm2 OFF
4472	69	RTD1	56	S15 Alarm1 ON
4473	69	RTD1	57	S15 Alarm1 OFF
4474	69	RTD1	58	S15 Alarm2 ON
4475	69	RTD1	59	S15 Alarm2 OFF
4476	69	RTD1	60	S16 Alarm1 ON
4477	69	RTD1	61	S16 Alarm1 OFF
4478	69	RTD1	62	S16 Alarm2 ON
4479	69	RTD1	63	S16 Alarm2 OFF
4480	70	RTD2	0	S1 Meas Ok
4481	70	RTD2	1	S1 Meas Invalid
4482	70	RTD2	2	S2 Meas Ok
4483	70	RTD2	3	S2 Meas Invalid
4484	70	RTD2	4	S3 Meas Ok
4485	70	RTD2	5	S3 Meas Invalid
4486	70	RTD2	6	S4 Meas Ok
4487	70	RTD2	7	S4 Meas Invalid
4488	70	RTD2	8	S5 Meas Ok
4489	70	RTD2	9	S5 Meas Invalid
4490	70	RTD2	10	S6 Meas Ok

Event number	Event channel	Event block name	Event code	Description
4491	70	RTD2	11	S6 Meas Invalid
4492	70	RTD2	12	S7 Meas Ok
4493	70	RTD2	13	S7 Meas Invalid
4494	70	RTD2	14	S8 Meas Ok
4495	70	RTD2	15	S8 Meas Invalid
4496	70	RTD2	16	S9 Meas Ok
4497	70	RTD2	17	S9 Meas Invalid
4498	70	RTD2	18	S10 Meas Ok
4499	70	RTD2	19	S10 Meas Invalid
4500	70	RTD2	20	S11 Meas Ok
4501	70	RTD2	21	S11 Meas Invalid
4502	70	RTD2	22	S12 Meas Ok
4503	70	RTD2	23	S12 Meas Invalid
4504	70	RTD2	24	S13 Meas Ok
4505	70	RTD2	25	S13 Meas Invalid
4506	70	RTD2	26	S14 Meas Ok
4507	70	RTD2	27	S14 Meas Invalid
4508	70	RTD2	28	S15 Meas Ok
4509	70	RTD2	29	S15 Meas Invalid
4510	70	RTD2	30	S16 Meas Ok
4511	70	RTD2	31	S16 Meas Invalid

5.3.10 Arc fault protection (IArc>/I0Arc>; 50Arc/50NArc)

Arc faults occur for a multitude of reasons: e.g. insulation failure, incorrect operation of the protected device, corrosion, overvoltage, dirt, moisture, incorrect wiring, or even because of aging caused by electric load. It is important to detect the arc as fast as possible in order to minimize its effects. Using arc sensors to detect arc faults is much faster than merely measuring currents and voltages. In busbar protection IEDs with normal protection can be too slow to disconnect arcs within a safe time frame. For example, it may be necessary to delay operation time for hundreds of milliseconds when setting up an overcurrent protection relay to control the feeder breakers to achieve selectivity. This delay can be avoided by using arc protection. The arc protection card has a high-speed output to trip signals faster as well as to extend the speed of arc protection.

Figure. 5.3.10 - 109. IED equipped with arc protection.



The arc protection card has four (4) sensor channels, and up to three (3) arc point sensors can be connected to each channel. The sensor channels support Arcteq AQ-01 (light sensing) and AQ-02 (pressure and light sensing) units. Optionally, the protection function can also be applied with a phase current or a residual current condition: the function trips only if the light and overcurrent conditions are met.

The outputs of the function are the following:

- Light In
- Pressure In
- Arc binary input signal status
- Zone trip
- Zone blocked
- Sensor fault signals.

The arc protection function uses a total of eight (8) separate setting groups which can be selected from one common source.

Table. 5.3.10 - 73. Output signals of the IArc>/I0Arc> function.

Outputs	Activation condition
Channel 1 Light In Channel 2 Light In Channel 3 Light In Channel 4 Light In	The arc protection card's sensor channel detects light.
Channel 1 Pressure In Channel 2 Pressure In Channel 3 Pressure In Channel 4 Pressure In	The arc protection card's sensor channel detects pressure.
ARC Binary input signal	The arc protection card's binary input is energized.

Outputs	Activation condition
I/I0 Arc> Ph. curr. START I/I0 Arc> Res. curr. START	The measured phase current or the residual current is over the set limit.
I/I0 Arc> Ph. curr. BLOCKED I/I0 Arc> Res. curr. BLOCKED	The phase current or the residual current measurement is blocked by an input.
I/I0 Arc> Zone 1 TRIP I/I0 Arc> Zone 2 TRIP I/I0 Arc> Zone 3 TRIP I/I0 Arc> Zone 4 TRIP	All required conditions for tripping the zone are met (light OR light and current).
I/I0 Arc> Zone 1 BLOCKED I/I0 Arc> Zone 2 BLOCKED I/I0 Arc> Zone 3 BLOCKED I/I0 Arc> Zone 4 BLOCKED	All required conditions for tripping the zone are met (light OR light and current) but the tripping is blocked by an input.
I/I0 Arc> S1 Sensor fault I/I0 Arc> S2 Sensor fault I/I0 Arc> S3 Sensor fault I/I0 Arc> S4 Sensor fault	The detected number of sensors in the channel does not match the settings.
I/I0 Arc> IO unit fault	The number of connected AQ-100 series units does not match the number of units set in the settings.

The operational logic consists of the following:

- input magnitude selection
- input magnitude processing
- threshold comparator
- two block signal checks
- 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.

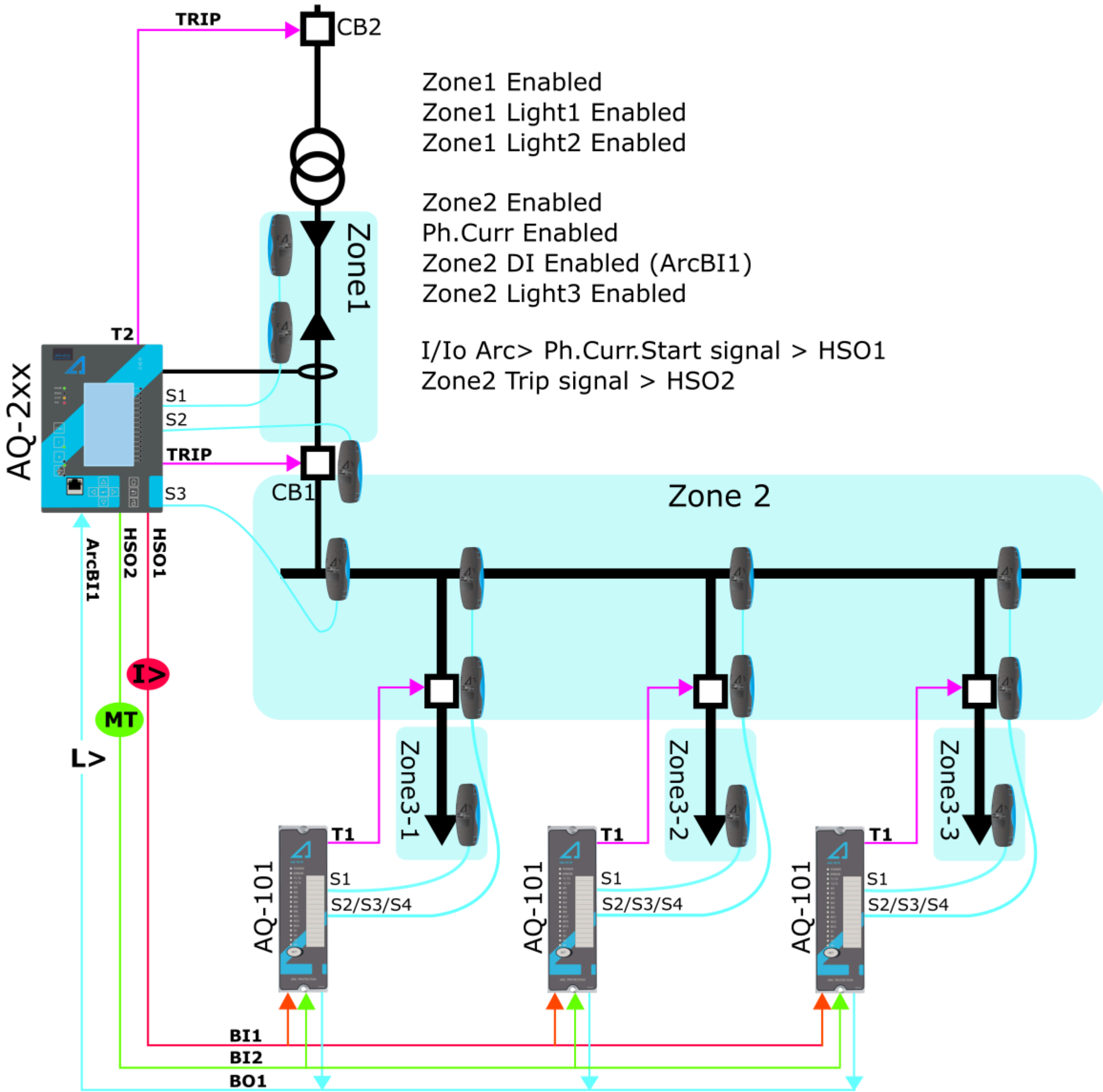
The function outputs the TRIP, BLOCKED, light sensing etc. signals which can be used for direct I/O controlling and user logic programming. The function generates general time-stamped ON/OFF events to the common event buffer from each of the 26 output signals. The time stamp resolution is 1 ms. The function also a resettable cumulative counter for the TRIP and BLOCKED events for each zone.

Example of scheme setting

The following examples helps the user better understand how the arc protection function is set. In the examples AQ-101 models are used to extend the protection of Zone 2 and to protect each outgoing feeder (Zone 3).

Scheme IA1 is a single-line diagram with AQ-2xx series relays and with AQ-101 arc protection relays. The settings are for an incomer AQ-200 relay.

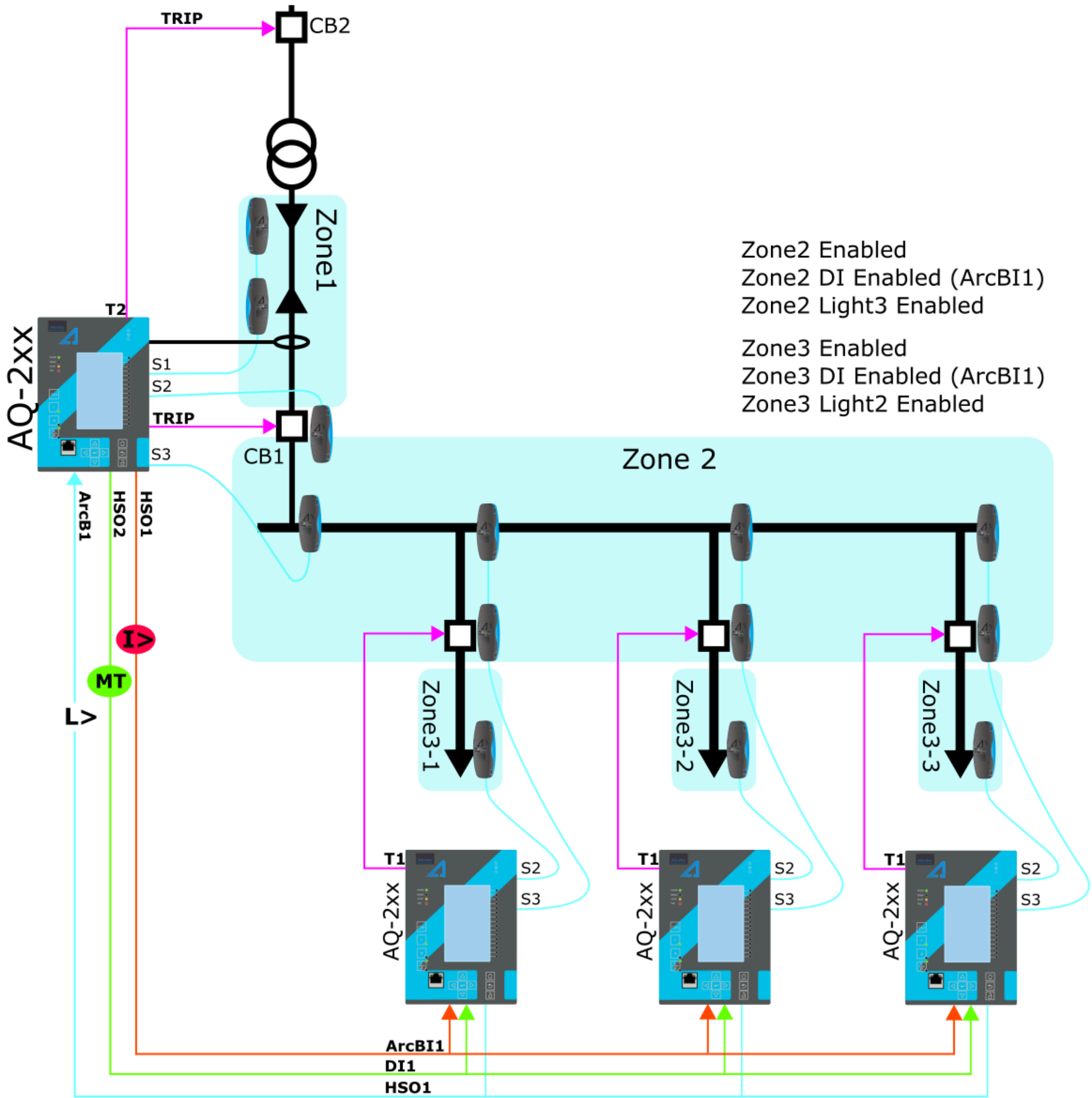
Figure. 5.3.10 - 110. Scheme IA1 (with AQ-101 arc protection relays).



To set the zones for the AQ-2xx models sensor channels start by enabling the protected zones (in this case, Zones 1 and 2). Then define which sensor channels are sensing which zones (in this case, sensor channels S1 and S2 are protecting Zone 1). Enable Light 1 of Zone 1 as well as Light 2 of Zone 2. The sensor channel S3 deals with Zone 2. Enable Light 3 of Zone 2. The high-speed output contacts HSO1 and HSO2 have been set to send overcurrent and master trip signals to the AQ-101 arc protection relays. The AQ-100 series units send out test pulses in specific intervals to check the health of the wiring between the AQ-100 series units. The parameter *I/I0 Arc> Self supervision test pulse* should be activated when connecting the AQ-100 series units to the AQ-200 series arc protection card to prevent the pulses from activating ArcBI1.

The next example is almost like the previous one: it is also a single-line diagram with AQ-2xx series relays. However, this time each outgoing feeder has an AQ-2xx protection relay instead of an AQ-101 arc protection relay.

Figure. 5.3.10 - 111. Scheme IA1 (with AQ-200 protection relays).



The settings for the relay supervising the incoming feeder are the same as in the first example. The relays supervising the busbar and the outgoing feeder, however, have a different setting. Both Zones 2 and 3 need to be enabled as there are sensors connected to both Zone 2 and 3 starts. Sensors connected to the channel S3 are in Zone 2. Then enable Light 3 of Zone 2. The sensor connected to the channel S2 is in Zone 3. Then enable Light 2 of Zone 3.

If any of the channels have a pressure sensing sensor, enable it the same way as the regular light sensors. If either phase overcurrent or residual overcurrent is needed for the tripping decision, they can be enabled in the same way as light sensors in the zone. When a current channel is enabled, the measured current needs to be above the set current limit in addition to light sensing.

Measured input

Arc protection uses samples based on current measurements. If the required number of samples is found to be above the setting limit, the current condition activates. The arc protection can alternatively use either phase currents or residual currents in the tripping decision.

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. 5.3.10 - 74. General settings of the function.

Name	Description	Range	Step	Default
Channel 1 sensors Channel 2 sensors Channel 3 sensors Channel 4 sensors	Defines the amount of sensors connected to channel 1/2/3/4.	0: No sensors 1: 1 sensor 2: 2 sensors 3: 3 sensors	-	1: No sensors
Channel 1 sensor status Channel 2 sensor status Channel 3 sensor status Channel 4 sensor status	Displays the status of the sensor channel. If amount of sensors connected to the channel don't match with "Channel 1/2/3/4 sensors" setting, this parameter will go to "Configuration fault" state.	0: Sensors OK 1: Configuration fault state	-	-

Pick-up

The pick-up of each zone of the Iarc>/I0arc> function is controlled by one of the following: the phase current pick-up setting, the residual current pick-up setting, or the sensor channels. The pick-up setting depends on which of these are activated in the zone.

Table. 5.3.10 - 75. Enabled Zone pick-up settings.

Name	Description	Range	Step	Default
Phase current pick-up	The phase current measurement's pick-up value (in p.u.).	0.05...40.00 x I_n	0.01 x I_n	1.2 x I_n
I0 input selection	Selects the residual current channel (I01 or I02).	0: None 1: I01 2: I02	-	0: None
Res.current pick-up	The residual current measurement's pick-up value (in p.u.).	0.05...40.00 x I_{0n}	0.01 x I_{0n}	1.2 x I_{0n}
Zone1/2/3/4 Enabled	Enables the chosen zone. Up to 4 zones can be enabled.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Ph. curr. Enabled	The phase overcurrent allows the zone to trip when light is detected.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Res. curr. Enabled	The residual overcurrent allows the zone to trip when light is detected.	0: Disabled 1: Enabled	-	0: Disabled

Name	Description	Range	Step	Default
Zone1/2/3/4 Light 1 Enabled	Light detected in sensor channel 1 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Light 2 Enabled	Light detected in sensor channel 2 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Light 3 Enabled	Light detected in sensor channel 3 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Light 4 Enabled	Light detected in sensor channel 4 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Pres. 1 Enabled	Pressure detected in sensor channel 1 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Pres. 2 Enabled	Pressure detected in sensor channel 2 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Pres. 3 Enabled	Pressure detected in sensor channel 3 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 Pres. 4 Enabled	Pressure detected in sensor channel 4 trips the zone.	0: Disabled 1: Enabled	-	0: Disabled
Zone1/2/3/4 DI Enabled	Arc protection option card digital input has to be active for the zone to trip.	0: Disabled 1: Enabled	-	0: Disabled

The pick-up activation of the function is not directly equal to the TRIP signal generation of the function. The TRIP 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. 5.3.10 - 76. Information displayed by the function.

Name	Range	Step	Description
I/I0 Arc> condition	0: Z1 Trip 1: Z1 Blocked 2: Z2 Trip 3: Z2 Blocked 4: Z3 Trip 5: Z3 Blocked 6: Z4 Trip 7:Z4 Blocked	-	Displays status of the protection function.
Sensor status	0: Ph Curr Blocked 1: Ph Curr Start 2: Res Curr Blocked 3: Res Curr Start 4: Channel1 Light 5: Channel1 Pressure 6: Channel2 Light 7: Channel2 Pressure 8: Channel3 Light 9: Channel3 Pressure 10: Channel4 Ligh t11: Channel4 Pressure 12: Digital input 13: I/I0 Arc> Sensor 1 Fault 14: I/I0 Arc> Sensor 2 Fault 15: I/I0 Arc> Sensor 3 Fault 16: I/I0 Arc> Sensor 4 Fault 17: I/I0 Arc> I/O-unit Fault	-	Displays the general status of sensors.

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 TRIP signal is generated.

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.

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.

Events and registers

The arc fault protection function (abbreviated "ARC" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. 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. 5.3.10 - 77. Event codes.

Event number	Event channel	Event block name	Event code	Description
4736	74	ARC1	0	Zone 1 Trip ON
4737	74	ARC1	1	Zone 1 Trip OFF
4738	74	ARC1	2	Zone 1 Block ON
4739	74	ARC1	3	Zone 1 Block OFF
4740	74	ARC1	4	Zone 2 Trip ON
4741	74	ARC1	5	Zone 2 Trip OFF
4742	74	ARC1	6	Zone 2 Block ON
4743	74	ARC1	7	Zone 2 Block OFF
4744	74	ARC1	8	Zone 3 Trip ON
4745	74	ARC1	9	Zone 3 Trip OFF
4746	74	ARC1	10	Zone 3 Block ON
4747	74	ARC1	11	Zone 3 Block OFF
4748	74	ARC1	12	Zone 4 Trip ON
4749	74	ARC1	13	Zone 4 Trip OFF
4750	74	ARC1	14	Zone 4 Block ON
4751	74	ARC1	15	Zone 4 Block OFF
4752	74	ARC1	16	Phase current Blocked ON
4753	74	ARC1	17	Phase current Blocked OFF
4754	74	ARC1	18	Phase current Start ON

Event number	Event channel	Event block name	Event code	Description
4755	74	ARC1	19	Phase current Start OFF
4756	74	ARC1	20	Residual current Blocked ON
4757	74	ARC1	21	Residual current Blocked OFF
4758	74	ARC1	22	Residual current Start ON
4759	74	ARC1	23	Residual current Start OFF
4760	74	ARC1	24	Channel 1 Light ON
4761	74	ARC1	25	Channel 1 Light OFF
4762	74	ARC1	26	Channel 1 Pressure ON
4763	74	ARC1	27	Channel 1 Pressure OFF
4764	74	ARC1	28	Channel 2 Light ON
4765	74	ARC1	29	Channel 2 Light OFF
4766	74	ARC1	30	Channel 2 Pressure ON
4767	74	ARC1	31	Channel 2 Pressure OFF
4768	74	ARC1	32	Channel 3 Light ON
4769	74	ARC1	33	Channel 3 Light OFF
4770	74	ARC1	34	Channel 3 Pressure ON
4771	74	ARC1	35	Channel 3 Pressure OFF
4772	74	ARC1	36	Channel 4 Light ON
4773	74	ARC1	37	Channel 4 Light OFF
4774	74	ARC1	38	Channel 4 Pressure ON
4775	74	ARC1	39	Channel 4 Pressure OFF
4776	74	ARC1	40	DI Signal ON
4777	74	ARC1	41	DI Signal OFF
4778	74	ARC1	42	I/I0 Arc> Sensor 1 Fault ON
4779	74	ARC1	43	I/I0 Arc> Sensor 1 Fault OFF
4780	74	ARC1	44	I/I0 Arc> Sensor 2 Fault ON
4781	74	ARC1	45	I/I0 Arc> Sensor 2 Fault OFF
4782	74	ARC1	46	I/I0 Arc> Sensor 3 Fault ON
4783	74	ARC1	47	I/I0 Arc> Sensor 3 Fault OFF
4784	74	ARC1	48	I/I0 Arc> Sensor 4 Fault ON
4785	74	ARC1	49	I/I0 Arc> Sensor 4 Fault OFF
4786	74	ARC1	50	I/I0 Arc> I/O-unit Fault ON
4787	74	ARC1	51	I/I0 Arc> I/O-unit Fault 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. 5.3.10 - 78. Register content.

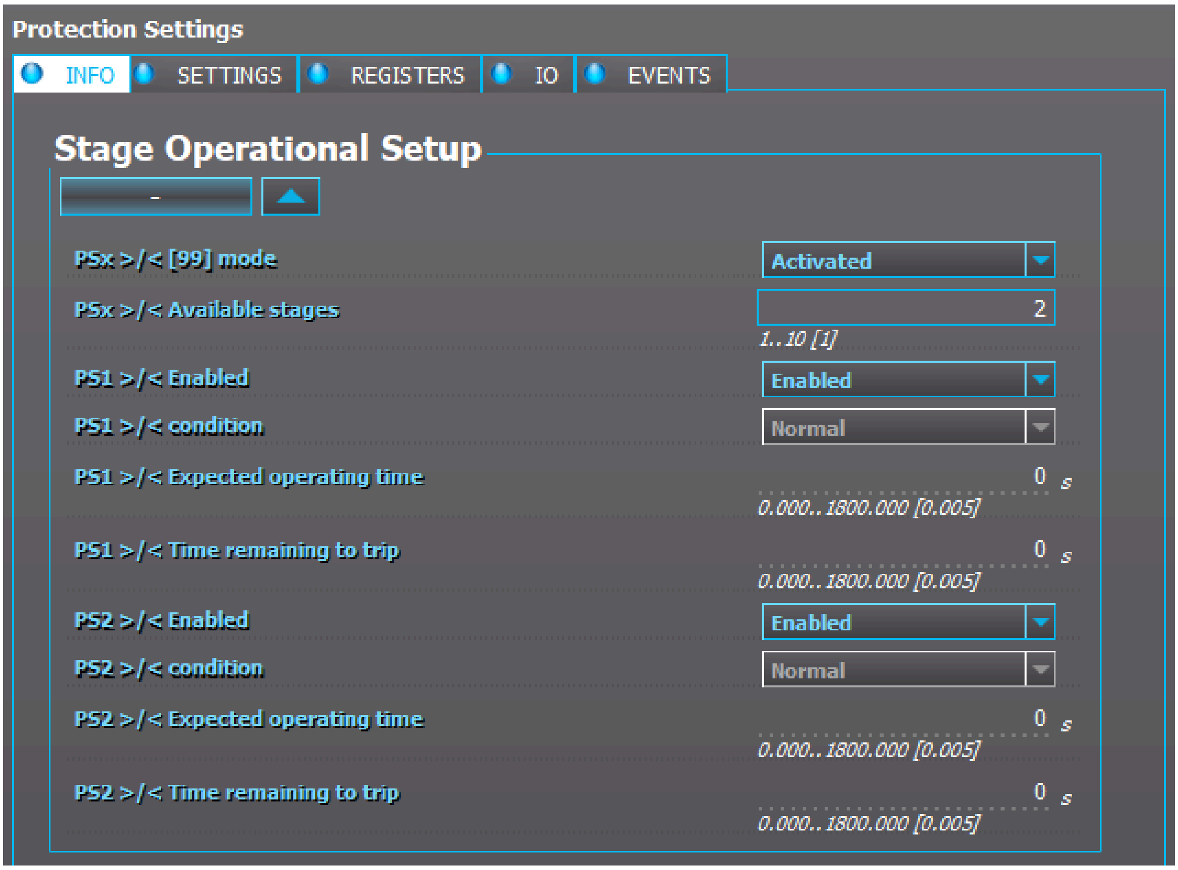
Date and time	Event code	Phase A current	Phase B current	Phase C current	Residual current	Active sensors	Used SG
dd.mm.yyyy hh:mm:ss.mss	4736-4787 Descr.	Trip -20ms averages	Trip -20ms averages	Trip -20ms averages	Trip -20ms averages	1...4	Setting group 1...8 active

5.3.11 Programmable stage (PGx>/<; 99)

The programmable stage is a stage that the user can program to create more advanced applications, either as an individual stage or together with programmable logic. The relay has ten programmable stages, and each can be set to follow one to three analog measurements. The programmable stages have three available pick up terms options: overX, underX and rate-of-change of the selected signal. Each stage includes a definite time delay to trip after a pick-up has been triggered.

The programmable stage cycle time is 5 ms. The pick-up delay depends on which analog signal is used as well as its refresh rate (typically under a cycle in a 50 Hz system).

The number of programmable stages to be used is set in the *INFO* tab. When this function has been set as "Activated", the number of programmable stages can be set anywhere between one (1) and ten (10) depending on how many the application needs. In the image below, the number of programmable stages have been set to two which makes PS1 and PS2 to appear. Inactive stages are hidden until they are activated.



Please note that setting the number of available stages does not activate those stages, as they also need to be enabled individually with the *PSx >/< Enabled* parameter. When enabled an active stage shows its current state (condition), the expected operating time and the time remaining to trip under the activation parameters. If a stage is not active the *PSx>/< condition* parameter will merely display “Disabled”.

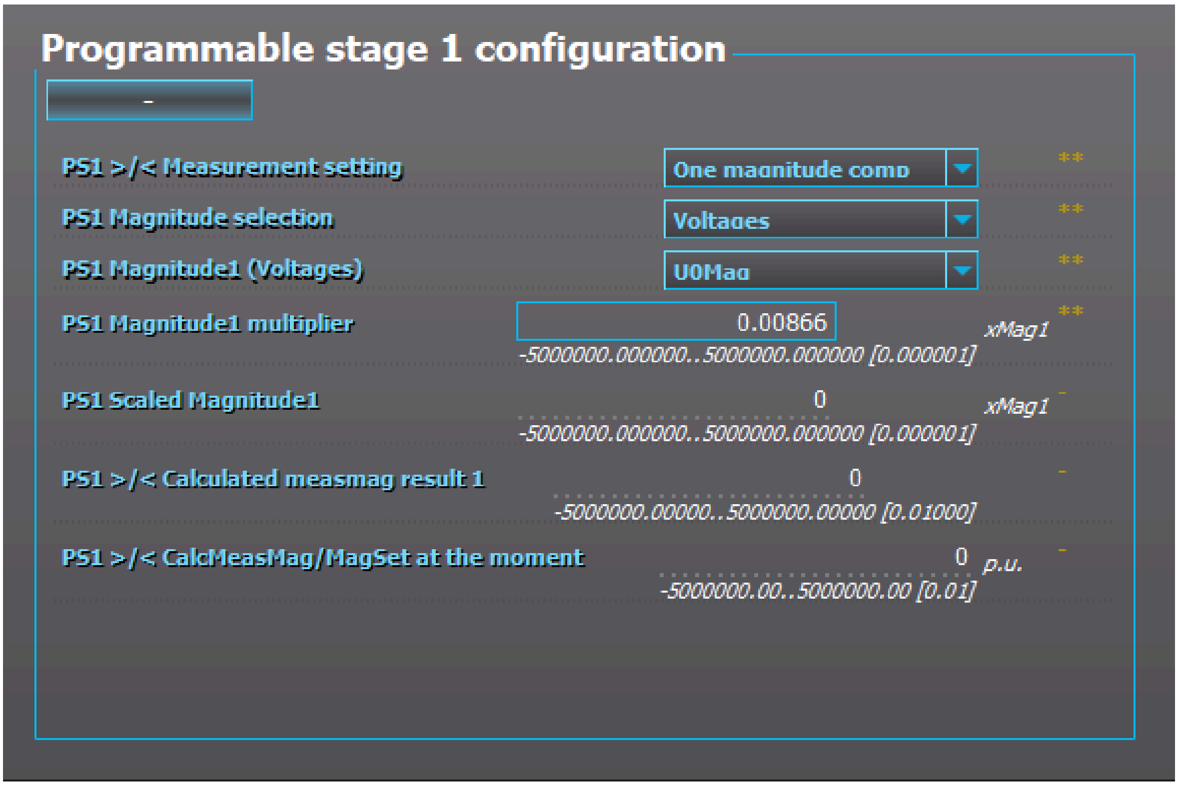
Setting up programmable stages

Programmable stages can be set to follow one, two or three analog measurements with the *PSx >/< Measurement setting* parameter. The user must choose a measurement signal value to be compared to the set value, and possibly also set a scaling for the signal. The image below is an example of scaling: a primary neutral voltage has been scaled to a percentage value for easier handling when setting up the comparator.

The scaling factor was calculated by taking the inverse value of a 20 kV system:

$$k = \frac{1}{20\,000\ \mathrm{V}/\sqrt{3}} = 0.008\,66$$

When this multiplier is in use, the full earth fault neutral voltage is 11 547 V primary which is then multiplied with the above-calculated scaling factor, inversing the final result to 100%. This way a pre-processed signal is easier to set, although it is also possible to just use the scaling factor of 1.0 and set the desired pick-up limit as the primary voltage. Similaryly, any chosen measurement value can be scaled to the desired form.

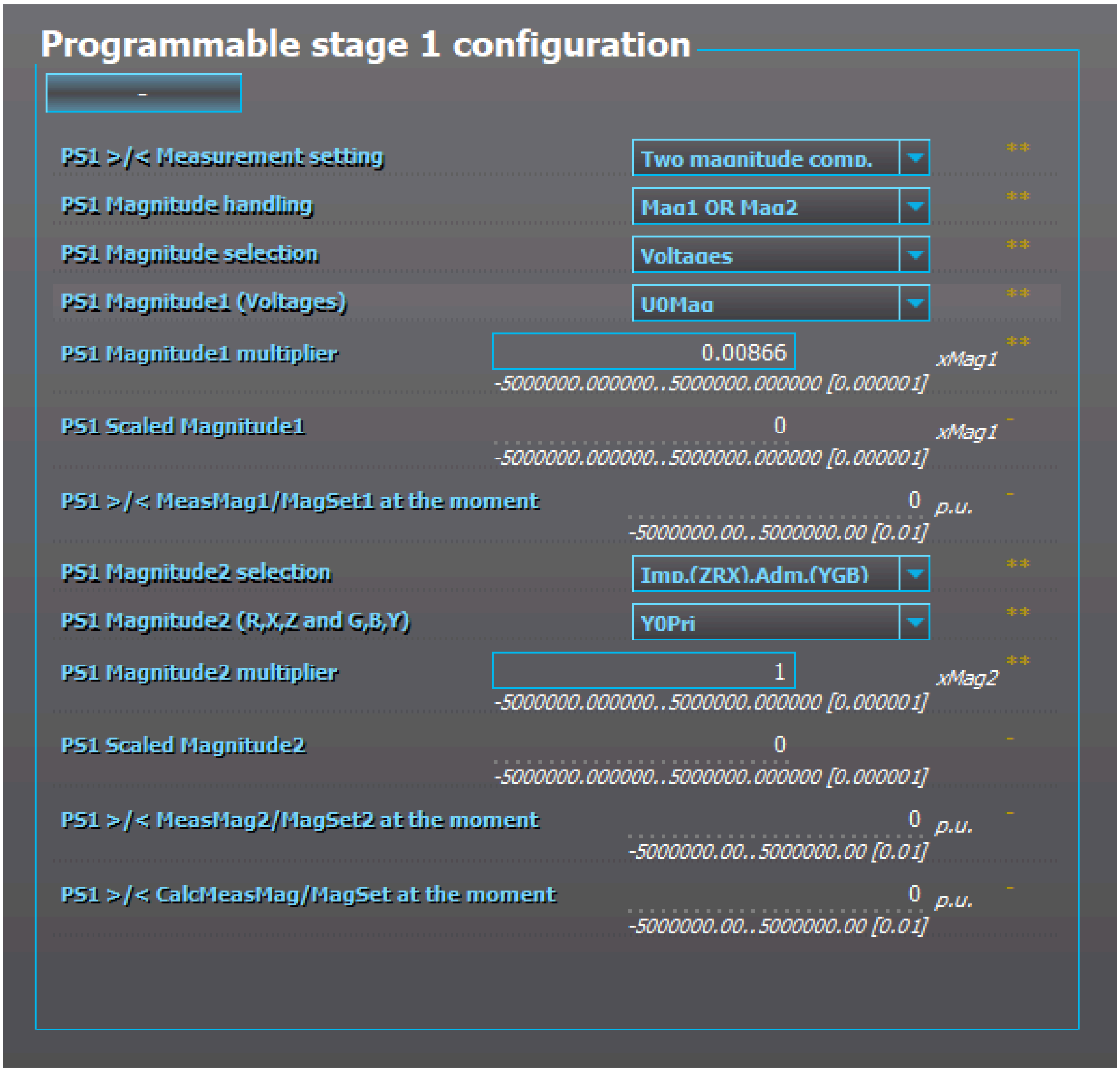


When two or three signals are chosen for comparison, an additional signal (*PSx Magnitude handling*) setting appears. From its drop-down menu the user chooses how the signals are pre-processed for comparison. The table below presents the available modes for a two-signal comparison.

Mode	Description
0: Mag1 x Mag2	Multiplies Signal 1 by Signal 2. The comparison uses the product of this calculation.
1: Mag1 / Mag2	Divides Signal 1 by Signal 2. The comparison uses the product of this calculation.
2: Max (Mag1, Mag2)	The bigger value of the chosen signals is used in the comparison.
3: Min (Mag1, Mag2)	The smaller value of the chosen signals is used in the comparison.

Mode	Description
4: Mag1 OR Mag2	Either of the chosen signals has to fulfill the pick-up condition. Both signals have their own pick-up setting.
5: Mag1 AND Mag2	Both of the chosen signals have to fulfill the pick-up condition. Both signals have their own pick-up setting.
6: Mag1 – Mag2	Subtracts Signal 2 from Signal 1. The comparison uses the product of this calculation.

The image below is an example of setting an analog comparison with two signals. The stage will trip if either of the measured signals fulfills the comparison condition.

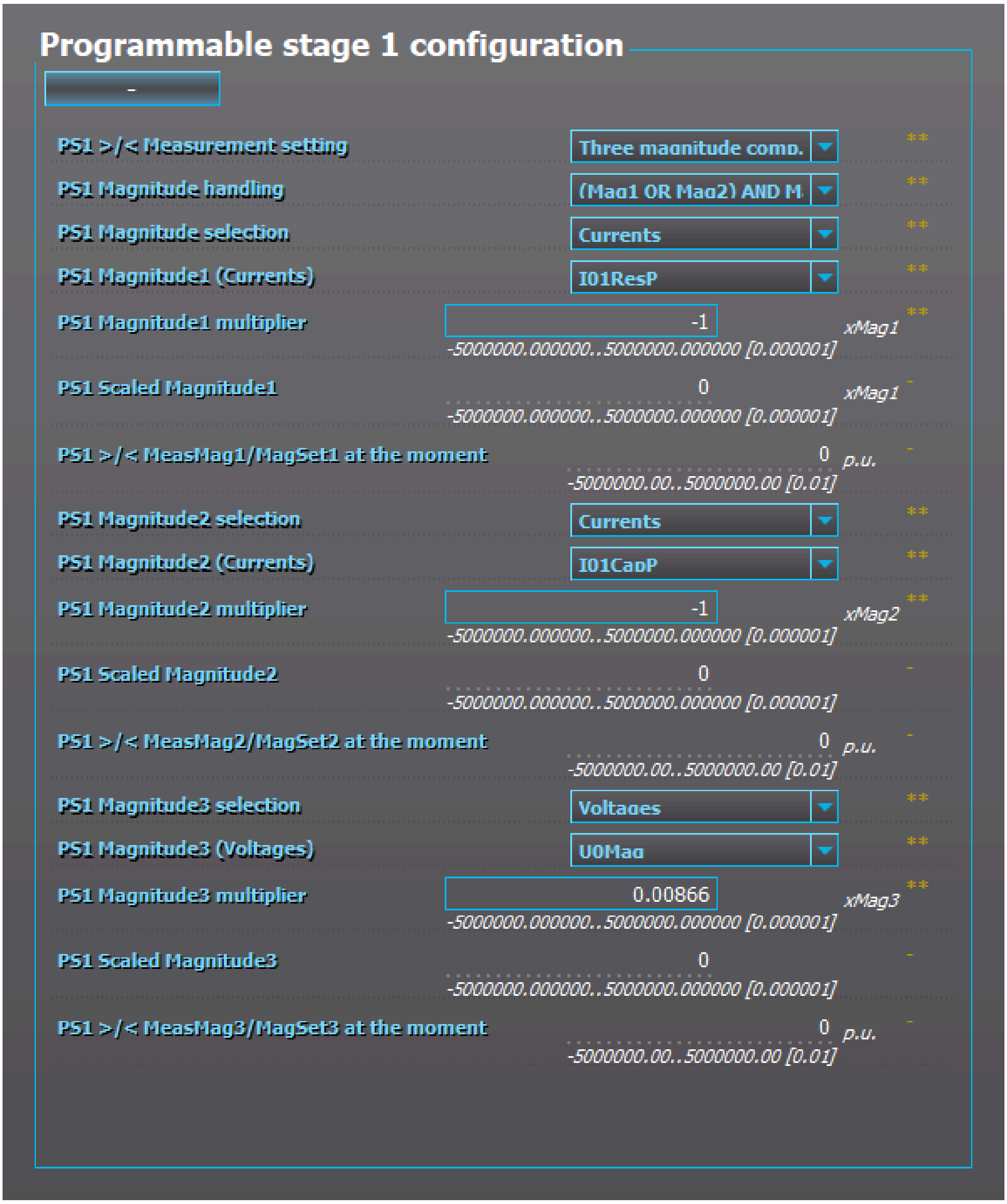


Similarly, the user can set up a comparison of three values. The table below presents the available modes for a three-signal comparison.

Mode	Description
0: Mag1 x Mag2 x Mag3	Multiplies Signals 1, 2 and 3. The comparison uses the product of this calculation.
1: Max (Mag1, Mag2, Mag3);	The biggest value of the chosen signals is used in the comparison.
2: Min (Mag1, Mag2, Mag3)	The smallest value of the chosen signals is used in the comparison.
3: Mag1 OR Mag2 OR Mag3	Any of the signals fulfills the pick-up condition. Each signal has their own pick-up setting.

Mode	Description
4: Mag1 AND Mag2 AND Mag3	All of the signals need to fulfill the pick-up condition. Each signal has their own pick-up setting.
5: (Mag1 OR Mag2) AND Mag3	Signals 1 OR 2 AND 3 need to fulfill the pick-up condition. Each signal has their own pick-up setting.

The image below is an example of setting an analog comparison with three signals. The stage will trip if Signal 1 or Signal 2 as well as Signal 3 fulfill the pick-up condition.



The settings for different comparisons are in the setting groups. This means that each signal parameter can be changed by changing the setting group.

When setting the comparators, the user must first choose a comparator mode. The following modes are available:

Mode	Description
0: Over >	Greater than. If the measured signal is greater than the set pick-up level, the comparison condition is fulfilled.
1: Over (abs) >	Greater than (absolute). If the absolute value of the measured signal is greater than the set pick-up level, the comparison condition is fulfilled.
2: Under <	Less than. If the measured signal is less than the set pick-up level, the comparison condition is fulfilled. The user can also set a blocking limit: the comparison is not active when the measured value is less than the set blocking limit.
3: Under (abs) <	Less than (absolute). If the absolute value of the measured signal is less than the set pick-up level, the comparison condition is fulfilled. The user can also set a blocking limit: the comparison is not active when the measured value is less than the set blocking limit.
4: Delta set (%) +/- >	Relative change over time. If the measured signal changes more than the set relative pick-up value in 20 ms, the comparison condition is fulfilled. The condition is dependent on direction.
5: Delta abs (%) >	Relative change over time (absolute). If the measured signal changes more than the set relative pick-up value in 20 ms in either direction, the comparison condition is fulfilled. The condition is not dependent on direction.
6: Delta +/- measval	Change over time. If the measured signal changes more than the set pick-up value in 20 ms, the comparison condition is fulfilled. The condition is dependent on direction.
7: Delta abs measval	Change over time (absolute). If the measured signal changes more than the set pick-up value in 20 ms in either direction, the comparison condition is fulfilled. The condition is not dependent on direction.

The pick-up level is set individually for each comparison. When setting up the pick-up level, the user needs to take into account the modes in use as well as the desired action. The pick-up limit can be set either as positive or as negative. Each pick-up level has a separate hysteresis setting which is 3 % by default.

The user can set the operating and releasing time delays for each stage.

Analog signals

The numerous analog signals have been divided into categories to help the user find the desired value.

<u>Currents</u>

IL1	Description
IL1 ff (p.u.)	IL1 Fundamental frequency RMS value (in p.u.)
IL1 2^{nd} h.	IL1 2^{nd} harmonic value (in p.u.)
IL1 3^{rd} h.	IL1 3^{rd} harmonic value (in p.u.)
IL1 4^{th} h.	IL1 4^{th} harmonic value (in p.u.)
IL1 5^{th} h.	IL1 5^{th} harmonic value (in p.u.)
IL1 7^{th} h.	IL1 7^{th} harmonic value (in p.u.)
IL1 9^{th} h.	IL1 9^{th} harmonic value (in p.u.)
IL1 11^{th} h.	IL1 11^{th} harmonic value (in p.u.)
IL1 13^{th} h.	IL1 13^{th} harmonic value (in p.u.)

IL1	Description
IL1 15th h.	IL1 15th harmonic value (in p.u.)
IL1 17th h.	IL1 17th harmonic value (in p.u.)
IL1 19th h.	IL1 19th harmonic value (in p.u.)
IL2	Description
IL2 ff (p.u.)	IL2 Fundamental frequency RMS value (in p.u.)
IL2 2nd h.	IL2 2nd harmonic value (in p.u.)
IL2 3rd h.	IL2 3rd harmonic value (in p.u.)
IL2 4th h.	IL2 4th harmonic value (in p.u.)
IL2 5th h.	IL2 5th harmonic value (in p.u.)
IL2 7th h.	IL2 7th harmonic value (in p.u.)
IL2 9th h.	IL2 9th harmonic value (in p.u.)
IL2 11th h.	IL2 11th harmonic value (in p.u.)
IL2 13th h.	IL2 13th harmonic value (in p.u.)
IL2 15th h.	IL2 15th harmonic value (in p.u.)
IL2 17th h.	IL2 17th harmonic value (in p.u.)
IL2 19th h.	IL2 19th harmonic value (in p.u.)
IL3	Description
IL3 ff (p.u.)	IL3 Fundamental frequency RMS value (in p.u.)
IL3 2nd h.	IL3 2nd harmonic value (in p.u.)
IL3 3rd h.	IL3 3rd harmonic value (in p.u.)
IL3 4th h.	IL3 4th harmonic value (in p.u.)
IL3 5th h.	IL3 5th harmonic value (in p.u.)
IL3 7th h.	IL3 7th harmonic value (in p.u.)
IL3 9th h.	IL3 9th harmonic value (in p.u.)
IL3 11th h.	IL3 11th harmonic value (in p.u.)
IL3 13th h.	IL3 13th harmonic value (in p.u.)
IL3 15th h.	IL3 15th harmonic value (in p.u.)
IL3 17th h.	IL3 17th harmonic value (in p.u.)
IL3 19th h.	IL3 19th harmonic value (in p.u.)
I01	Description
I01 ff (p.u.)	I01 Fundamental frequency RMS value (in p.u.)
I01 2nd h.	I01 2nd harmonic value (in p.u.)
I01 3rd h.	I01 3rd harmonic value (in p.u.)
I01 4th h.	I01 4th harmonic value (in p.u.)

IL1	Description
I01 5^{th} h.	I01 5^{th} harmonic value (in p.u.)
I01 7^{th} h.	I01 7^{th} harmonic value (in p.u.)
I01 9^{th} h.	I01 9^{th} harmonic value (in p.u.)
I01 11^{th} h.	I01 11^{th} harmonic value (in p.u.)
I01 13^{th} h.	I01 13^{th} harmonic value (in p.u.)
I01 15^{th} h.	I01 15^{th} harmonic value (in p.u.)
I01 17^{th} h.	I01 17^{th} harmonic value (in p.u.)
I01 19^{th} h.	I01 19^{th} harmonic value (in p.u.)
IL02	Description
I02 ff (p.u.)	I02 Fundamental frequency RMS value (in p.u.)
I02 2^{nd} h.	I02 2^{nd} harmonic value (in p.u.)
I02 3^{rd} h.	I02 3^{rd} harmonic value (in p.u.)
I02 4^{th} h.	I02 4^{th} harmonic value (in p.u.)
I02 5^{th} h.	I02 5^{th} harmonic value (in p.u.)
I02 7^{th} h.	I02 7^{th} harmonic value (in p.u.)
I02 9^{th} h.	I02 9^{th} harmonic value (in p.u.)
I02 11^{th} h.	I02 11^{th} harmonic value (in p.u.)
I02 13^{th} h.	I02 13^{th} harmonic value (in p.u.)
I02 15^{th} h.	I02 15^{th} harmonic value (in p.u.)
I02 17^{th} h.	I02 17^{th} harmonic value (in p.u.)
I02 19^{th} h.	I02 19^{th} harmonic value (in p.u.)
TRMS	Description
IL1 TRMS	IL1 TRMS value (in p.u.)
IL2 TRMS	IL2 TRMS value (in p.u.)
IL3 TRMS	IL3 TRMS value (in p.u.)
I01 TRMS	I01 TRMS value (in p.u.)
I02 TRMS	I02 TRMS value (in p.u.)
Calculated	Description
I0Z Mag	Zero sequence current value (in p.u.)
I0CALC Mag	Calculated I0 value (in p.u.)
I1 Mag	Positive sequence current value (in p.u.)
I2 Mag	Negative sequence current value (in p.u.)
IL1 Ang	IL1 angle of current
IL2 Ang	IL2 angle of current
IL3 Ang	IL3 angle of current
I01 Ang	I01 angle of current

IL1	Description
I02 Ang	I02 angle of current
I0CALC Ang	Angle of calculated residual current
I1 Ang	Angle of positive sequence current
I2 Ang	Angle of negative sequence current
I01ResP	I01 primary current of a current-resistive component
I01CapP	I01 primary current of a current-capacitive component
I01ResS	I01 secondary current of a current-resistive component
I01CapS	I01 secondary current of a current-capacitive component
I02ResP	I02 primary current of a current-resistive component
I02CapP	I02 primary current of a current-capacitive component

Voltages

Phase-to-phase voltages	Description
UL12Mag	UL12 Primary voltage V
UL23Mag	UL23 Primary voltage V
UL31Mag	UL31 Primary voltage V
Phase-to-neutral voltages	Description
UL1Mag	UL1 Primary voltage V
UL2Mag	UL2 Primary voltage V
UL3Mag	UL3 Primary voltage V
U0Mag	U0 Primary voltage V
Angles	Description
UL12Ang	UL12 angle
UL23Ang	UL23 angle
UL31Ang	UL31 angle
UL1Ang	UL1 angle
UL2Ang	UL2 angle
UL3Ang	UL3 angle
U0Ang	U0 angle
Calculated	Description
U0CalcMag	Calculated residual voltage
U1 pos.seq.V Mag	Positive sequence voltage
U2 neg.seq.V Mag	Negative sequence voltage
U0CalcAng	Calculated residual voltage angle
U1 pos.seq.V Ang	Positive sequence voltage angle
U2 neg.seq.V Ang	Negative sequence voltage angle

Powers

Name	Description
S3PH	Three-phase apparent power S (kVA)
P3PH	Three-phase active power P (kW)
Q3PH	Three-phase reactive power Q (kvar)
tanfi3PH	Three-phase active power direction
cosfi3PH	Three-phase reactive power direction
SL1	Apparent power L1 S (kVA)
PL1	Active power L1 P (kW)
QL1	Reactive power L1 Q (kVar)
tanfiL1	Phase active power direction L1
cosfiL1	Phase reactive power direction L1
SL2	Apparent power L2 S (kVA)
PL2	Active power L2 P (kW)
QL2	Reactive power L2 Q (kVar)
tanfiL2	Phase active power direction L2
cosfiL2	Phase reactive power direction L2
SL3	Apparent power L3 S (kVA)
PL3	Active power L3 P (kW)
QL3	Reactive power L3 Q (kVar)
tanfiL3	Phase active power direction L3
cosfiL3	Phase reactive power direction L3

Impedance and admittance (ZRX & YGB)

Name	Description
RL12Pri	Resistance R L12 primary (Ω)
XL12Pri	Reactance X L12 primary (Ω)
RL23Pri	Resistance R L23 primary (Ω)
XL23Pri	Reactance X L23 primary (Ω)
RL31Pri	Resistance R L31 primary (Ω)
XL31Pri	Reactance X L31 primary (Ω)
RL12Sec	Resistance R L12 secondary (Ω)
XL12Sec	Reactance X L12 secondary (Ω)
RL23Sec	Resistance R L23 secondary (Ω)
XL23Sec	Reactance X L23 secondary (Ω)
RL31Sec	Resistance R L31 secondary (Ω)
XL31Sec	Reactance X L31 secondary (Ω)
Z12Pri	Impedance Z L12 primary (Ω)
Z23Pri	Impedance Z L23 primary (Ω)
Z31Pri	Impedance Z L31 primary (Ω)

Name	Description
Z12Sec	Impedance Z L12 secondary (Ω)
Z23Sec	Impedance Z L23 secondary (Ω)
Z31Sec	Impedance Z L31 secondary (Ω)
Z12Angle	Impedance Z L12 angle
Z23Angle	Impedance Z L23 angle
Z31Angle	Impedance Z L31 angle
RL1Pri	Resistance R L1 primary (Ω)
XL1Pri	Reactance X L1 primary (Ω)
RL2Pri	Resistance R L2 primary (Ω)
XL2Pri	Reactance X L2 primary (Ω)
RL3Pri	Resistance R L3 primary (Ω)
XL3Pri	Reactance X L3 primary (Ω)
RL1Sec	Resistance R L1 secondary (Ω)
XL1Sec	Reactance X L1 secondary (Ω)
RL2Sec	Resistance R L2 secondary (Ω)
XL2Sec	Reactance X L2 secondary (Ω)
RL3Sec	Resistance R L3 secondary (Ω)
XL3Sec	Reactance X L3 secondary (Ω)
Z1Pri	Impedance Z L1 primary (Ω)
Z2Pri	Impedance Z L2 primary (Ω)
Z3Pri	Impedance Z L3 primary (Ω)
Z1Sec	Impedance Z L1 secondary (Ω)
Z2Sec	Impedance Z L2 secondary (Ω)
Z3Sec	Impedance Z L3 secondary (Ω)
Z1Angle	Impedance Z L1 angle
Z2Angle	Impedance Z L2 angle
Z3Angle	Impedance Z L3 angle
RSeqPri	Positive Resistance R primary (Ω)
XSeqPri	Positive Reactance X primary (Ω)
RSeqSec	Positive Resistance R secondary (Ω)
XSeqSec	Positive Reactance X secondary (Ω)
ZSeqPri	Positive Impedance Z primary (Ω)
ZSeqSec	Positive Impedance Z secondary (Ω)
ZSeqAngle	Positive Impedance Z angle
GL1Pri	Conductance G L1 primary (mS)
BL1Pri	Susceptance B L1 primary (mS)
GL2Pri	Conductance G L2 primary (mS)
BL2Pri	Susceptance B L2 primary (mS)

Name	Description
GL3Pri	Conductance G L3 primary (mS)
BL3Pri	Susceptance B L3 primary (mS)
GL1Sec	Conductance G L1 secondary (mS)
BL1Sec	Susceptance B L1 secondary (mS)
GL2Sec	Conductance G L2 secondary (mS)
BL2Sec	Susceptance B L2 secondary (mS)
GL3Sec	Conductance G L3 secondary (mS)
BL3Sec	Susceptance B L3 secondary (mS)
YL1PriMag	Admittance Y L1 primary (mS)
YL2PriMag	Admittance Y L2 primary (mS)
YL3PriMag	Admittance Y L3 primary (mS)
YL1SecMag	Admittance Y L1 secondary (mS)
YL2SecMag	Admittance Y L2 secondary (mS)
YL3SecMag	Admittance Y L3 secondary (mS)
YL1Angle	Admittance Y L1 angle
YL2Angle	Admittance Y L2 angle
YL3Angle	Admittance Y L3 angle
G0Pri	Conductance G0 primary (mS)
B0Pri	Susceptance B0 primary (mS)
G0Sec	Conductance G0 secondary (mS)
B0Sec	Susceptance B0 secondary (mS)
Y0Pri	Admittance Y0 primary (mS)
Y0Sec	Admittance Y0 secondary (mS)
Y0Angle	Admittance Y0 angle

Others

Name	Description
System f.	System frequency
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)
mA input 7,8,15,16	mA input channels 7, 8, 15, 16
ASC 1…4	Analog scaled curves 1…4

The outputs of the function are the START, TRIP and BLOCKED signals. The overvoltage function uses a total of eight (8) separate setting groups which can be selected from one common source.

The function can operate on instant or time-delayed mode. Definite time (DT) delay can be selected in the In time-delayed mode.

The inputs for the function are the following:

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

The function outputs the START, TRIP and BLOCKED signals which 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 three (3) output signals. In the instant operating mode the function outputs START and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

Pick-up

The *Pick-up setting Mag* setting parameter controls the pick-up of the PGx>/< function. This defines the maximum or minimum allowed measured magnitude before action from the function. The function constantly calculates the ratio between the set and the measured magnitudes. The user can set the reset hysteresis in the function (by default 3 %). It is always relative to the *Pick-up setting Mag* value.

Table. 5.3.11 - 79. Pick-up settings.

Name	Description	Range	Step	Default
PS# Pick-up setting Mag#/calc >/<	Pick-up magnitude	-5 000 000.0000…5 000 000.0000	0.0001	0.01
PS# Setting hysteresis Mag#	Setting hysteresis	0.0000…50.0000%	0.0001%	3%
Definite operating time delay	Delay setting	0.000…1800.000s	0.005s	0.04s
Release time delays	Pick-up release delay	0.000…1800.000s	0.005s	0.06s

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.

The user can reset characteristics through the application. The default setting is a 60 ms delay; the time calculation is held during the release time.

In the release delay option the operating time counter calculates the operating time during the release. When using this option the function does not trip if the input signal is not re-activated while the release time count is on-going.

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 values of the selected signal 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.

Events and registers

The programmable stage function (abbreviated "PGS" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. 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. 5.3.11 - 80. Event codes.

Event number	Event channel	Event block name	Event code	Description
8576	134	PGS1	0	PS1 >/< Start ON
8577	134	PGS1	1	PS1 >/< Start OFF
8578	134	PGS1	2	PS1 >/< Trip ON
8579	134	PGS1	3	PS1 >/< Trip OFF
8580	134	PGS1	4	PS1 >/< Block ON
8581	134	PGS1	5	PS1 >/< Block OFF
8582	134	PGS1	6	PS2 >/< Start ON
8583	134	PGS1	7	PS2 >/< Start OFF
8584	134	PGS1	8	PS2 >/< Trip ON
8585	134	PGS1	9	PS2 >/< Trip OFF
8586	134	PGS1	10	PS2 >/< Block ON
8587	134	PGS1	11	PS2 >/< Block OFF
8588	134	PGS1	12	PS3 >/< Start ON
8589	134	PGS1	13	PS3 >/< Start OFF
8590	134	PGS1	14	PS3 >/< Trip ON
8591	134	PGS1	15	PS3 >/< Trip OFF
8592	134	PGS1	16	PS3 >/< Block ON
8593	134	PGS1	17	PS3 >/< Block OFF
8594	134	PGS1	18	PS4 >/< Start ON
8595	134	PGS1	19	PS4 >/< Start OFF
8596	134	PGS1	20	PS4 >/< Trip ON
8597	134	PGS1	21	PS4 >/< Trip OFF
8598	134	PGS1	22	PS4 >/< Block ON
8599	134	PGS1	23	PS4 >/< Block OFF
8600	134	PGS1	24	PS5 >/< Start ON

Event number	Event channel	Event block name	Event code	Description
8601	134	PGS1	25	PS5 >/< Start OFF
8602	134	PGS1	26	PS5 >/< Trip ON
8603	134	PGS1	27	PS5 >/< Trip OFF
8604	134	PGS1	28	PS5 >/< Block ON
8605	134	PGS1	29	PS5 >/< Block OFF
8606	134	PGS1	30	reserved
8607	134	PGS1	31	reserved
8608	134	PGS1	32	PS6 >/< Start ON
8609	134	PGS1	33	PS6 >/< Start OFF
8610	134	PGS1	34	PS6 >/< Trip ON
8611	134	PGS1	35	PS6 >/< Trip OFF
8612	134	PGS1	36	PS6 >/< Block ON
8613	134	PGS1	37	PS6 >/< Block OFF
8614	134	PGS1	38	PS7 >/< Start ON
8615	134	PGS1	39	PS7 >/< Start OFF
8616	134	PGS1	40	PS7 >/< Trip ON
8617	134	PGS1	41	PS7 >/< Trip OFF
8618	134	PGS1	42	PS7 >/< Block ON
8619	134	PGS1	43	PS7 >/< Block OFF
8620	134	PGS1	44	PS8 >/< Start ON
8621	134	PGS1	45	PS8 >/< Start OFF
8622	134	PGS1	46	PS8 >/< Trip ON
8623	134	PGS1	47	PS8 >/< Trip OFF
8624	134	PGS1	48	PS8 >/< Block ON
8625	134	PGS1	49	PS8 >/< Block OFF
8626	134	PGS1	50	PS9 >/< Start ON
8627	134	PGS1	51	PS9 >/< Start OFF
8628	134	PGS1	52	PS9 >/< Trip ON
8629	134	PGS1	53	PS9 >/< Trip OFF
8630	134	PGS1	54	PS9 >/< Block ON
8631	134	PGS1	55	PS9 >/< Block OFF
8632	134	PGS1	56	PS10 >/< Start ON
8633	134	PGS1	57	PS10 >/< Start OFF
8634	134	PGS1	58	PS10 >/< Trip ON
8635	134	PGS1	59	PS10 >/< Trip OFF
8636	134	PGS1	60	PS10 >/< Block ON
8637	134	PGS1	61	PS10 >/< Block 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 START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.3.11 - 81. Register content.

Date and time	Event code	>/< Mag#	Mag#/Set#	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	8576-8637 Descr.	The numerical value of the magnitude	Ratio between the measured magnitude and the pick-up setting	0 ms...1800s	Setting group 1...8 active

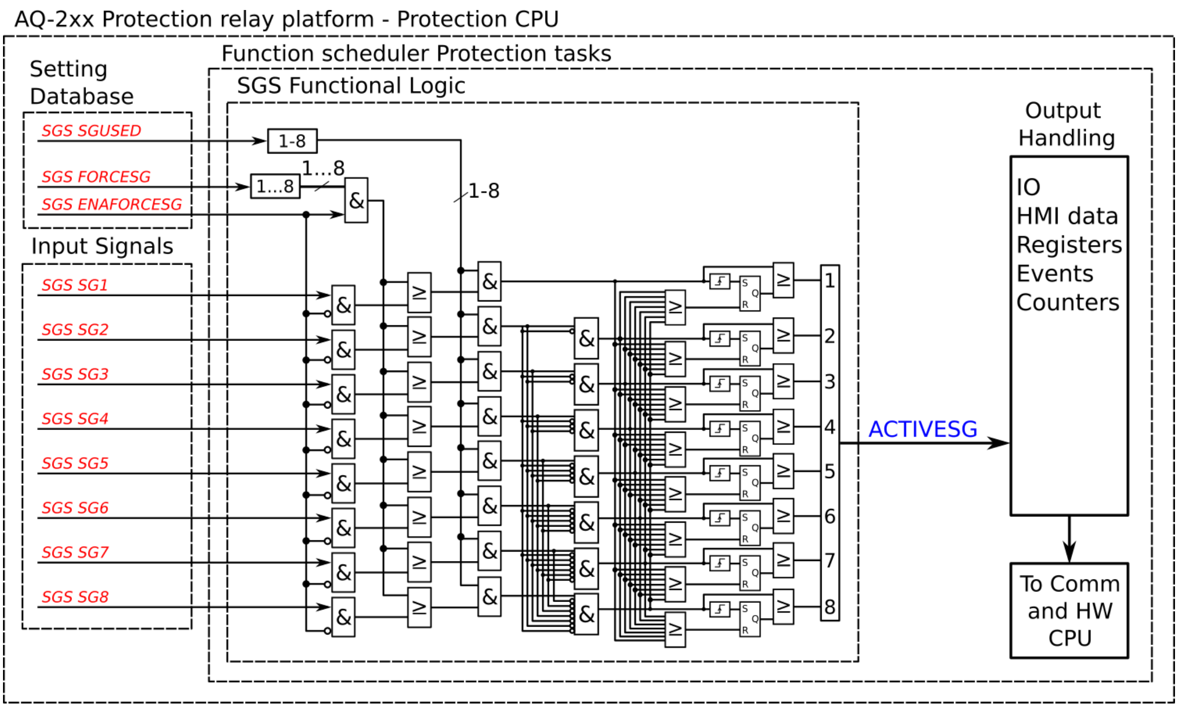
5.4 Control functions

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 - 112. Simplified function block diagram of the setting group selection function.

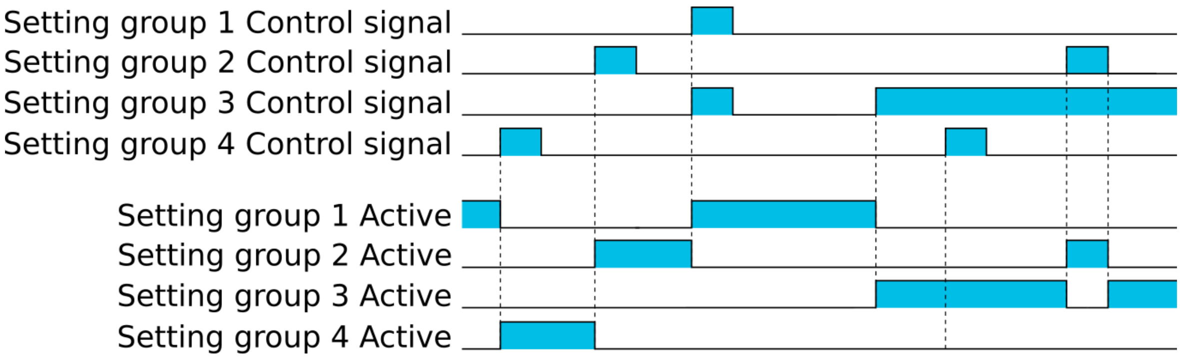


Setting group selection can be applied to each of the setting groups individually by activating one of the various internal logic inputs and connected digital inputs. The user can also force any of the setting groups on when the "Force SG change" setting is enabled by giving the wanted quantity of setting 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 and activation signal.

Figure. 5.4.1 - 113. 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 - 82. 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 overriden. 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.

Name	Range	Step	Default	Description
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.
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 - 83. Signals of the setting group selection function.

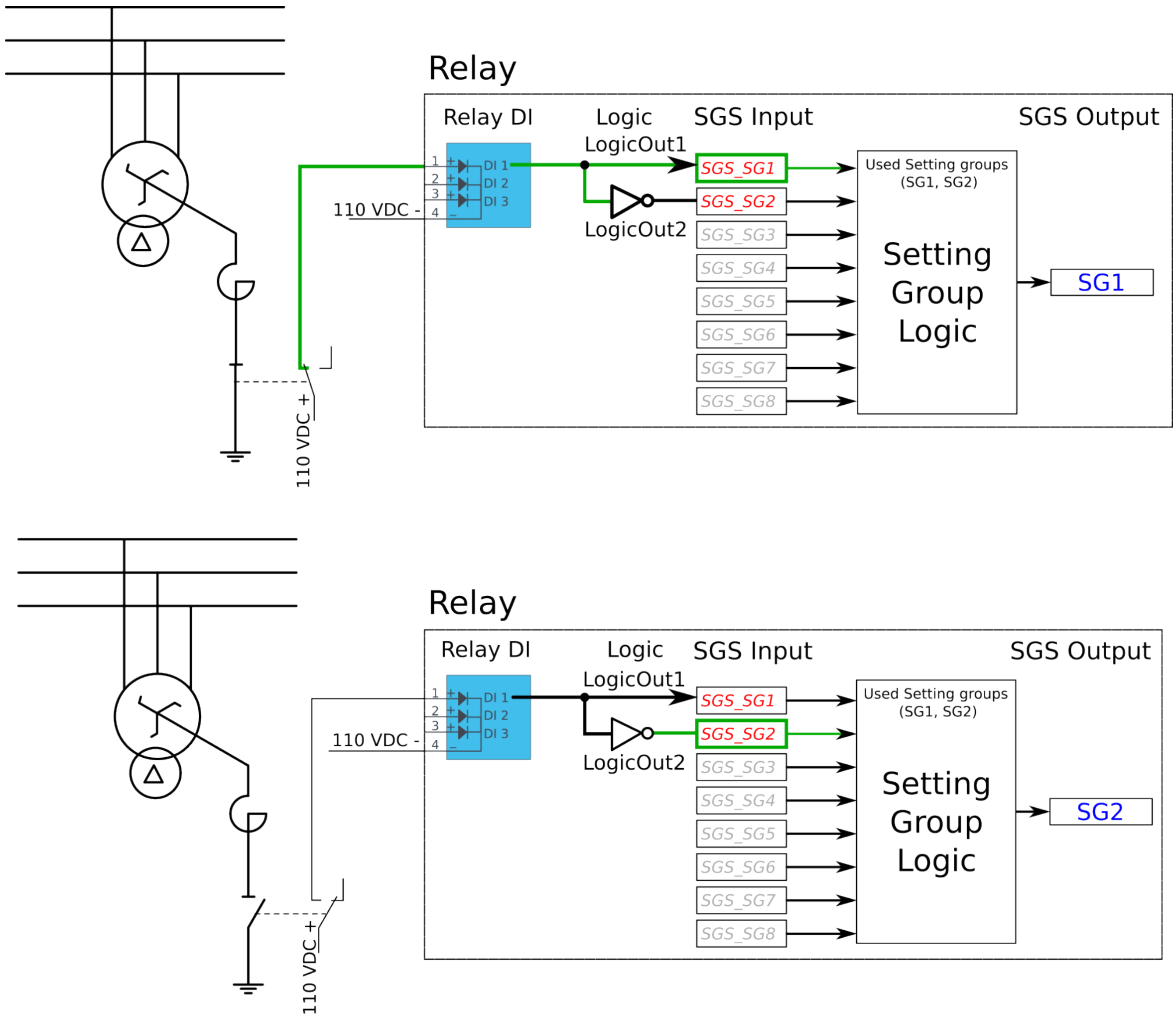
Name	Range	Step	Default	Description
Setting group 1	0: Not active 1: Active	-	0: Not active	The selection of Setting group 1 ("SG1"). Has the highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no other SG requests will 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 - 114. 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 - 115. Setting group control – two-wire connection from Petersen coil status.

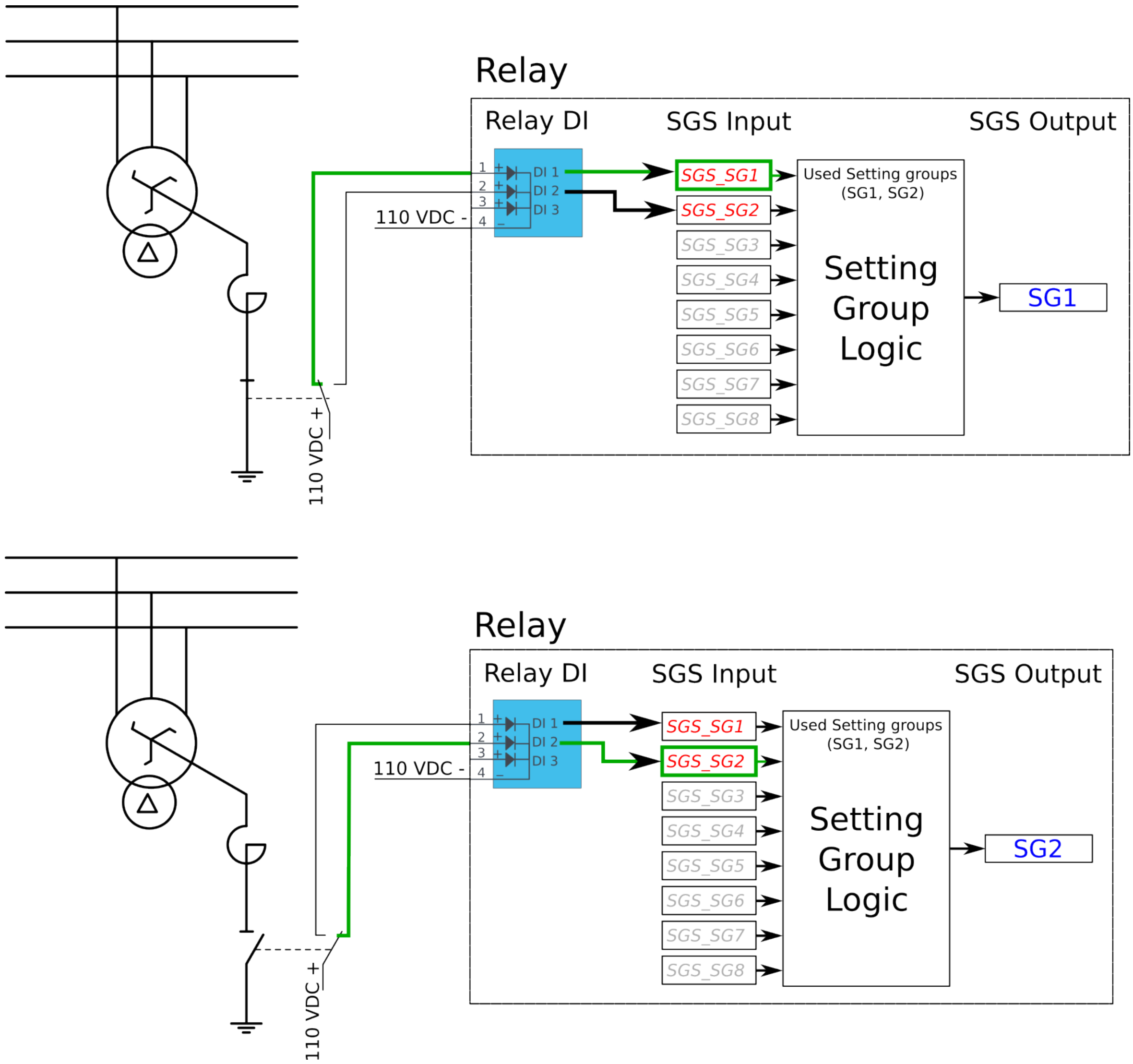
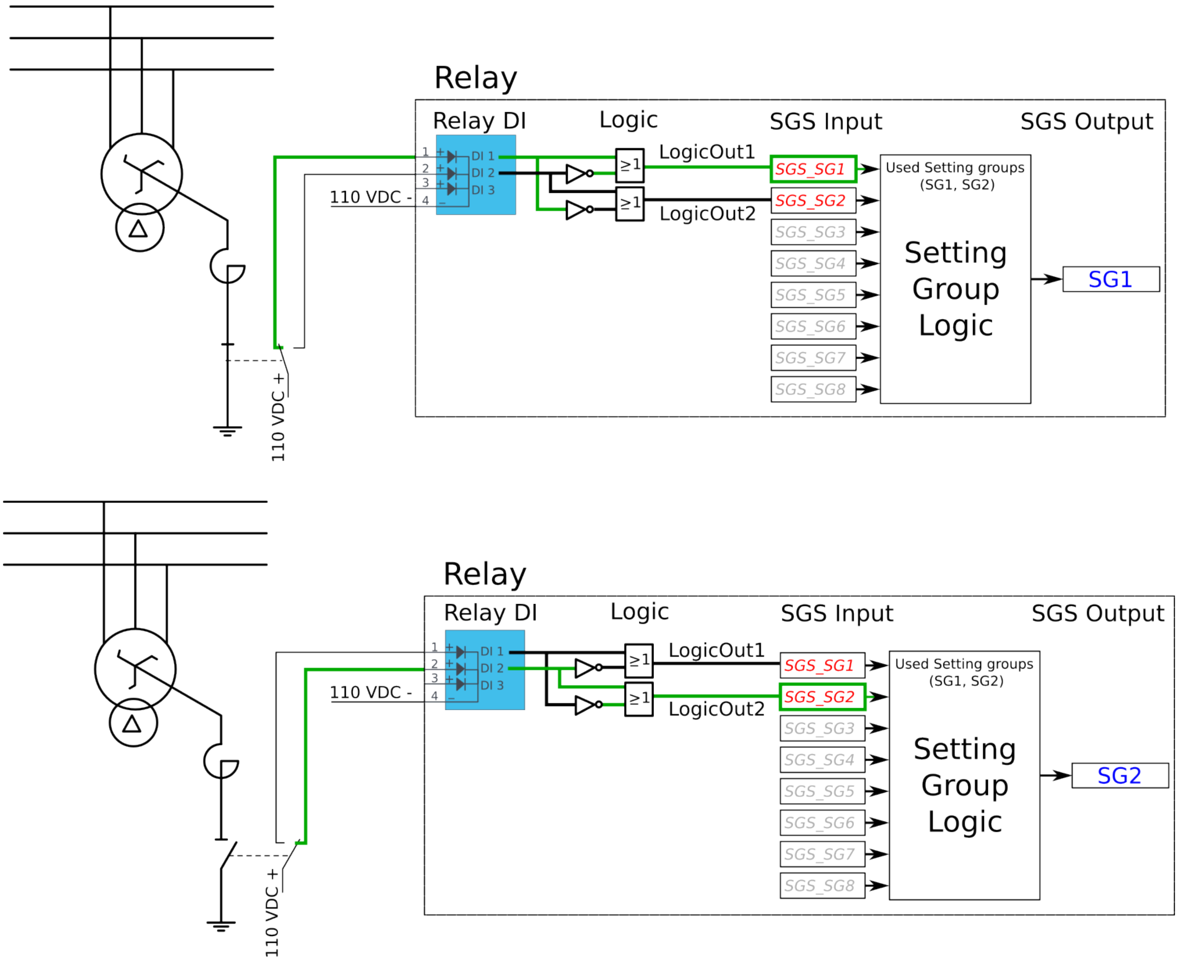


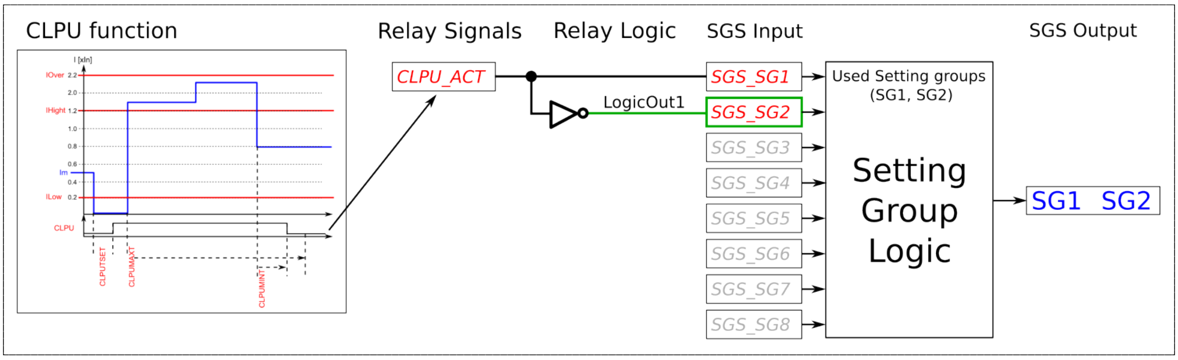
Figure. 5.4.1 - 116. Setting group control – two-wire connection from Petersen coil status with additional logic.

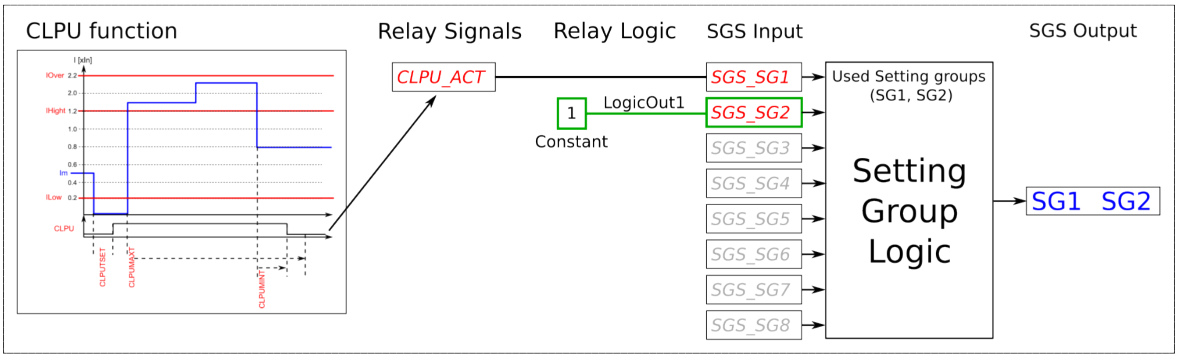


The images above depict a two-wire connection from the Petersen coil: the two images at the top show a direct connection, while the two images on the bottom include additional logic. With a two-wire connection the state of the Petersen coil can be monitored more securely. The additional logic ensures 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 - 117. 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 - 84. 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.

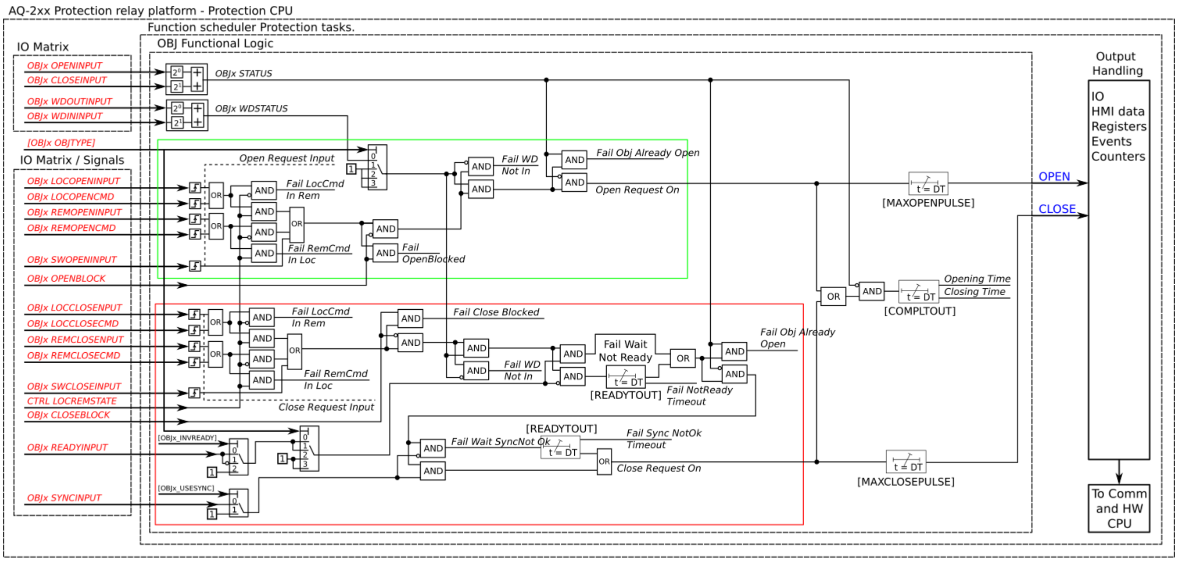
The inputs for the function are the following:

- 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 - 118. 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 - 85. 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: Disconnector (MC) 3: Disconnector (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 - 86. 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.
Disconnector (MC)	Position indication Control	The position monitoring and control of the disconnector.
Disconnector (GND)	Position indication	The position indication of the earth switch.

Table. 5.4.2 - 87. 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 - 88. 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 it status in this given time the function will issue 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 - 89. Control settings (DI and Application).

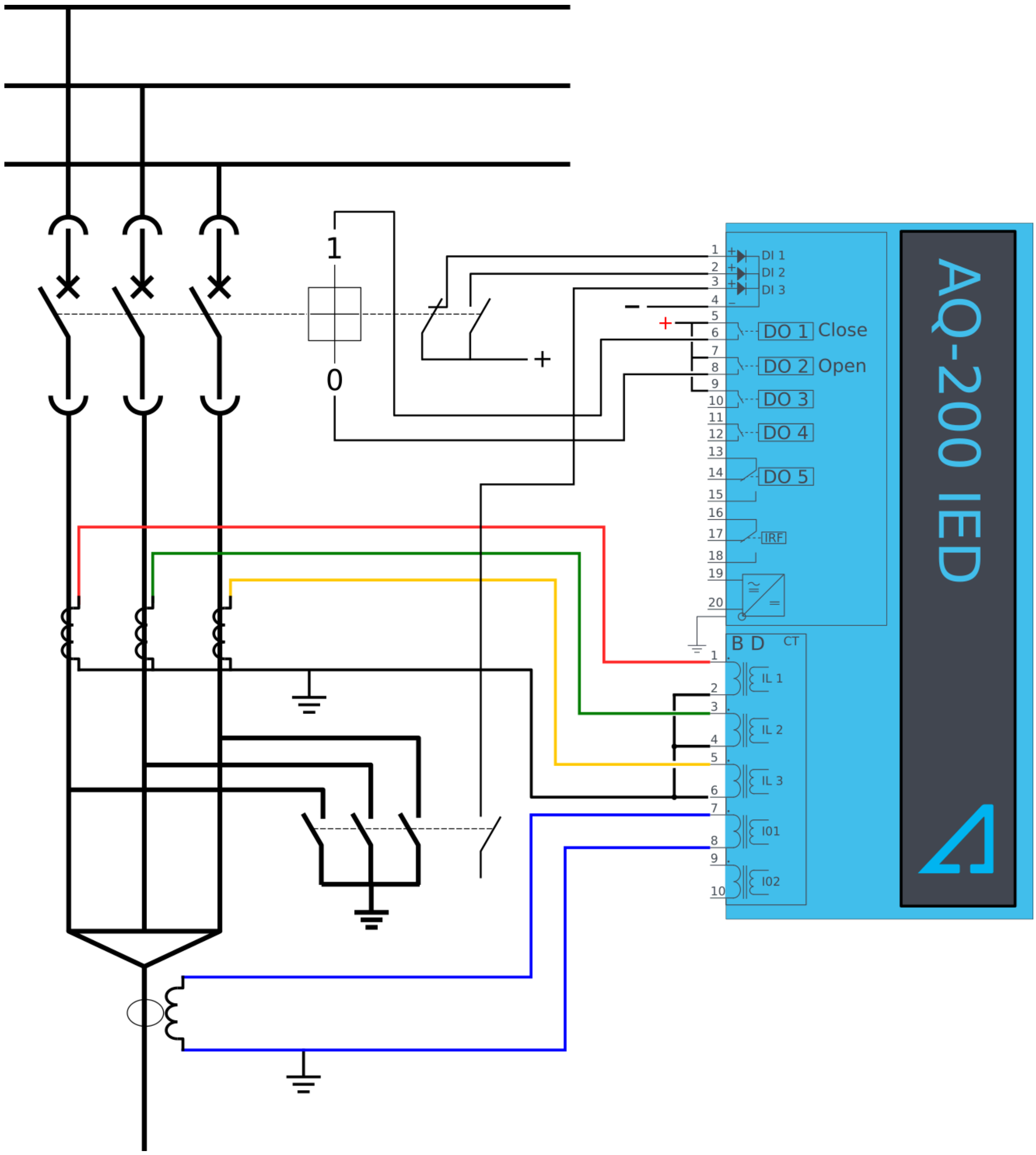
Signal	Range	Description
Access level for MIMIC control	0: User 1: Operator 2: Configurator 3: Super user	Defines what level of access is required for MIMIC control. The default is the "Configurator" level.
Objectx LOCAL Close control input	Digital input or other logical signal selected by the user	The 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 Close 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 - 119. 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 - 90. Event codes of the OBJ function instances 1 – 5.

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

Table. 5.4.2 - 91. 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.

Name	Description
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 - 92. 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 - 93. 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.

Signal	Range	Description
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 - 94. 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
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 Synchrocheck (ΔV/Δa/Δf; 25)

Checking the synchronization is important to ensure the safe closing of the circuit breaker between two systems. Closing the circuit breaker when the systems are not synchronized can cause several problems such as current surges which damage the interconnecting elements. The synchrocheck function has three stages: SYN1, SYN2 and SYN3. Their function and availability of these stages depend on which voltage channels are set to "SS" mode or not. Voltage measurement settings are located at *Measurements → Transformers → VT module*.

When only U3 or U4 voltage measurement channel has been set to "SS" mode:

- SYN1 – Supervises the synchronization condition between the channel set to "SS" mode and the selected system voltage (UL1, UL2, UL3, UL12, UL23 or UL31).
- SYN2 – Not active and not visible.
- SYN3 – Not active and not visible.

When both U3 and U4 have been set to "SS" mode:

- SYN1 – Supervises the synchronization condition between the U3 channel and the selected system voltage (UL1, UL2, UL3, UL12, UL23 or UL31).
- SYN2 – Supervises the synchronization condition between the U4 channel and the selected system voltage (UL1, UL2, UL3, UL12, UL23 or UL31).
- SYN3 – Supervises the synchronization condition between the channels U3 and U4.

The seven images below present three different example connections and four example applications of the synchrocheck function.

Figure. 5.4.4 - 120. Example connection of the synchrocheck function (3LN+U4 mode, SYN1 in use, UL1 as reference voltage).

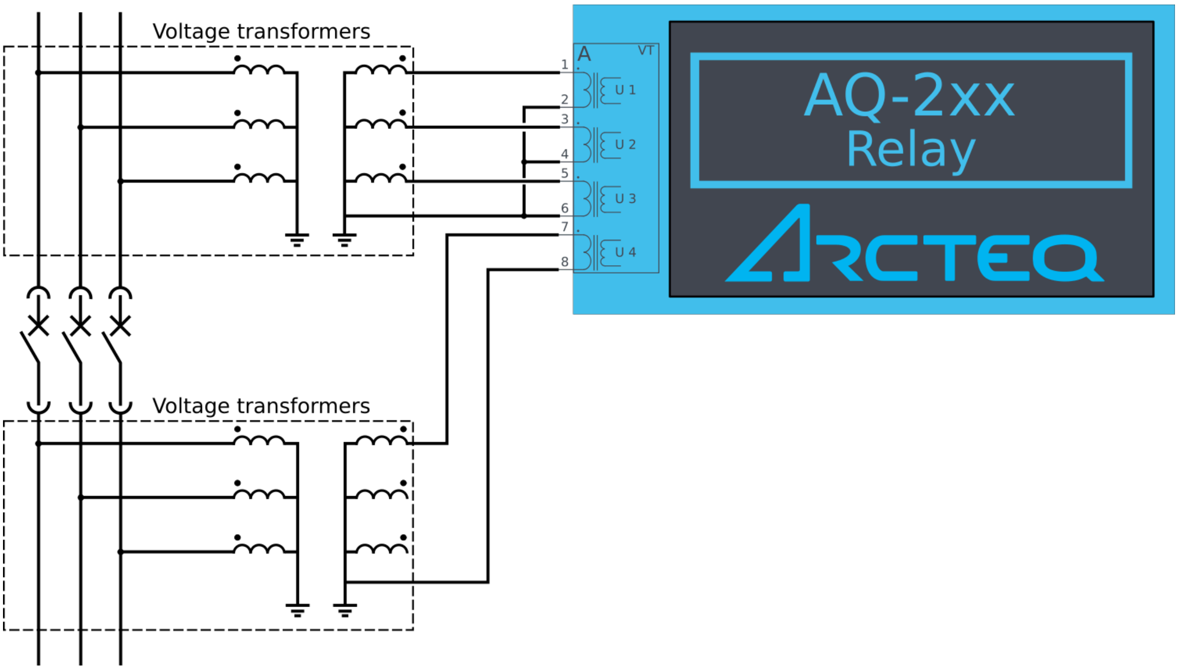


Figure. 5.4.4 - 121. Example connection of the synchrocheck function (2LL+U0+U4 mode, SYN1 in use, UL12 as reference voltage).

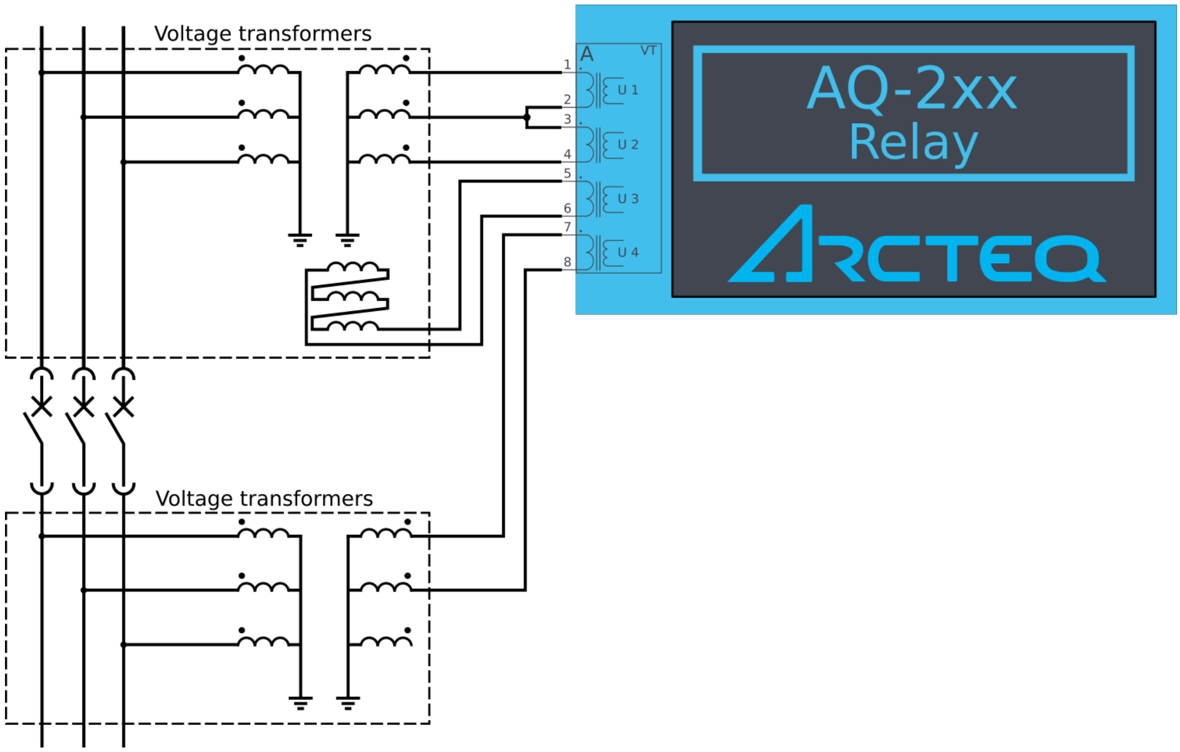


Figure. 5.4.4 - 122. Example connection of the synchrocheck function (2LL+U3+U4 mode, SYN3 in use, UL12 as reference voltage).

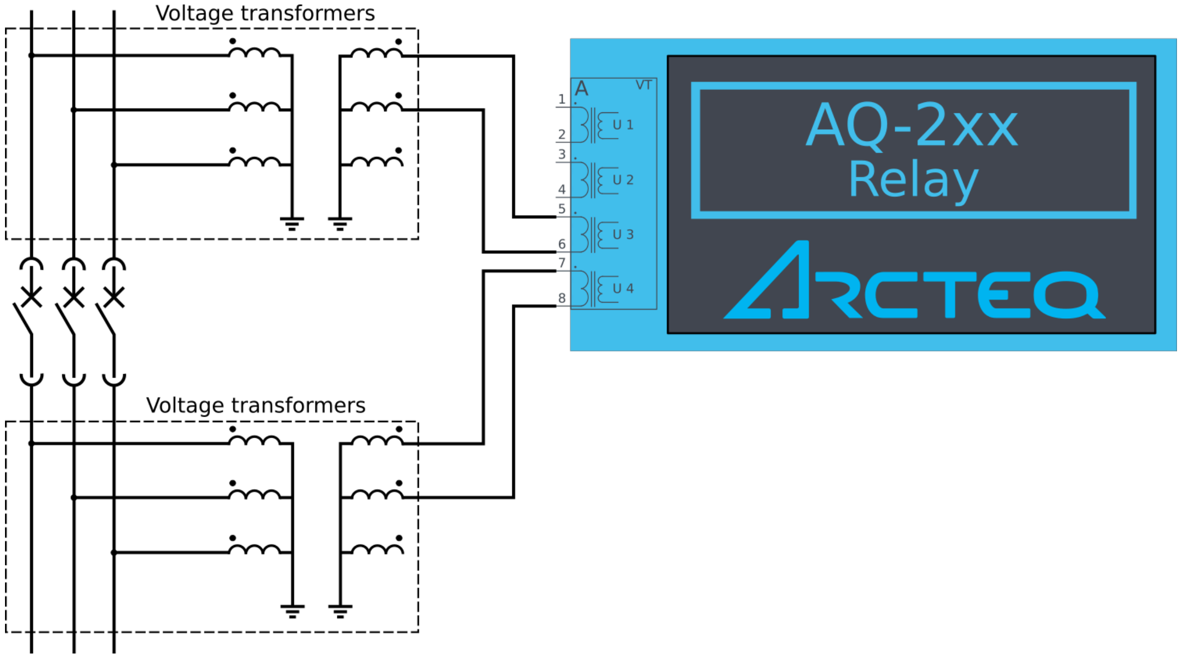


Figure. 5.4.4 - 123. Example application (synchrocheck over one breaker, with 3LL and 3LN VT connections).

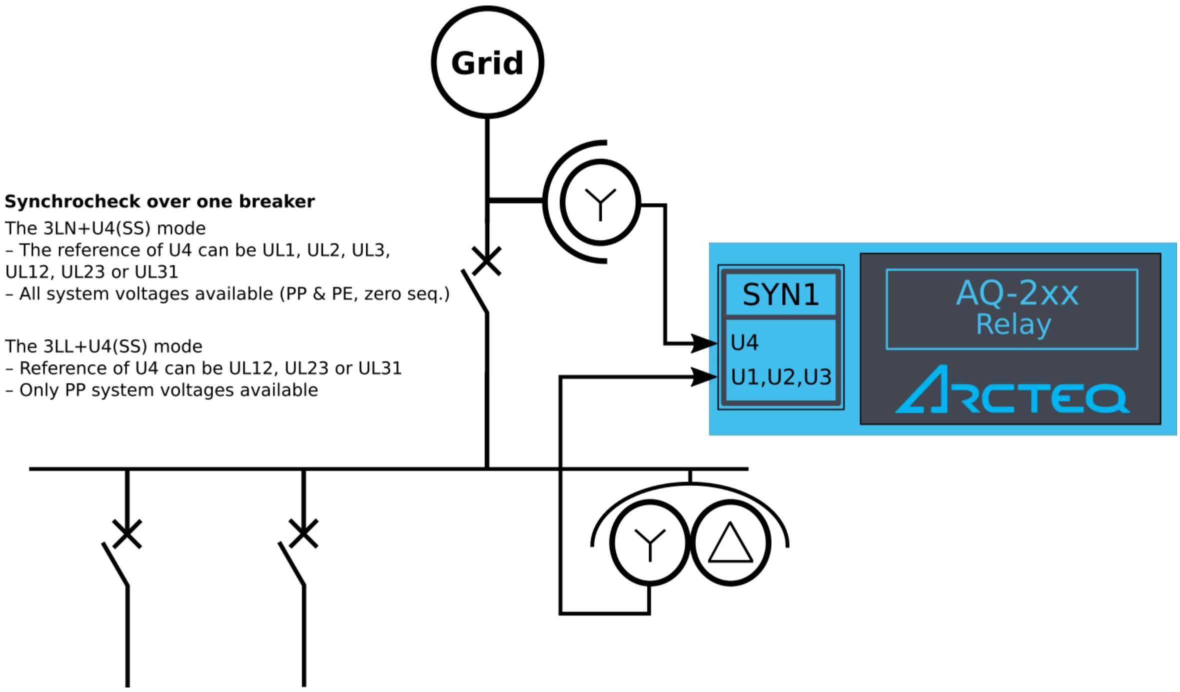


Figure. 5.4.4 - 124. Example application (synchrocheck over one breaker, with 2LL VT connection).

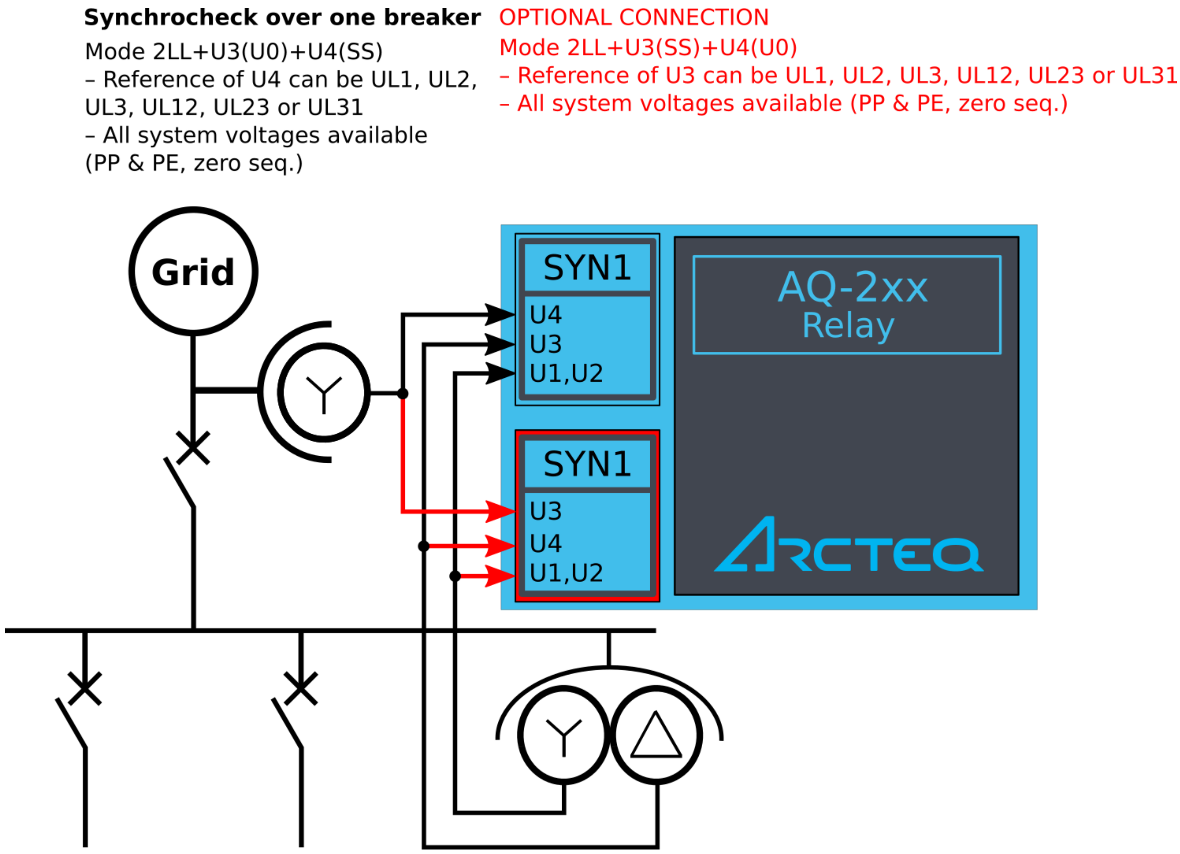


Figure. 5.4.4 - 125. Example application (synchrocheck over two breakers, with 2LL VT connection).

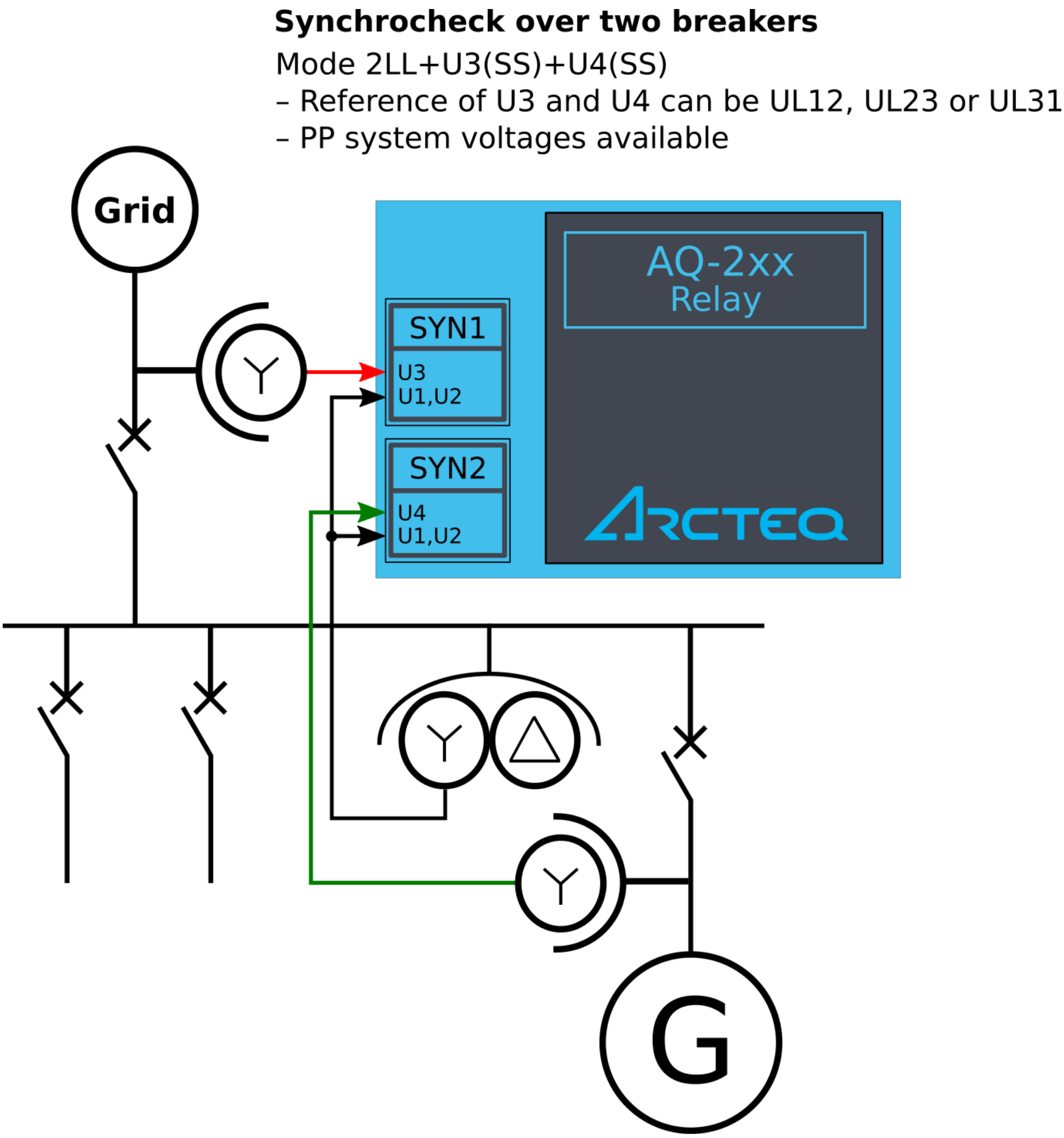
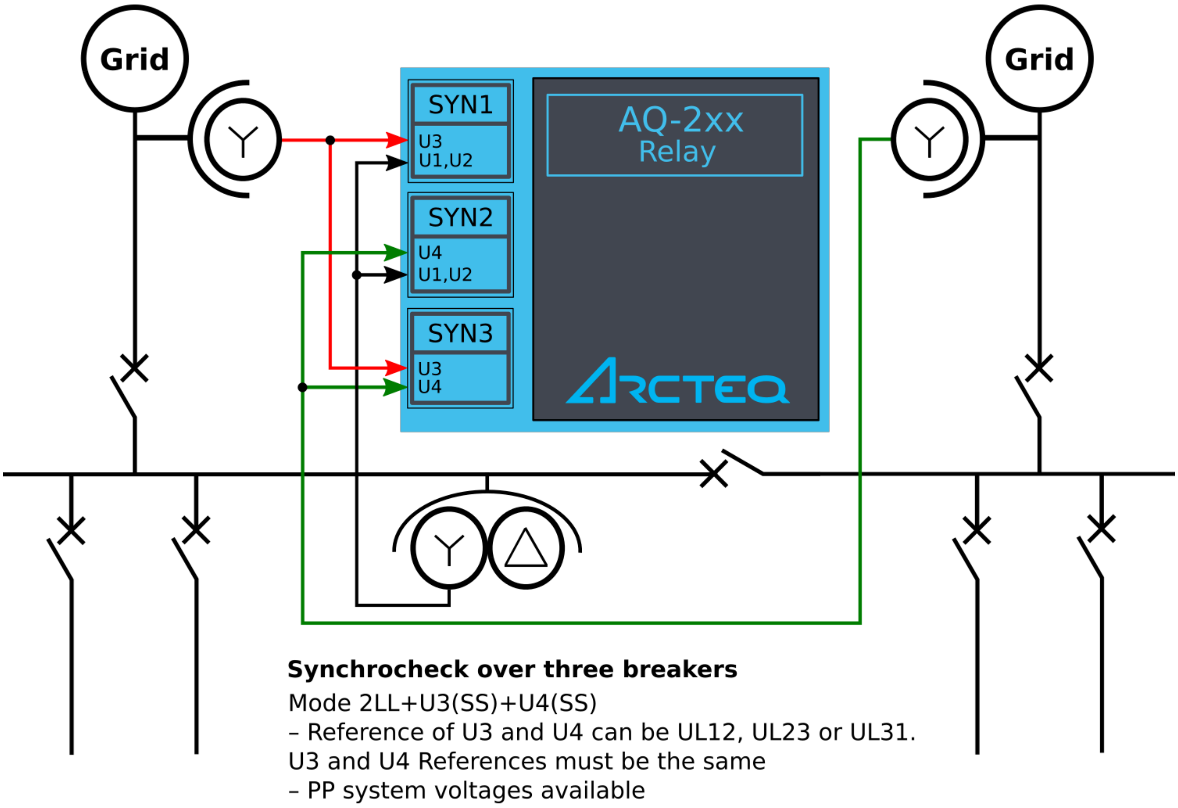


Figure. 5.4.4 - 126. Example application (synchrocheck over three breakers, with 2LL+U3+U4 connection).



The following aspects of the compared voltages are used in synchorization:

- voltage magnitudes
- voltage frequencies
- voltage phase angles

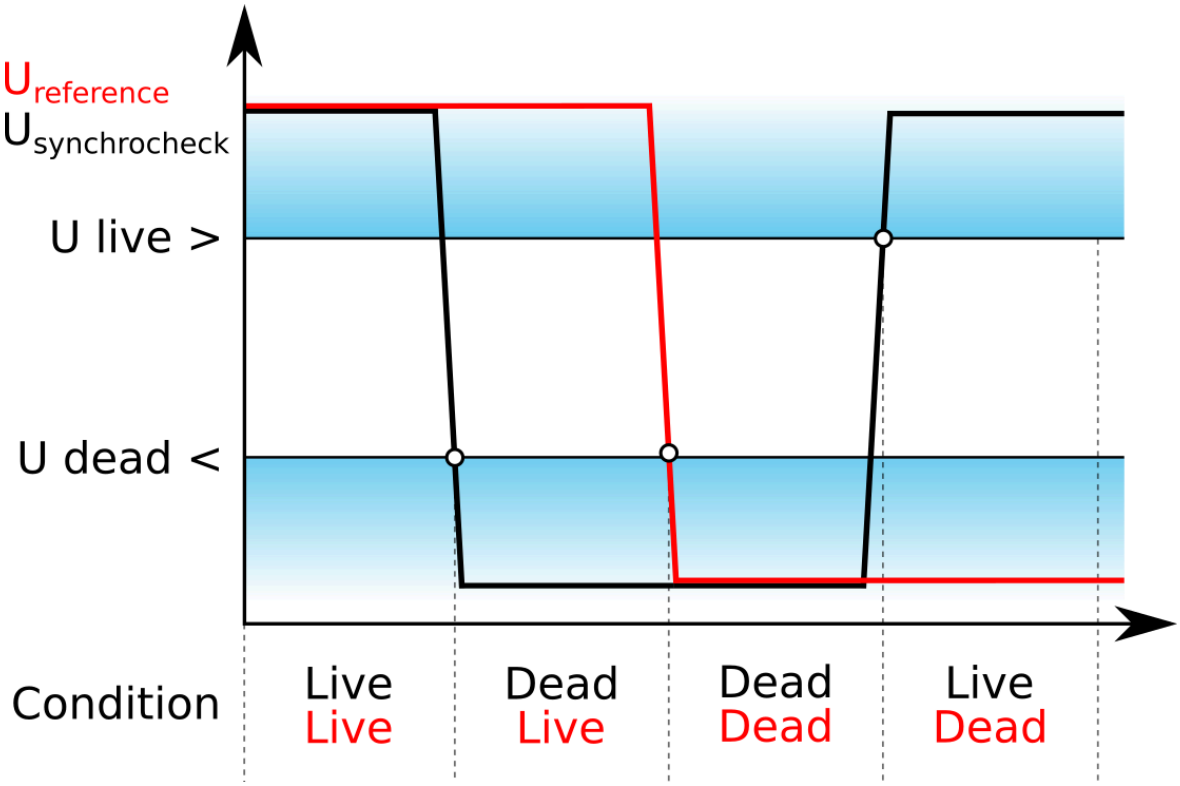
The two systems are synchronized when these three aspects are matched. All three cannot, of course, ever be exactly the same so the function requires the user to set the maximum difference between the measured voltages.

The outputs of the function are the SYN OK, BYPASS, and BLOCKED signals. The synchrocheck function uses a total of eight (8) separate setting groups which can be selected from one common source.

Depending on how the measured voltage compares to the set *U live>* and *U dead<* parameters, either system can be in a "live" or a "dead" state. The parameter *SYNx U conditions* is used to determine the conditions (in addition to the three aspects) which are required for the systems to be considered synchronized.

The image below shows the different states the systems can be in.

Figure. 5.4.4 - 127. System states.



The following figures present simplified function block diagrams of the synchrocheck function.

Figure. 5.4.4 - 128. Simplified function block diagram of the SYN1 and SYN2 function.

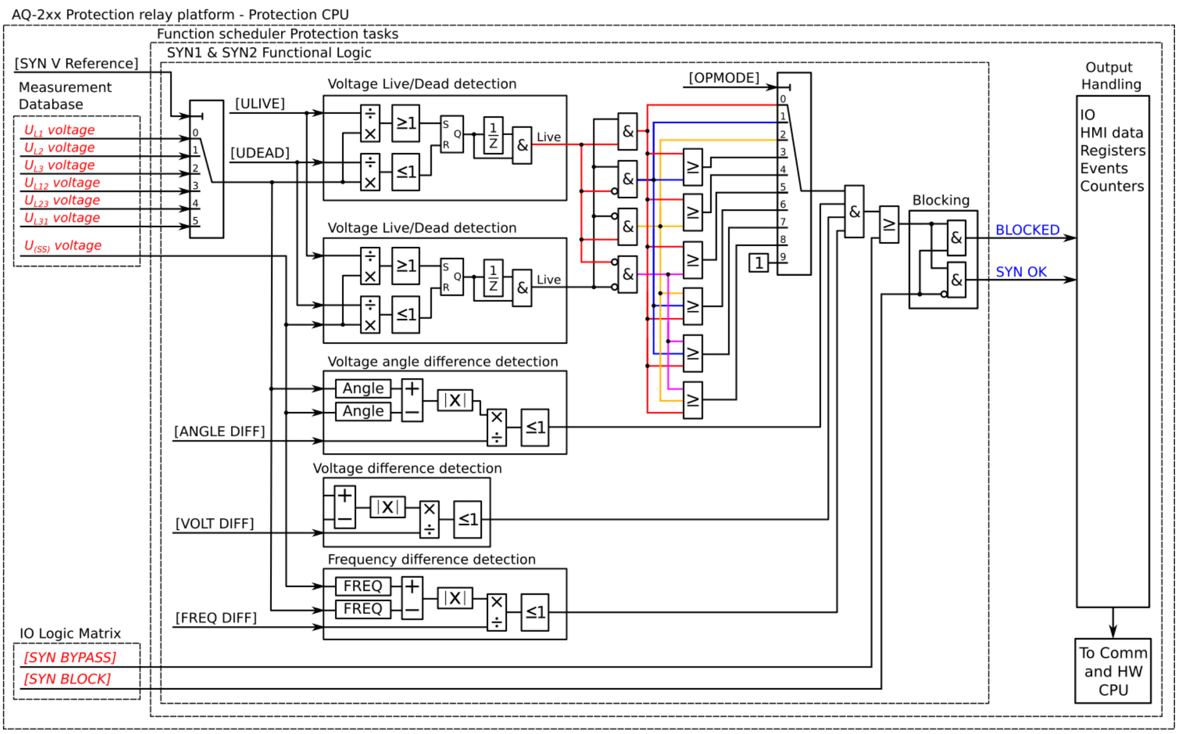
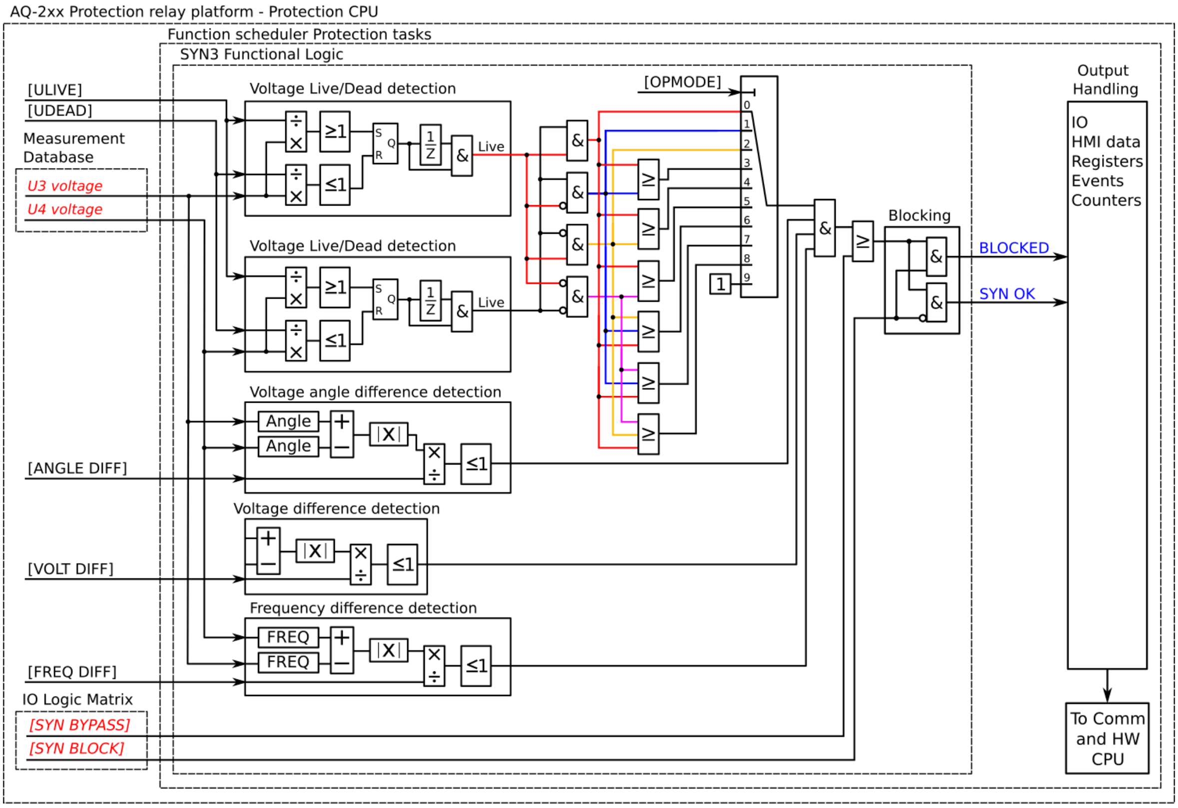


Figure. 5.4.4 - 129. Simplified function block diagram of the SYN3 function.



Measured input

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

Table. 5.4.4 - 95. Measurement inputs of the synchrocheck function.

Signal	Description	Time base
U_1RMS	RMS measurement of voltage U_1/V	5ms
U_2RMS	RMS measurement of voltage U_2/V	5ms
U_3RMS	RMS measurement of voltage U_3/V	5ms
U_4RMS	RMS measurement of voltage U_4/V	5ms

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. 5.4.4 - 96. Information displayed by the function.

Name	Range	Step	Description
SYN condition	0: SYN1 Blocked 1: SYN1 Ok 2: SYN1 Bypass 3: SYN1 Vcond Ok 4: SYN1 Vdiff Ok 5: SYN1 Adiff Ok 6: SYN1 fdiff Ok	-	Displays status of the control function.
SYN volt status	0: Dead Dead 1: Live Dead 2: Dead Live 3: Live Live 4: Undefined 5: Not monitored	-	Displays the voltage status of both sides.
SYN Mag diff	-120...120%Un	0.01%Un	Displays voltage difference between the two measured voltages.
SYN Ang diff	-360'...360deg	0.01deg	Displays angle difference between the two measured voltages.
SYN Freq diff	-75...75Hz	0.001Hz	Displays frequency difference between the two measured voltages.
SYN Switch status	0: Still 1: Departing 2: Enclosing	-	Displays the synchroswitching status. This parameter is visible when "SYN1 Switching" parameter has been set to "Use SynSW".
Estimated BRK closing time	0...360s	0.005s	Estimated time left to breaker closing.
Networks rotating time	0...360s	0.005s	Estimated time how long it takes for the network to rotate fully.
Networks placement atm	-360...360deg	0.001deg	Networks placement in degrees.

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 synchronization is OK, a SYN OK signal is generated.

If the blocking signal is active when the SYN OK activates, a BLOCKED signal is generated and the function does not process the situation further. If the SYN OK function has been activated before the blocking signal, it resets.

The blocking of the function causes an HMI display event and a-time stamped blocking event with information of the startup voltage 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.

Setting parameters

NOTE! Before these settings can be accessed, a voltage channel (U3 or U4) must be set into the synchrocheck mode ("SS") in the voltage transformer settings (*Measurements → VT Module*).

The general settings can be found at the synchrocheck function's *INFO* tab, while the synchrocheck stage settings can be found in the *Settings* tab (*Control → Control functions → Synchrocheck*).

Table. 5.4.4 - 97. General settings.

Name	Range	Step	Default	Description
Use SYNx	0: No 1: Yes	-	0: No	Activated/de-activates the individual stages (SYN1, 2, and 3) of the synchrocheck function. Activating a stage reveals the parameter settings for the configuration.
SYN1 V Reference	0: Not in use 1: UL12 2: UL23 3: UL31 4: UL1 5: UL2 6: UL3	-	0: Not in use	Selects the reference voltage of the stage. Please note that the available references depend on the selected mode. All references available: - 3LN+U4(SS) - 2LL+U3(U0)+U4(SS) - 2LL+U3(SS)+U4(U0) Reference options 0...3 available: - 3LL+U4(SS) - 2LL+U3(Not in use)+U4(SS) - 2LL+U3(SS)+U4(Not in use)
SYN1 Switching	0: Not in use 1: Use SynSW	-	0: Not in use	Disables or enables synchroswitching. Synchroswitching is available only for SYN1. When synchroswitching is used, the function automatically closes the breaker when both sides of the breaker are synchronized. This setting is only visible when "Use SYN1" is activated.
SYN1 Switch bk time	0.000...1800.000s	0.005s	0.05s	Estimated time between a close command given to a breaker and the breaker entering the closed state. This setting is used to time the closing of the breaker so that both sides are as synchronized as possible when the breaker is actually closed. This setting is only visible when "SYN1 switching" is activated.
SYN1 Switching object	0: Object 1 1: Object 2 2: Object 3 3: Object 4 4: Object 5	-	0: Object 1	When synchroswitching is enabled, this parameter defines which object receives the breaker's closing command. This setting is only visible when "SYN1 switching" is activated.
Estimated BRK closing time	0.000…360.000s	0.005s	-	Displays the estimated time until networks are synchronized.
Networks rotating time	0.000…360.000s	0.005s	-	Displays the time it takes for both sides of the network to fully rotate.
Networks placement atm	-360.000…360.000deg	0.001deg	-	Indicates the angle difference between the two sides of the breaker at the moment.
SYN2 V Reference	0: Not in use 1: UL12 2: UL23 3: UL31 4: UL1 5: UL2 6: UL3	-	0: Not in use	Selects the reference voltage of the stage. SYN2 is available when both U3 and U4 have been set to SS mode.
SYN3 V Reference	0: Not in use 1: U3–U4	-	0: Not in use	Enables and disables the SYN3 stage. Operable in the 2LL+U3+U4 mode, with references UL12, UL23 and UL31 can be connected to the channels..

Table. 5.4.4 - 98. Synchrocheck stage settings.

Name	Range	Step	Default	Description
SYNx U conditions	0: LL only 1: LD only 2: DL only 3: LL & LD 4: LL & DL 5: LL & DD 6: LL & LD & DL 7: LL & LD & DD 8: LL & DL & DD 9: Bypass	-	0: LL only	Determines the allowed states of the supervised systems. L = Live D = Dead
SYNx U live >	0.10…100.00%Un	0.01%Un	20%Un	The voltage limit of the live state.
SYNx U dead <	0.00…100.00%Un	0.01%Un	20%Un	The voltage limit of the dead state.
SYNx U diff <	2.00…50.00%Un	0.01%Un	2.00%Un	The maximum allowed voltage difference between the systems.
SYNx angle diff <	3.00…90.00deg	0.01deg	3deg	The maximum allowed angle difference between the systems.
SYNx freq diff <	0.05…0.50Hz	0.01Hz	0.1Hz	The maximum allowed frequency difference between the systems.

Events and registers

The synchrocheck function (abbreviated "SYN" in event block names) generates events and registers from status changes such as SYN OK, BYPASS, and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both. The function offers three (3) independent stages; the events are segregated for each stage operation.

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

Table. 5.4.4 - 99. Event codes.

Event number	Event channel	Event block name	Event code	Description
2880	45	SYN1	0	SYN1 Blocked On
2881	45	SYN1	1	SYN1 Blocked OFF
2882	45	SYN1	2	SYN1 Ok ON
2883	45	SYN1	3	SYN1 Ok OFF
2884	45	SYN1	4	SYN1 Bypass ON
2885	45	SYN1	5	SYN1 Bypass OFF
2886	45	SYN1	6	SYN1 Volt condition OK
2887	45	SYN1	7	SYN1 Volt cond not match
2888	45	SYN1	8	SYN1 Volt diff Ok
2889	45	SYN1	9	SYN1 Volt diff out of setting
2890	45	SYN1	10	SYN1 Angle diff Ok
2891	45	SYN1	11	SYN1 Angle diff out of setting
2892	45	SYN1	12	SYN1 Frequency diff Ok
2893	45	SYN1	13	SYN1 Frequency diff out of setting
2894	45	SYN1	14	SYN2 Blocked ON
2895	45	SYN1	15	SYN2 Blocked OFF

Event number	Event channel	Event block name	Event code	Description
2896	45	SYN1	16	SYN2 Ok ON
2897	45	SYN1	17	SYN2 Ok OFF
2898	45	SYN1	18	SYN2 Bypass ON
2899	45	SYN1	19	SYN2 Bypass OFF
2900	45	SYN1	20	SYN2 Volt condition OK
2901	45	SYN1	21	SYN2 Volt cond not match
2902	45	SYN1	22	SYN2 Volt diff Ok
2903	45	SYN1	23	SYN2 Volt diff out of setting
2904	45	SYN1	24	SYN2 Angle diff Ok
2905	45	SYN1	25	SYN2 Angle diff out of setting
2906	45	SYN1	26	SYN2 Frequency diff Ok
2907	45	SYN1	27	SYN2 Frequency diff out of setting
2908	45	SYN1	28	SYN3 Blocked ON
2909	45	SYN1	29	SYN3 Blocked OFF
2910	45	SYN1	30	SYN3 Ok ON
2911	45	SYN1	31	SYN3 Ok OFF
2912	45	SYN1	32	SYN3 Bypass ON
2913	45	SYN1	33	SYN3 Bypass OFF
2914	45	SYN1	34	SYN3 Volt condition OK
2915	45	SYN1	35	SYN3 Volt cond not match
2916	45	SYN1	36	SYN3 Volt diff Ok
2917	45	SYN1	37	SYN3 Volt diff out of setting
2918	45	SYN1	38	SYN3 Angle diff Ok
2919	45	SYN1	39	SYN3 Angle diff out of setting
2920	45	SYN1	40	SYN3 Frequency diff Ok
2921	45	SYN1	41	SYN3 Frequency diff out of setting
2922	45	SYN1	42	SYN1 Switch ON
2923	45	SYN1	43	SYN1 Switch OFF
2924	45	SYN1	44	SYN2 Switch ON
2925	45	SYN1	45	SYN2 Switch OFF
2926	45	SYN1	46	SYN3 Switch ON
2927	45	SYN1	47	SYN3 Switch 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. 5.4.4 - 100. Register content.

Name	Range
Date and time	dd.mm.yyyy hh:mm:ss.mss
Event code	2880...2927 Descr.

Name	Range
SYNx Ref1 voltage	The reference voltage of the selected stage.
SYNx Ref2 voltage	The reference voltage of the selected stage.
SYNx Volt Cond	The voltage condition of the selected stage.
SYNx Volt status	The voltage status of the selected stage.
SYNx Vdiff	The voltage difference of the selected stage.
SYNx Vdiff cond	The set condition of the voltage difference of the selected stage.
SYNx Adiff	The angle difference of the selected stage.
SYNx Adiff cond	The set condition of the angle difference of the selected stage.
SYNx fdiff	The frequency difference of the selected stage.
SYNx fdiff cond	The set condition of the frequency difference of the selected stage.
Setting group in use	Setting group 1...8 active.

5.4.5 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. 5.4.5 - 130. Activating mA output channels.

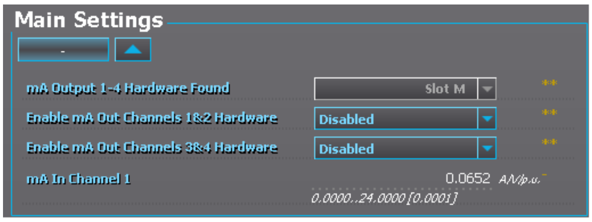


Table. 5.4.5 - 101. Main settings (output channels).

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.

Name		Range	Default	Description
	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. 5.4.5 - 102. 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	$-10^7 \ldots 10^7$	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	$-10^7 \ldots 10^7$	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. 5.4.5 - 131. Example of the effects of mA output channel settings.

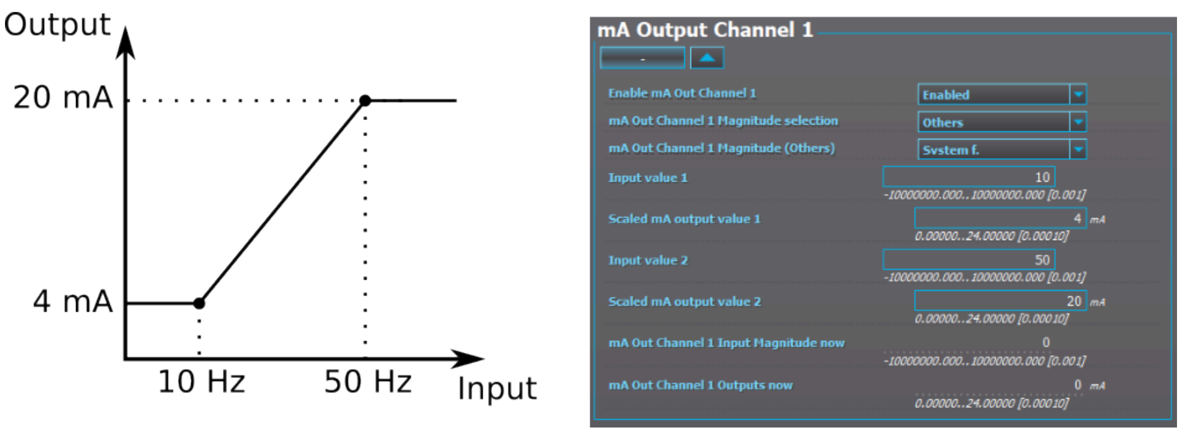


Table. 5.4.5 - 103. Hardware indications.

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. 5.4.5 - 104. Measurement values reported by mA output cards.

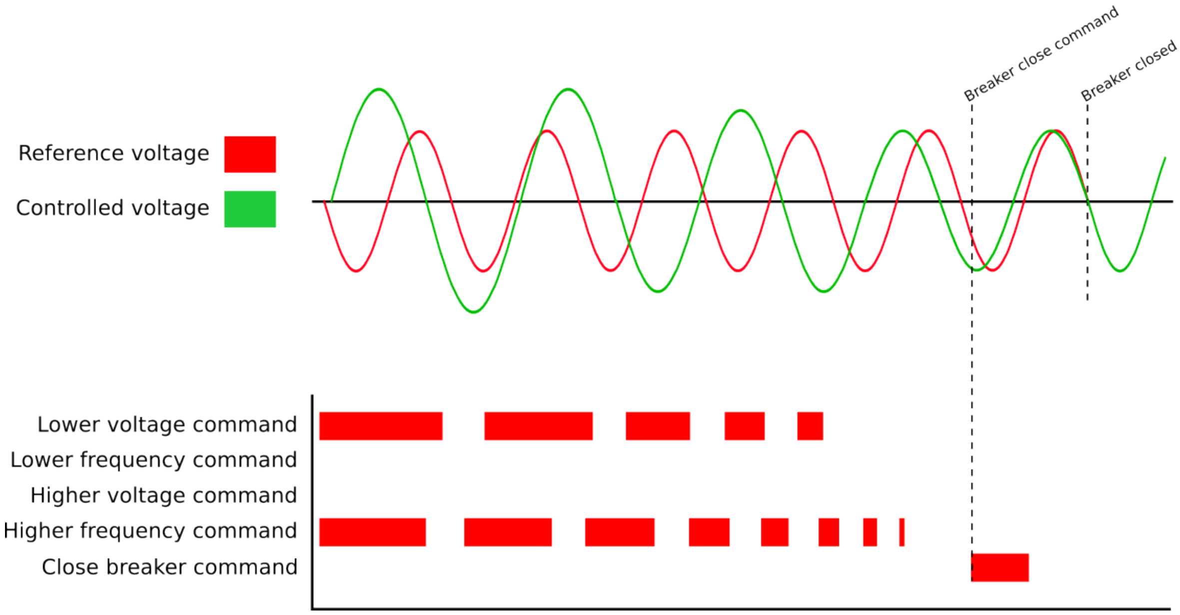
Name	Range	Step	Description
mA in Channel 1	0.0000…24.0000mA	0.0001mA	Displays the measured mA value of the selected input channel.
mA in Channel 2			
mA Out Channel Input Magnitude now	$-10^{7}…10^{7}$	0.001	Displays the input value of the selected mA output channel at that moment.
mA Out Channel Outputs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

5.4.6 Synchronizer (ΔV/Δa/Δf; 25)

The synchronizer function is used to automatically synchronize generators to power grids. Proper synchronizing is essential to avoid inrush currents, power system oscillations as well as thermal and mechanical stress on the generator when connecting a synchronous generator to a grid.

The user can synchronize up to eight (8) circuit breakers with the same synchronizing function by using different setting groups and the logic editor. The synchrocheck function is used to parallel or energize power lines.

Figure. 5.4.6 - 132. Simplified presentation of synchronizer operation



The synchronizing function uses voltage signals from each side of the circuit breaker to be closed.

- The amplitude difference between the two voltages is used to send "Increase" and "Decrease" commands to the generator's voltage regulator. The pulse length for these commands can be set, and it is automatically adjusted depending on the difference between the two measured signals.
- The frequency difference between the two voltages (the slip frequency) is used to send "Increase" and "Decrease" commands to the turbine's speed governor. The pulse length for these commands can be adjusted individually to take into account turbine governors with different speeds. The pulse length is automatically adjusted depending on the difference between the two measured signals.
- Settings can be adjusted to only allow positive slip to avoid reverse power at synchronizing.
- When the amplitude, the speed, and the phase-angle between the two voltages match (within pre-set limits), a "Close" command signal is sent to the generator's circuit breaker.

Pre-closing time can be used to allow for delay time in a circuit breaker and any auxiliary relays. The pre-closing angle is adjusted automatically depending on the slip frequency.

The outputs of the function are the following signals:

- Voltage Magnitude Difference Ok
- Voltage Frequency Difference Ok
- Voltage Angle Difference Ok
- Blocked
- Running
- Increase Voltage
- Decrease Voltage
- Increase Frequency
- Decrease Frequency
- Breaker Close Pulse
- Long Sync Time
- Nets Standstill
- Nets Departing
- Nets Enclosing

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 signals can be used for direct I/O controlling and user logic programming. The time stamp resolution is 1 ms.

Measured input

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

Table. 5.4.6 - 105. Measurement inputs of the synchronizer function.

Signal	Description	Time base
U_1RMS	RMS measurement of voltage U_1/V	5ms
U_2RMS	RMS measurement of voltage U_2/V	5ms
U_3RMS	RMS measurement of voltage U_3/V	5ms
U_4RMS	RMS measurement of voltage U_4/V	5ms

Setting parameters

Table. 5.4.6 - 106. General setting parameters.

Name	Range	Step	Default
Voltage difference calculation mode	0: System is reference 1: U3/U4 input is reference	-	0: System is reference
Synchronizer voltage reference	0: UL12 1: UL23 2: UL31 3: UL1 4: UL2 5: UL3	-	0: UL12
Synchronizer measurement settings	0: Meas.Conf.Incorrect 1: PP and PE voltages 2: PP Voltages	-	-
Synchronizer status	0: Conf.Error 1: Idle Ready 2: Synchronizing 3: Blocked	-	-
Synchroswitch status	0: Standstill 1: Departing 2: Enclosing	-	-
Magnitude difference	-200.000...200.000%Un	0.001%Un	0%Un
Frequency difference	-100.000...100.000Hz	0.001Hz	0Hz
Angle difference	-360.000...360.000deg	0.001deg	0deg
Magnitude difference on closing BRK	-200.000...200.000%Un	0.001%Un	0%Un
Frequency difference on closing BRK	-100.000...100.000Hz	0.001Hz	0Hz
Angle difference on closing BRK	-360.000...360.000deg	0.001deg	0deg
Estimated BRK Closing time	0.000...360.000s	0.005s	0s
Networks rotating time	0.000...360.000s	0.005s	0s

Name	Range	Step	Default
Networks placement atm	-360.000...360.000deg	0.001deg	0deg
Synchronizing time left	0.000...1800.000s	0.005s	0s
Get measurement errors for fine tuning	0: - 1: Get errors	-	0: -
Magnitude difference fine tune	-200.000...200.000%	0.001%	0%
Frequency difference fine tune	-100.000...100.000Hz	0.001Hz	0Hz
Angle difference fine tune	-360.000...360.000deg	0.001deg	0deg

Table. 5.4.6 - 107. Synchronizing settings.

Name	Range	Step	Default
Maximum allowed voltage difference	0.10...50.00%Un	0.01%Un	2.00%Un
Maximum allowed overfrequency difference to allow synchronizing	0.00...2.00Hz	0.01Hz	0.2Hz
Maximum allowed underfrequency difference to allow synchronizing	0.00...2.00Hz	0.01Hz	0Hz
Maximum time for synchronizing	0.000...1800.000s	0.005s	300.000s
Maximum allowed angular disposition to allow synchronizing	-25.00...25.00deg	0.01deg	10.00deg
Adjustment for measurement inaccuracy or set of desired volt. offset	-95.0000...95.0000%Un	0.0001%Un	0%Un
Adjustment for measurement inaccuracy or set of desired angular offset	-60.0000...60.0000deg	0.0001deg	0deg
Adjustment for measurement inaccuracy or set of desired freq. offset	-0.5000...2.0000Hz	0.0001Hz	-0.1000Hz
Voltage adjustment slope	0.00...25.00%/s	0.01%/s	0.20%/s
Volt. Max. adjustment pulse length	0.000...1800.000s	0.005s	3.000s
Volt. Min. adjustment pulse length	0.000...1800.000s	0.005s	0.100s
Volt. Min. Resting time between pulses	0.000...1800.000s	0.005s	2.500s
Freq. Max. adjustment pulse length	0.000...1800.000s	0.005s	3.000s
Freq. Min. adjustment pulse length	0.000...1800.000s	0.005s	0.100s
Freq. Min. Resting time between pulses	0.000...1800.000s	0.005s	2.500s
Frequency adjustment slope when increasing	0.00...10.00Hz/s	0.01Hz/s	0.10Hz/s
Frequency adjustment slope when decreasing	-10.00...0.00Hz/s	0.01Hz/s	-0.10Hz/s
Circuit breaker pre-closing time incl auxiliary relays	0.000...1800.000s	0.005s	0.100s
Lenght of circuit breaker closing pulse	0.000...1800.000s	0.005s	0.250s
Multiple On pulses	0: Single On pulse 1: Multiple pulses	-	0: Single On pulse

Table. 5.4.6 - 108. Synchronizer internal parameters.

Name	Range	Step	Default
Maximum allowed voltage difference to start synchronizing	0.00...50.00%Un	0.01%Un	20.00%Un
Block voltage up commands over	0.00...50.00%Un	0.01%Un	20.00%Un
Block voltage down commands under	-50.00...50.00%Un	0.01%Un	-20.00%Un

Name	Range	Step	Default
Integrator sum when voltage adjustment pulse is generated	0.00...50.00%	0.01%	10.00%
Voltage adjustment pulse length constant	0.00...5000.00	0.01	1000.00
Maximum allowed frequency difference to start synchronizing	0.00...25.00Hz	0.01Hz	5.00Hz
Integrator sum when frequency adjustment pulse is generated	0.00...50.00Hz	0.01Hz	1.00Hz
Frequency adjustment pulse length constant	0.00...5000.00	0.01	1000.00
Filter time for angle derivative	0.000...1800.000s	0.005s	1.000s
Circuit breaker pre-closing adjustment constant	0.00...10.00	0.01	0.10

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 BREAKER CLOSE PULSE 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.

The blocking of the function causes an HMI display event and a-time stamped blocking event with information of the startup voltage 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.

Events

The synchronizing function (abbreviated "GSYN" in event block names) generates events and registers from the status changes in the following: VOLTAGE MAG/FREQ/ANG DIFFERENCE OK, RUNNING, DECREASE/INCREASE VOLTAGE/FREQUENCY, BREAKER CLOSE PULSE, LONG SYNC TIME, and BLOCKED. The user can select which event messages are stored in the main event buffer: ON, OFF, or both.

Table. 5.4.6 - 109. Event codes.

Event number	Event channel	Event block name	Event code	Description
10368	162	GSYN	0	Synchronizing Blocked ON
10369	162	GSYN	1	Synchronizing Blocked OFF
10370	162	GSYN	2	Synchronizing Running ON
10371	162	GSYN	3	Synchronizing Running OFF
10372	162	GSYN	4	Synchr. Increase Voltage ON
10373	162	GSYN	5	Synchr. Increase Voltage OFF
10374	162	GSYN	6	Synchr. Decrease Voltage ON
10375	162	GSYN	7	Synchr. Decrease Voltage OFF
10376	162	GSYN	8	Synchr. Increase Frequency ON

Event number	Event channel	Event block name	Event code	Description
10377	162	GSYN	9	Synchr. Increase Frequency OFF
10378	162	GSYN	10	Synchr. Decrease Frequency ON
10379	162	GSYN	11	Synchr. Decrease Frequency OFF
10380	162	GSYN	12	Synchronizer BRK Close ON
10381	162	GSYN	13	Synchronizer BRK Close OFF
10382	162	GSYN	14	Synchronizer Long Sync. Time ON
10383	162	GSYN	15	Synchronizer Long Sync. Time OFF
10384	162	GSYN	16	Synchroswitch Close fail Re-init ON
10385	162	GSYN	17	Synchroswitch Close fail Re-init OFF
10386	162	GSYN	18	Synchroswitching requested ON
10387	162	GSYN	19	Synchroswitching requested OFF

5.4.7 Vector jump (Δφ; 78)

Distribution systems may include different kinds of distributed power generation sources, such as wind farms and diesel or fuel generators. When a fault occurs in the distribution system, it is usually detected and isolated by the protection system closest to the faulty point, resulting in the electrical power system shutting dow either partially or completely. The remaining distributed generators try to deliver the power to the part of the distribution system that has been disconnected from the grid, and usually an overload condition can be expected. Under such overload conditions, it is normal to have a drop in voltage and frequency. This overload results in the final system disconnection from the islanding generator(s). The disconnection depends greatly on the ratio between the power generation and the demand of the islanded system. When any power is supplied to a load only from distributed generators, (due to the opening of the main switch), the situation is called an isolated island operation or an islanded operation of the electrical distribution network.

The vector jump control function is suitable to detect most islanding situations and to switch off the mains breaker in order to let the generator only supply loads according to their rated power value. Therefore, an overload does not cause any mechanical stress to the generator unit(s). The vector jump relay should be located either on the mains side of the operated breaker or on the islanding generator side.

The vector jump function is used for instant tripping and has only one operating stage. The function has an algorithm which follows the samples of chosen measured voltages (64 samples/cycle). The reference voltage used can be all or any of the phase-to-phase or phase-to-neutral voltages.

The outputs of the function are the ALARM, TRIP and BLOCKED signals. Both ALARM and TRIP signals have an individual pick-up setting. 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. The vector jump 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 checks (undervoltage block or stage external signal)
- time delay characteristics
- output processing.

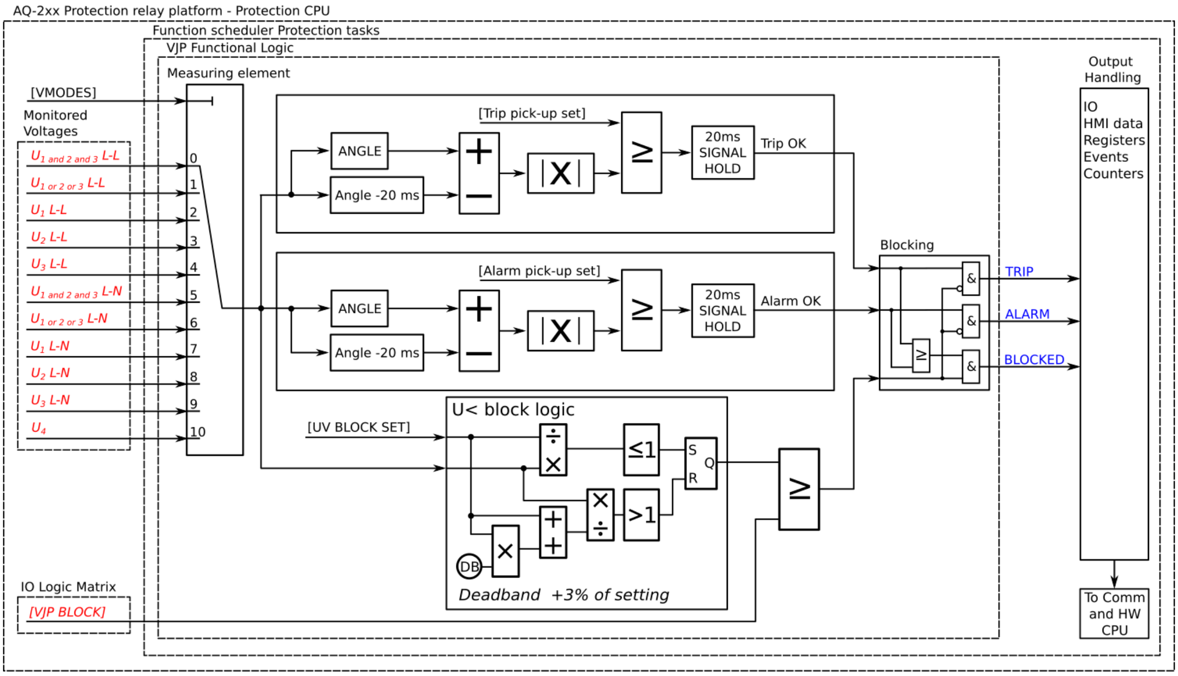
The inputs for the function are the following:

- available stages
- setting parameters
- digital inputs and logic signals
- measured and pre-processed voltage magnitudes.

The function outputs the ALARM, TRIP and BLOCKED signals which 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 three (3) output signals. When tripping, the function outputs ALARM and TRIP events simultaneously with an equivalent time stamp. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the ALARM, TRIP and BLOCKED events.

The following figure presents a simplified function block diagram of the vector jump function.

Figure. 5.4.7 - 133. Simplified function block diagram of the Δφ function.



Measured input

The function block uses analog voltage measurement values and always uses complex measurement from samples. A -20 ms averaged value of the selected magnitude is used for pre-fault data registering.

Table. 5.4.7 - 110. Measurement inputs of the vector jump function.

Signal	Description	Time base
U_1L-L	Measured line-to-line voltage U_1/V	5ms
U_2L-L	Measured line-to-line voltage U_2/V	5ms
U_3L-L	Measured line-to-line voltage U_3/V	5ms
U_1L-N	Measured line-to-neutral voltage U_1/V	5ms
U_2L-N	Measured line-to-neutral voltage U_2/V	5ms
U_3L-N	Measured line-to-neutral voltage U_3/V	5ms

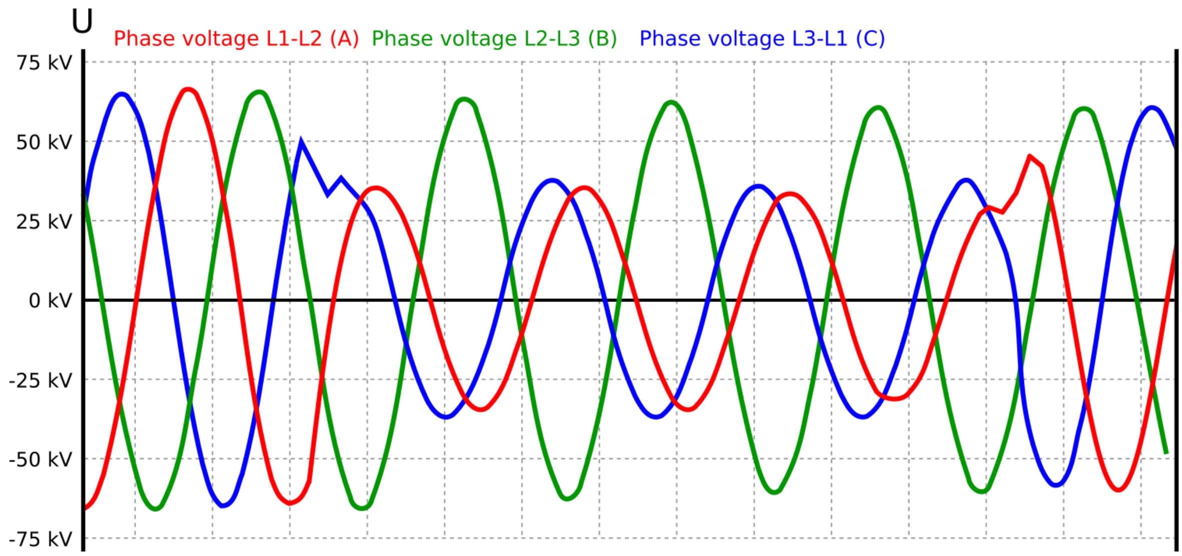
Signal	Description	Time base
U_4	Measured voltage U_4/V	5ms

The selection of the used AI channel is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from ALARM or TRIP event.

Pick-up

When a fault appears in the power system and some areas are disconnected, normally the remaining generators connected to the network must supply the area disconnected from the utility side supply. This results in an instantaneous demand of power that the generators must tackle. The excitation and the mechanical systems cannot answer such a huge demand of power quickly even if there were enough reserve power. The worst of the situation is received by the rotors of the generator units: they suffer a torsion torque that can even break the rotor and cause subsequent damage not only for the generator but for the entire power plant too.

Figure. 5.4.7 - 134. Generator islanding.



As can be seen in the example above, only phase-to-phase voltages L1-L2 and L3-L1 have been reduced, while voltage L2-L3 remains the same. This means that the problem occured in phase L1 of the network. The voltage level is not reduced to zero, nor is the voltage in any phase is totally lost. The phases without the fault condition remain normal with the same value. On the other hand, the frequency can sag as can be seen in the figure above.

The *Δα* setting parameter controls the pick-up of the vector jump function. This defines the minimum allowed rapid measured voltage angle change before action from the function. The function constantly calculates the ratio between the $\Delta\alpha_{set}$ and the measured magnitude ($\Delta\alpha_{m}$) for each of the selected voltages. The function's stage trip signal lasts for 20 ms and automatically resets after that time has passed. The setting value is common for all measured amplitudes.

Figure. 5.4.7 - 135. Vector jump from the relay's point of view.

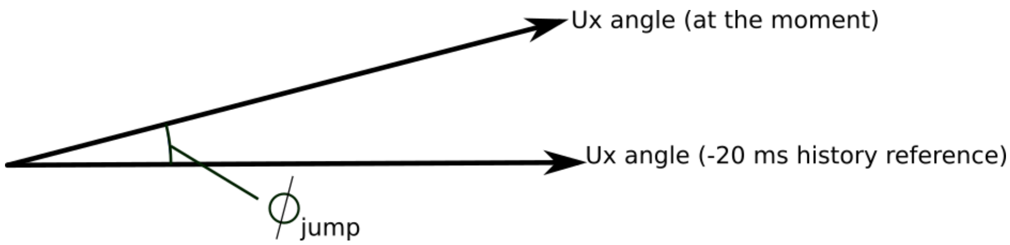


Table. 5.4.7 - 111. Pick-up settings.

Name	Description	Range	Step	Default
Available stages	Defines if alarm is included with trip or not.	0: Trip 1: Trip and alarm	-	0: Trip
Monitored voltages	Defines the monitored voltage channel(s)	0: System all P-P Voltages 1: System any P-P Voltage 2: System L12 Voltage 3: System L23 Voltage 4: System L31 Voltage 5: System all P-E voltages 6: System any P-E voltage 7: System L1 Voltage 8: System L2 Voltage 9: System L3 Voltage 10: U4 Voltage	-	0: System all P-P Voltages
Pick-up setting Δα (lead or lag) Trip	Pick-up setting for trip signal	0.05…30.00°	0.01°	5°
Pick-up setting Δα (lead or lag) Alarm	Pick-up setting for alarm signal	0.05…30.00°	0.01°	5°
Undervoltage block limit % < Un	Block setting. If set to zero, blocking is not in use. The operation is explained in the next chapter.	0.00…100.00%U_n	0.01%U_n	95%U_n

The pick-up activation of the function is not directly equal to the START or TRIP 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. 5.4.7 - 112. Information displayed by the function.

Name	Range	Step	Description
Δα > condition	0: Normal 1: Blocked 2: Trip 3: Alarm	-	Displays status of the protection function.
Voltage meas selected	0: Selection Ok 1: Selection not available	-	Displays validity of the voltage channel(s) selected in "Monitored voltages" parameter.
Δα > U1 Angle difference	-360...360deg	0.01deg	Displays the angle difference between present time and 20 ms ago.
Δα > U2 Angle difference			
Δα > U3 Angle difference			

Name	Range	Step	Description
Δα > U1meas/set	-360...360p.u.	0.01p.u.	Displays the ratio between the measured voltage and undervoltage block limit setting.
Δα > U2meas/set			
Δα > U3meas/set			

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 ALARM or TRIP 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.

The blocking of the function causes an HMI display event and a time-stamped blocking event with information of the startup voltage 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.

Events and registers

The vector jump function (abbreviated "VJP" in event block names) generates events and registers from the status changes in START, TRIP, and BLOCKED. 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. 5.4.7 - 113. Event codes.

Event number	Event channel	Event block name	Event code	Description
9920	155	VJP1	0	Block ON
9921	155	VJP1	1	Block OFF
9922	155	VJP1	2	Trip ON
9923	155	VJP1	3	Trip OFF
9924	155	VJP1	4	Alarm ON
9925	155	VJP1	5	Alarm OFF

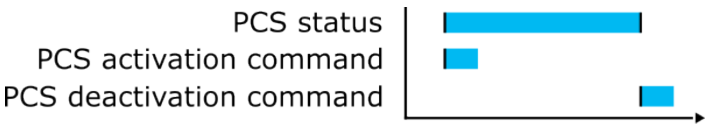
The function registers its operation into the last twelve (12) time-stamped registers. The register of the function records the ON event process data for START, TRIP or BLOCKED. The table below presents the structure of the function's register content.

Table. 5.4.7 - 114. Register content.

Date and time	Event code	Fault type	Trip Δα meas / dataset	Alarm Δα meas / dataset	Used SG
dd.mm.yyyy hh:mm:ss.mss	9920-9925 Descr.	L1(2), L2(3), L3(1) and U4	Trip angle difference	Alarm angle difference	Setting group 1...8 active

5.4.8 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. 5.4.8 - 115. 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. 5.4.8 - 116. 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

5.4.9 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. 5.4.9 - 117. 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.
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.

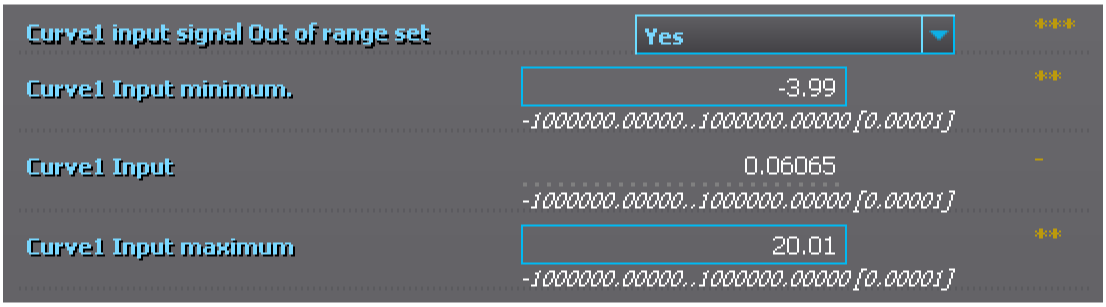
Name	Range	Step	Default	Description
Curve1...4 output	-1 000 000.00...1 000 000.00	0.00001	-	Displays the output of the curve.

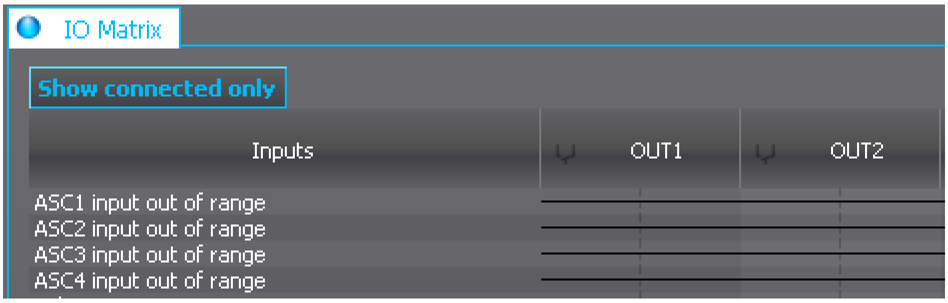
The input signal filter (see the image below) calculates the average of received signals according to the set time constant. This is why rapid changes and disturbances (such as fast spikes) are smothered.

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. 5.4.9 - 118. Output settings and indications.

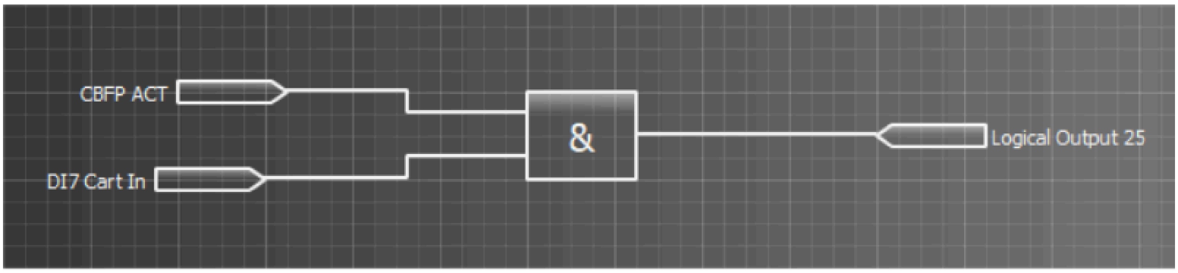
Name	Range	Step	Default	Description
Curve 1...4 update cycle	5...10 000ms	5ms	150ms	Defines the length of the input measurement update cycle. If the user wants a fast operation, this setting should be fairly low.

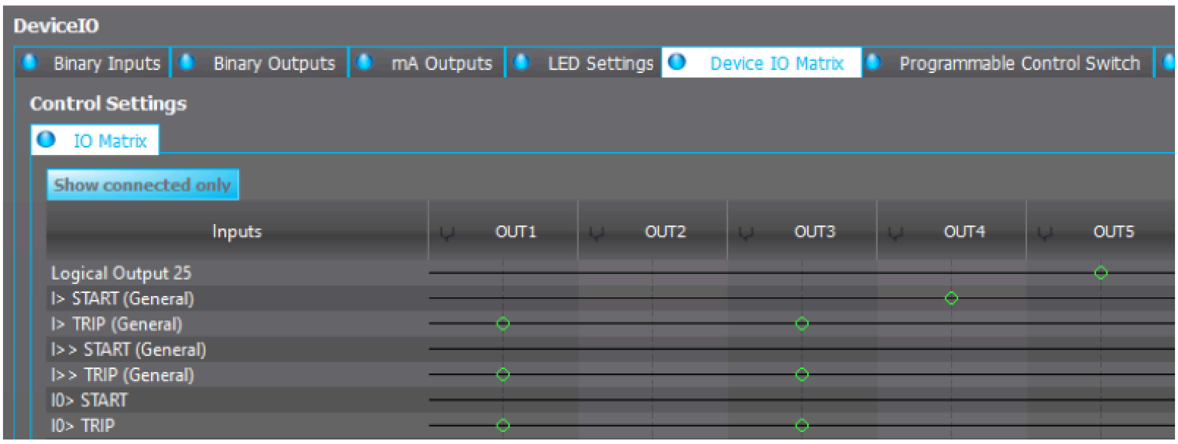
Name	Range	Step	Default	Description
Scaled value handling	0: Floating point 1: Integer out (Floor) 2: Integer (Ceiling) 3: Integer (Nearest)	-	0: Floating point	Rounds the milliampere signal output as selected.
Input value 1	0...4000	0.000 01	0	The measured input value at Curve Point 1.
Scaled output 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.

5.4.10 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. 5.4.10 - 136. Logic output example.





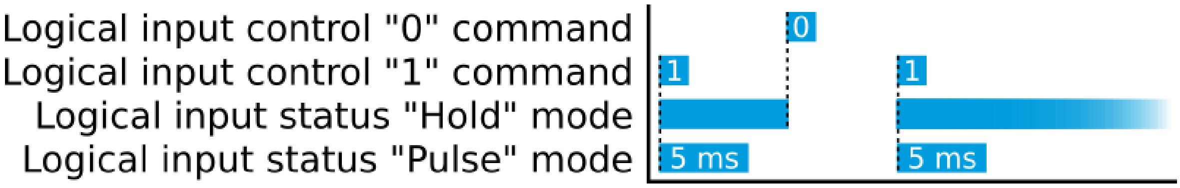
5.4.11 Logical inputs

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.

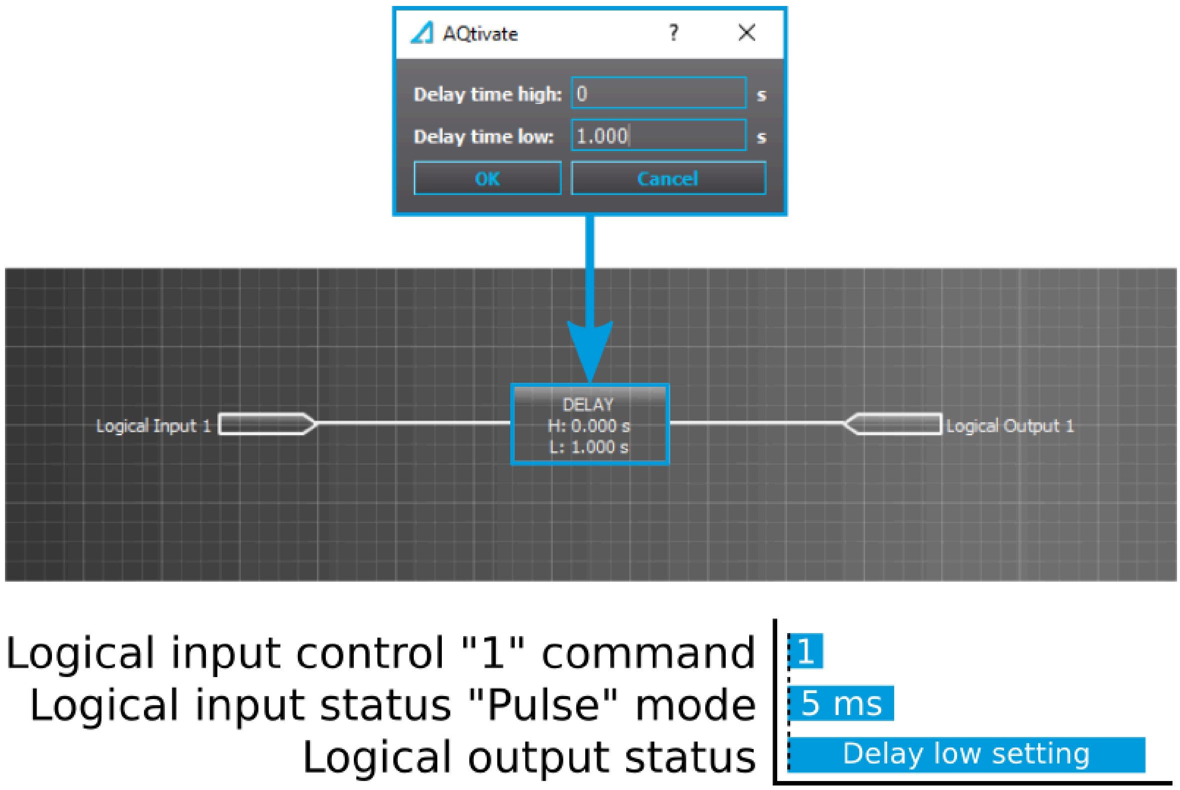
The figure below presents the operation of a logical input in Hold mode and in Pulse mode.

Figure. 5.4.11 - 137. 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. 5.4.11 - 138. Extending a logical input pulse.

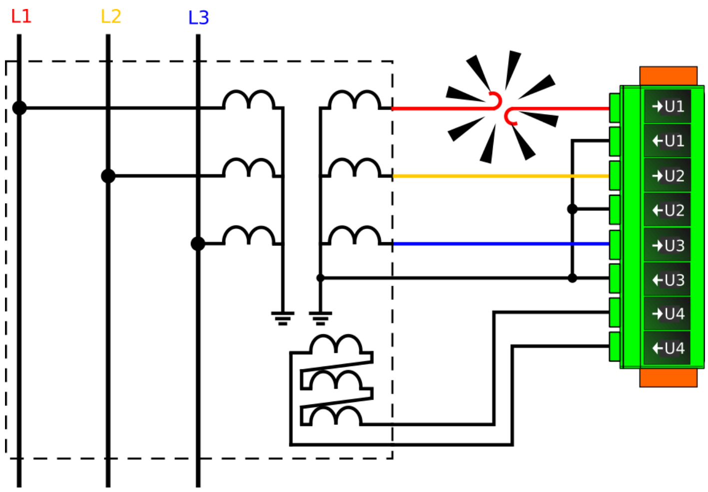


5.5 Monitoring functions

5.5.1 Voltage transformer supervision (60)

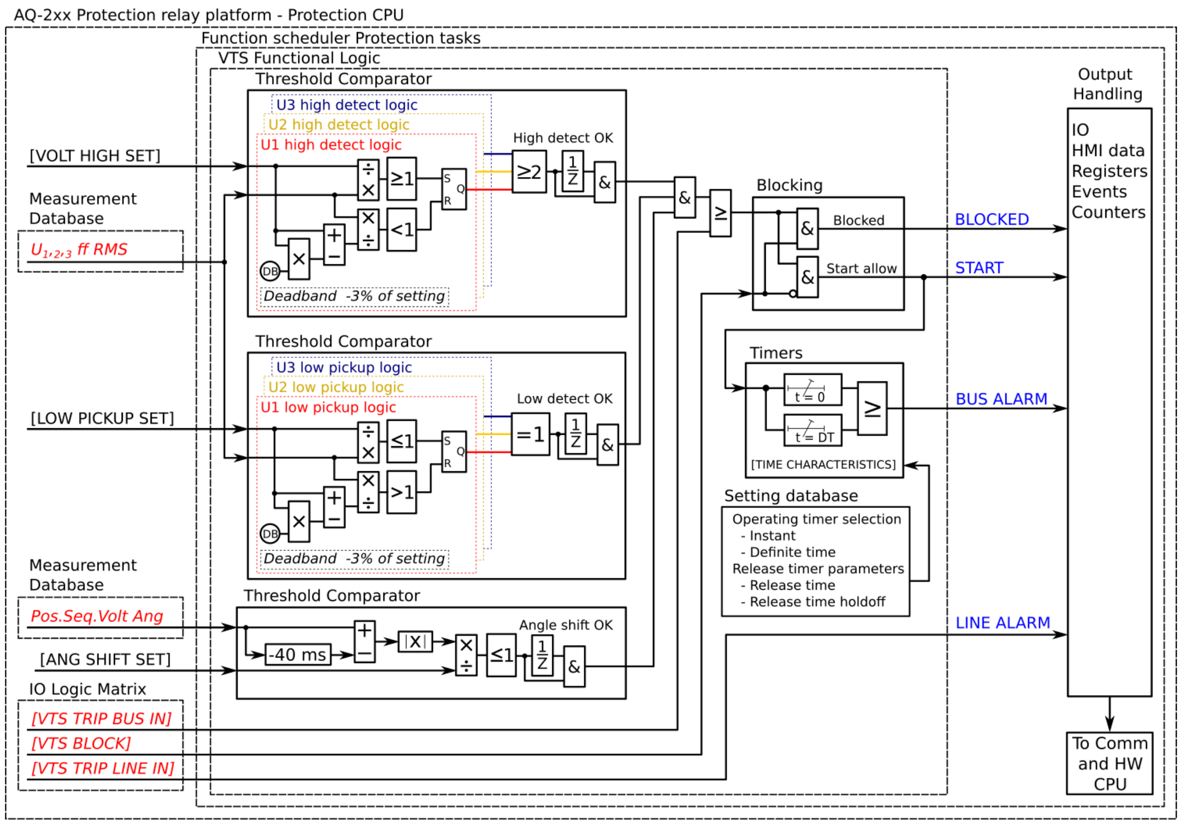
Voltage transformer supervision is used to detect errors in the secondary circuit of the voltage transformer during fuse failure. This signal is mostly used as an alarming function or to disable functions that require adequate voltage measurement.

Figure. 5.5.1 - 139. Secondary circuit fault in phase L1 wiring.



The following figure presents a simplified function block diagram of the voltage transformer supervision function.

Figure. 5.5.1 - 140. Simplified function block diagram of the VTS function.



Measured input

The function block uses analog voltage measurement values. Function uses the RMS value of the voltage measurement inputs and the calculated (positive, negative and zero) sequence currents.

Table. 5.5.1 - 119. Measurement inputs of the voltage transformer supervision function.

Signal	Description	Time base
U_{L12}RMS	RMS measurement of voltage U_{L12}/V	5ms
U_{L23}RMS	RMS measurement of voltage U_{L23}/V	5ms
U_{L31}RMS	RMS measurement of voltage U_{L31}/V	5ms
U_{L1}RMS	RMS measurement of voltage U_{L1}/V	5ms
U_{L2}RMS	RMS measurement of voltage U_{L2}/V	5ms
U_{L3}RMS	RMS measurement of voltage U_{L3}/V	5ms
U1P	Positive sequence voltage	5ms
U2N	Negative sequence voltage	5ms
UZ0	Zero sequence voltage	5ms
U_{L12}Ang	Angle of U_{L12} voltage	5ms
U_{L23}Ang	Angle of U_{L23} voltage	5ms
U_{L31}Ang	Angle of U_{L31} voltage	5ms
U_{L1}Ang	Angle of U_{L1} voltage	5ms
U_{L2}Ang	Angle of U_{L2} voltage	5ms
U_{L3}Ang	Angle of U_{L3} voltage	5ms

The selection of the AI channel in use is made with a setting parameter. In all possible input channel variations the pre-fault condition is presented with a 20 ms averaged history value from -20 ms from START or TRIP event.

Pick-up

The *Voltage low pick-up* and *Voltage high detect* setting parameters control the voltage-dependent pick-up and activation of the voltage transformer supervision function. The function's pick-up activates, if at least one of the three voltages is under the set *Voltage low pick-up* value, or if at least two of the three voltages exceed the set *Voltage high detect* value. The function constantly calculates the ratio between the setting values and the measured magnitude for each of the three phases.

Table. 5.5.1 - 120. Pick-up settings.

Name	Range	Step	Default	Description
Voltage low pickup	0.05…0.50×U_n	0.01×U_n	0.05×U_n	If one the measured voltages is below low pickup value and two of the measured voltages exceed high detect value the function's pick-up activates.
Voltage high detect	0.01…1.10×U_n	0.01×U_n	0.80×U_n	
Angle shift limit	2.00…90.00deg	0.10deg	5.00deg	If the difference between the present angle and the angle 40 ms before is below the set value, the function's pick-up is blocked.

Name	Range	Step	Default	Description
Bus fuse fail check	0: No 1: Yes	-	1: Yes	Selects whether or not the state of the bus fuse is supervised. The supervised signal is determined the "VTS MCB Trip bus" setting (*I/O → Fuse failure inputs*).
Line fuse fail check	0: No 1: Yes	-	1: Yes	Selects whether or not the state of the line fuse is supervised. The supervised signal is determined by the "VTS MCB Trip line" setting (*I/O → Fuse failure inputs*).

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. When the activation of the pick-up is based on binary signals, the activation happens immediately after the monitored signal is activated.

The voltage transformer supervision can also report several different states of the measured voltage. These can be seen in the function's *INFO* tab in the relay's HMI or in AQtivate.

Name	Description
Bus dead	No voltages.
Bus Live VTS Ok	All of the voltages are within the set limits.
Bus Live VTS Ok SEQ Rev	All of the voltages are within the set limits BUT the voltages are in a reversed sequence.
Bus Live VTS Ok SEQ Undef	Voltages are within the set limits BUT the sequence cannot be defined.
Bus Live VTS problem	Any of the VTS pick-up conditions are met.

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 - 121. Information displayed by the function.

Name	Range	Step	Description
VTS condition	0: Normal 1: Start 2: VTLinefail 3: VTBusfail 4: Blocked	-	Displays status of the monitoring function.
Bus voltages	0: Bus dead 1: Bus Live VTS Ok SEQ Ok 2: Bus Live VTS Ok SEQ Rev 3: Bus Live VTS Ok SEQ Undef 4: Bus Live VTS problem	-	Displays the status of bus voltages.
Expected operating time	0.000...1800.000s	0.005s	Displays the expected operating time when a fault occurs.
Time remaining to trip	-1800.000...1800.000s	0.005s	When the function has detected a fault and counts down time towards a operation, this displays how much time is left before operation occurs.

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 voltage 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

This function supports definite time delay (DT). For detailed information on this delay type please refer to the chapter "General properties of a protection function" and its section "Operating time characteristics for trip and reset".

Events and registers

The voltage transformer supervision function (abbreviated "VTS" in event block names) generates events and registers from the status changes in ALARM ACTIVATED and 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 - 122. Event codes.

Event number	Event channel	Event block name	Event code	Description
3392	53	VTS1	0	Bus VT fail Start ON
3393	53	VTS1	1	Bus VT fail Start OFF
3394	53	VTS1	2	Bus VT fail Trip ON
3395	53	VTS1	3	Bus VT fail Trip OFF
3396	53	VTS1	4	Bus VT fail Block ON
3397	53	VTS1	5	Bus VT fail Block OFF
3398	53	VTS1	6	Line VT fail ON
3399	53	VTS1	7	Line VT fail OFF
3400	53	VTS1	8	Bus Fuse fail ON
3401	53	VTS1	9	Bus Fuse fail OFF
3402	53	VTS1	10	Line Fuse fail ON
3403	53	VTS1	11	Line Fuse fail 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.

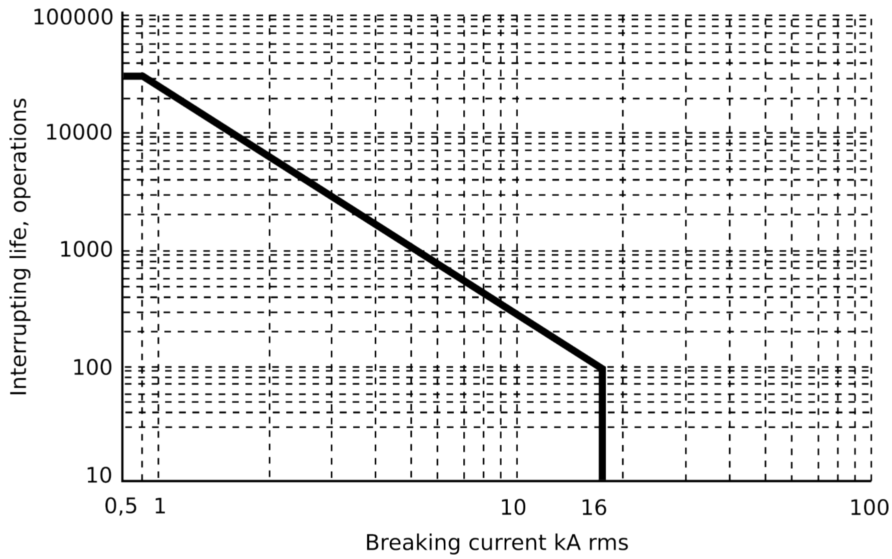
Table. 5.5.1 - 123. Register content.

Date and time	Event code	Volt 1, 2, 3, 4 status	System status	Input A, B, C, D angle diff	Trip time remaining	Used SG
dd.mm.yyyy hh:mm:ss.mss	3392-3403 Descr.	0: No voltage 1: Voltage OK 2: Low voltage	0: Bus dead 1: Bus live, VTS OK, Seq. OK 2: Bus live, VTS OK, Seq. reversed 3: Bus live, VTS OK, Seq. undefined 4: Bus live, VTS fault	0.00...360.00deg	0...1800s	Setting group 1...8 active

5.5.2 Circuit breaker wear

The circuit breaker wear function is used for monitoring the circuit breaker's lifetime and its maintenance needs caused by interrupting currents and mechanical wear. The function uses the circuit breaker's manufacturer-supplied data for the breaker operating cycles in relation to the interrupted current magnitudes. The function is integrated into the object control function and can be enabled and set under that function's settings. However, the circuit breaker wear function is an independent function and it initializes as an independent instance which has its own events and settings not related to the object it is linked to.

Figure. 5.5.2 - 141. Example of the circuit breaker interrupting life operations.



The function is triggered from the circuit breaker's "Open" command output and it monitors the three-phase current values in both the tripping moment and the normal breaker opening moment. The maximum value of interrupting life operations for each phase is calculated from these currents. The value is cumulatively deducted from the starting operations starting value. The user can set up two separate alarm levels, which are activated when the value of interrupting life operations is below the setting limit. The "Trip contact" setting defines the output that triggers the current monitoring at the breaker's "Open" command.

The outputs of the function are the ALARM 1 and ALARM 2 signals.

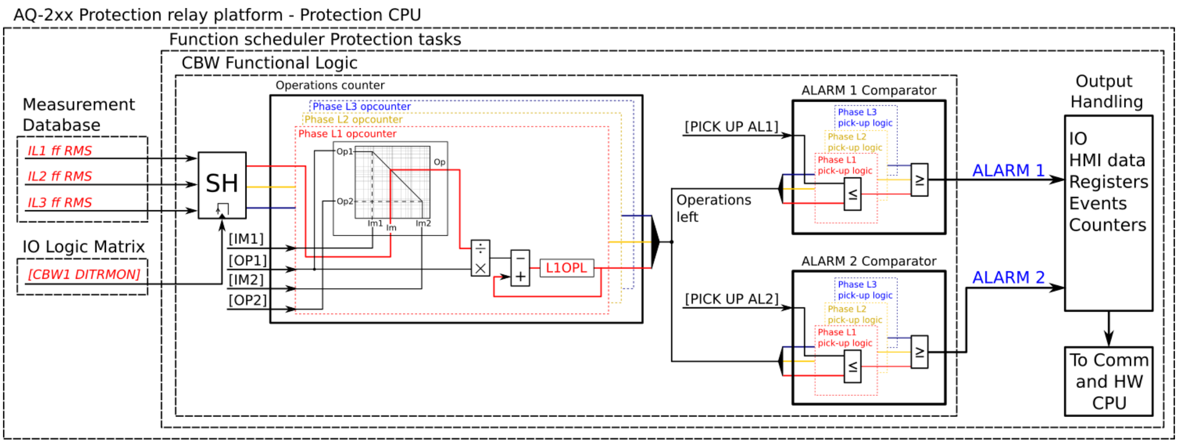
The inputs for the function are the following:

- setting parameters
- binary output signals
- measured and pre-processed current magnitudes.

The function's output signals 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 two (2) output signal. The time stamp resolution is 1 ms. The function also provides a resettable cumulative counter for the "Open" operations as well as the ALARM 1 and ALARM 2 events. The function can also monitor the operations left for each phase.

The following figure presents a simplified function block diagram of the circuit breaker wear function.

Figure. 5.5.2 - 142. Simplified function block diagram of the circuit breaker wear function.



Measured input

The function block uses analog current measurement values and always uses the RMS magnitude of the current measurement input.

Table. 5.5.2 - 124. Measurement inputs of the circuit breaker wear 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

Circuit breaker characteristics settings

The circuit breaker characteristics are set by two operating points, defined by the nominal breaking current, the maximum allowed breaking current and their respective operation settings. This data is provided by the circuit breaker's manufacturer.

Table. 5.5.2 - 125. Settings for circuit breaker characteristics.

Name	Range	Step	Default	Description
Operations 1	0…200 000	1	50 000	The number of interrupting life operations at the nominal current (Close - Open).
Operations 2	0…200 000	1	100	The number of interrupting life operations at the rated breaking current (Open).
Current 1 (I_{nom})	0…100.00kA	0.01kA	1kA	The rated normal current (RMS).

Name	Range	Step	Default	Description
Current 2 (I_{max})	0…100.00kA	0.01kA	20kA	The rated short-circuit breaking current (RMS).

Pick-up for alarming

For the alarm stages Alarm 1 and Alarm 2, the user can set the pick-up level for the number of operations left. The pick-up setting is common for all phases and the alarm stage picks up if any of the phases goes below this setting.

Table. 5.5.2 - 126. Pick-up settings.

Name	Range	Step	Default	Description
Alarm 1	0: Disabled 1: Enabled	-	0: Disabled	Enable and disable the Alarm 1 stage.
Alarm 1 Set	0…200 000	1	1 000	Defines the pick-up threshold for remaining operations. When the number of remaining operations is below this setting, the ALARM 1 signal is activated.
Alarm 2	0: Disabled 1: Enabled	-	0: Disabled	Enable and disable the Alarm 2 stage.
Alarm 2 Set	0…200 000	1	100	Defines the pick-up threshold for remaining operations. When the number of remaining operations is below this setting, the ALARM 2 signal is activated.

Setting example

Let us examine the settings, using a low-duty vacuum circuit breaker (ISM25_LD_1/3) manufactured by Tavrida as an example. The image below presents the technical specifications provided by the manufacturer, with the data relevant to our settings highlighted in red:

Rated voltage, kV	24
Rated current, A	800
Rated power frequency test voltage, kV	50
Rated frequency, Hz	50/60
Rated impulse test voltage, kV peak	125
Partial discharge level at 1,1 rated voltage kV, pC	<10
Rated short-circuit breaking current, kA	16
Rated short-circuit making current, kA peak	41.5
Short time withstand current, 4s, kA	16
Mechanical life, CO cycles, not less than	30,000
Interrupting life operations, not less than	
at rated current	30,000
at breaking current	100
at other currents	see Fig.41
Closing time, ms, not more than	35
Opening time, ms, not more than	15
Breaking time, ms, not more than	25
Main contact resistance, μOhm, not more than	40
Maximum ambient temperature, C°	+55
Minimum ambient temperature, C°	-40
Design class (according to IEC 60932)	1
Electrical endurance class at rated IEEE/IEC duty	E2
Mechanical endurance class at rated IEEE/IEC duty	M2
Capacitive current switching class	C2
"Mechanical vibration and shock withstand capability, IEC 60721, IEC 60068"	Class 4M4
Maximum altitude above sea level, m	3000*
Maximum humidity, non condensing	98 %
Weight, kg - LD_1	35
Weight, kg - LD_6	55

Now, we set the stage as follows:

Parameter	Setting
Current 1	0.80 kA
Operation 1	30 000 operations
Current 2	16.00 kA
Operations 2	100 operations
Enable Alarm 1	1: Enabled
Alarm 1 Set	1000 operations
Enable Alarm 2	1: Enabled
Alarm 2 Set	100 operations

With these settings, Alarm 1 is issued when the cumulative interruption counter for any of the three phases dips below the set 1000 remaining operations ("Alarm 1 Set"). Similarly, when any of the counters dips below 100 remaining operations, Alarm 2 is issued.

Events and registers

The circuit breaker wear function (abbreviated "CBW" in event block names) generates events and registers from the status changes in Triggered, Alarm 1 and Alarm 2 signals as well as in internal pick-up comparators. 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. 5.5.2 - 127. Event codes.

Event number	Event channel	Event block name	Event code	Description
3712	58	CBW1	0	CBWEAR1 Triggered
3713	58	CBW1	1	CBWEAR1 Alarm 1 ON
3714	58	CBW1	2	CBWEAR1 Alarm 1 OFF
3715	58	CBW1	3	CBWEAR1 Alarm 2 ON
3716	58	CBW1	4	CBWEAR1 Alarm 2 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. The table below presents the structure of the function's register content.

Table. 5.5.2 - 128. Register content.

Date and time	Event code	Trigger current	All.Op.ITrg	Deduct. Op	Op.Left
dd.mm.yyyy hh:mm:ss.mss	3712-3716 Descr.	Phase currents on trigger time	Allowed operations with trigger current	Deducted operations from the cumulative sum	Operations left

5.5.3 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. 5.5.3 - 129. Analog recording channels.

Signal	Description
IL1	Phase current I_{L1}
IL2	Phase current I_{L2}

Signal	Description
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)
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. 5.5.3 - 130. 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. 5.5.3 - 131. 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)

Signal	Description	Signal	Description
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
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)

Signal	Description	Signal	Description
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".
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 admittace 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. 5.5.3 - 132. Digital recording channels – Binary signals.

Signal	Description	Signal	Description
DIx	Digital input 1...11	Timer x Output	Output of Timer 1...10
Open/close control buttons	Active if buttons I 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.

Signal	Description	Signal	Description
MBIO ModB 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. 5.5.3 - 133. 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+	$0 \ldots 2^{32}-1$	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.

Name	Range	Step	Default	Description
Recordings in memory	0…100	1	-	Displays how many recordings are stored in the memory.

Table. 5.5.3 - 134. 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. 5.5.3 - 135. Recorder settings.

Name	Range	Step	Default	Description
Recording length	0.100...1800.000s	0.01s	1s	Sets the length of a recording.
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 *Disturbance recorder → Get DR files* 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.

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

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 µs)
- 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. 5.5.3 - 143. Disturbance recorder settings.

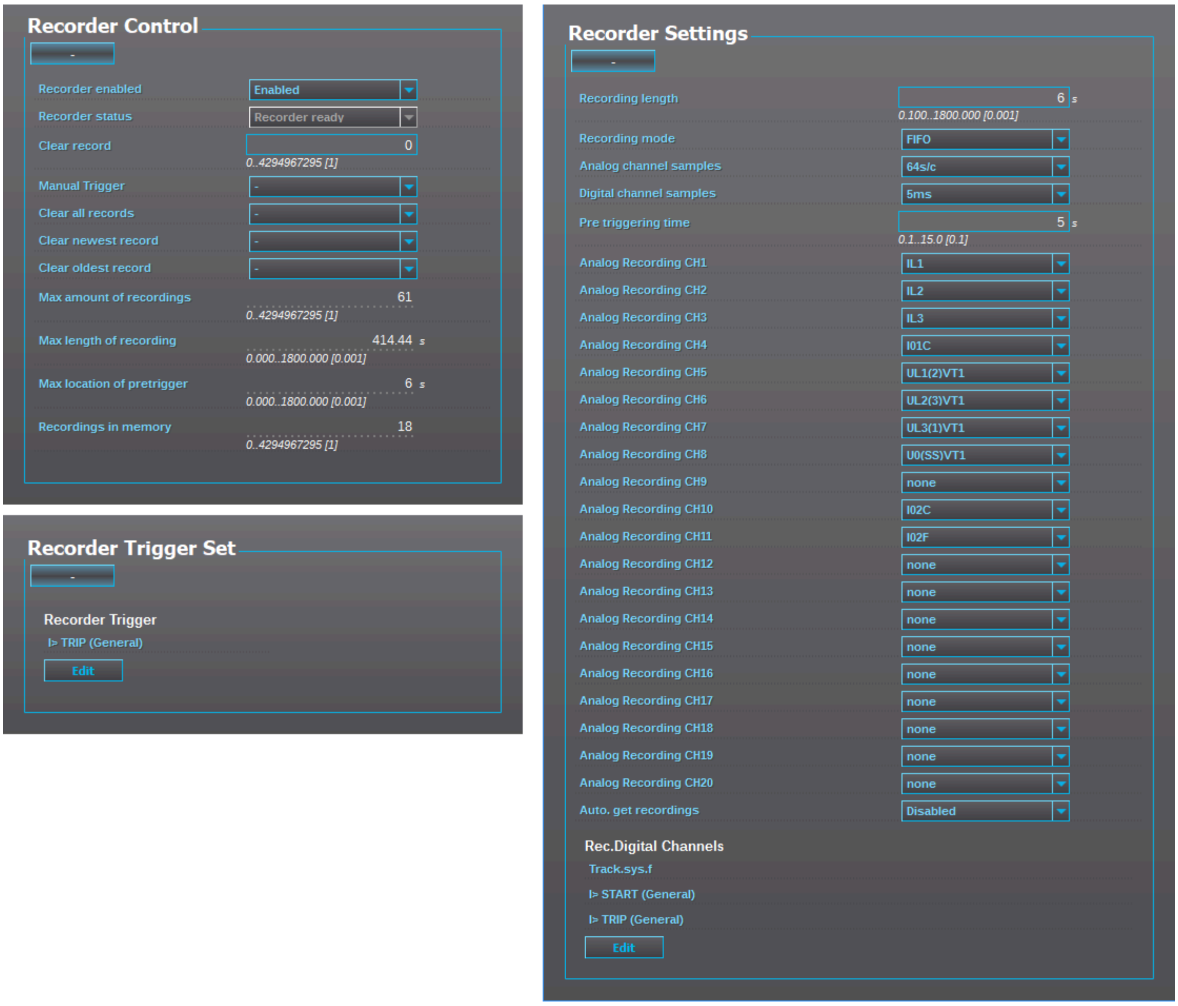
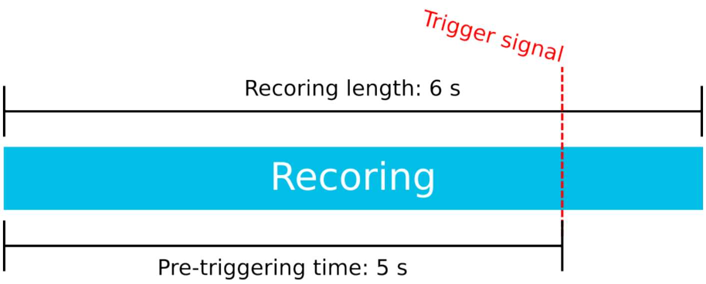
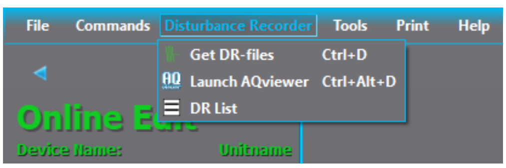


Figure. 5.5.3 - 144. Effects of recording length and pre-triggering time signals. This example is based on the settings shown above.



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

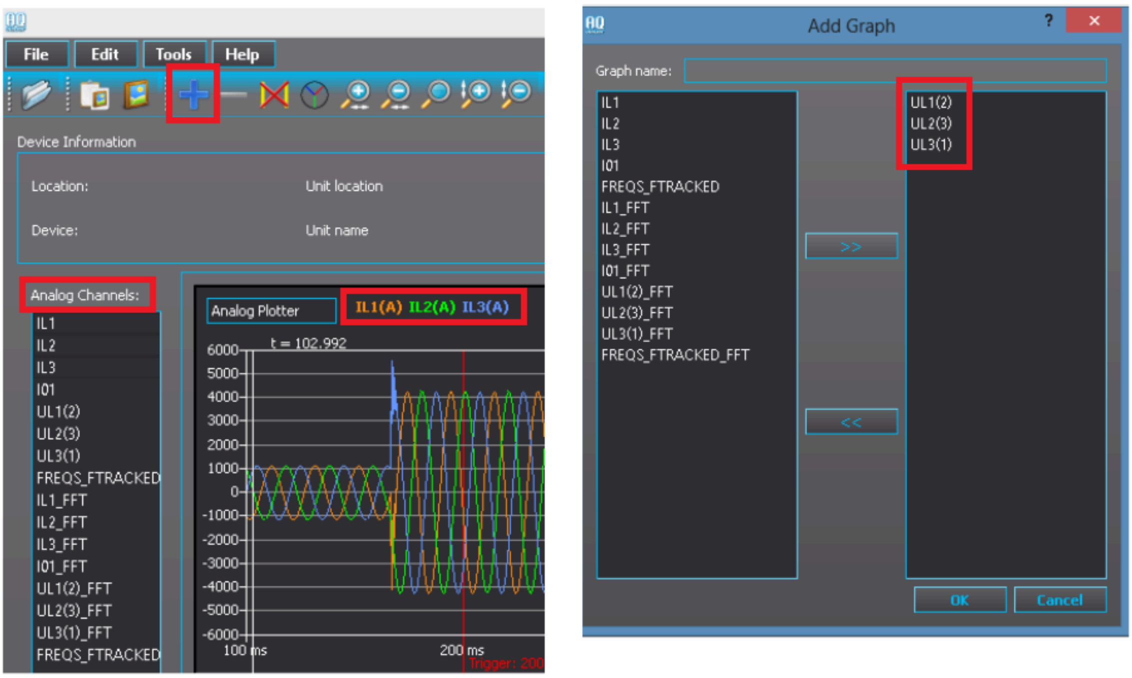
Opening folders

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 are located in same directory.

Adding signals to plotters

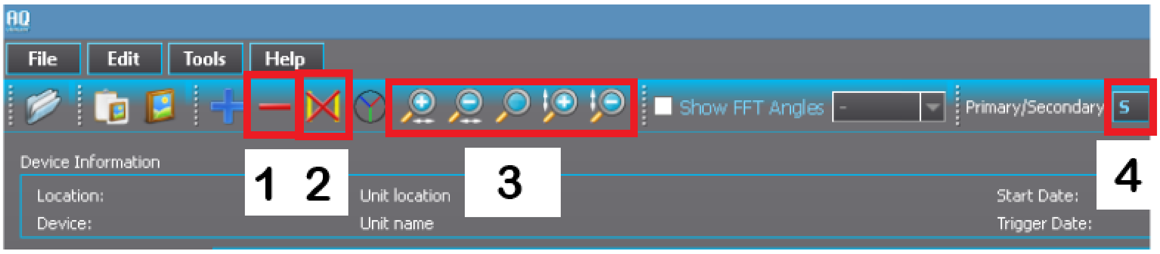
By default, the default plotter is empty. Choose the measured signals ("Analog channels") on the left to move them to the plotter. In the image below (on the left) the phase currents IL1, IL2 and IL3 are selected; AQViewer color-codes them automatically. If you want to add another plotter, choose the 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. 5.5.3 - 145. 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).



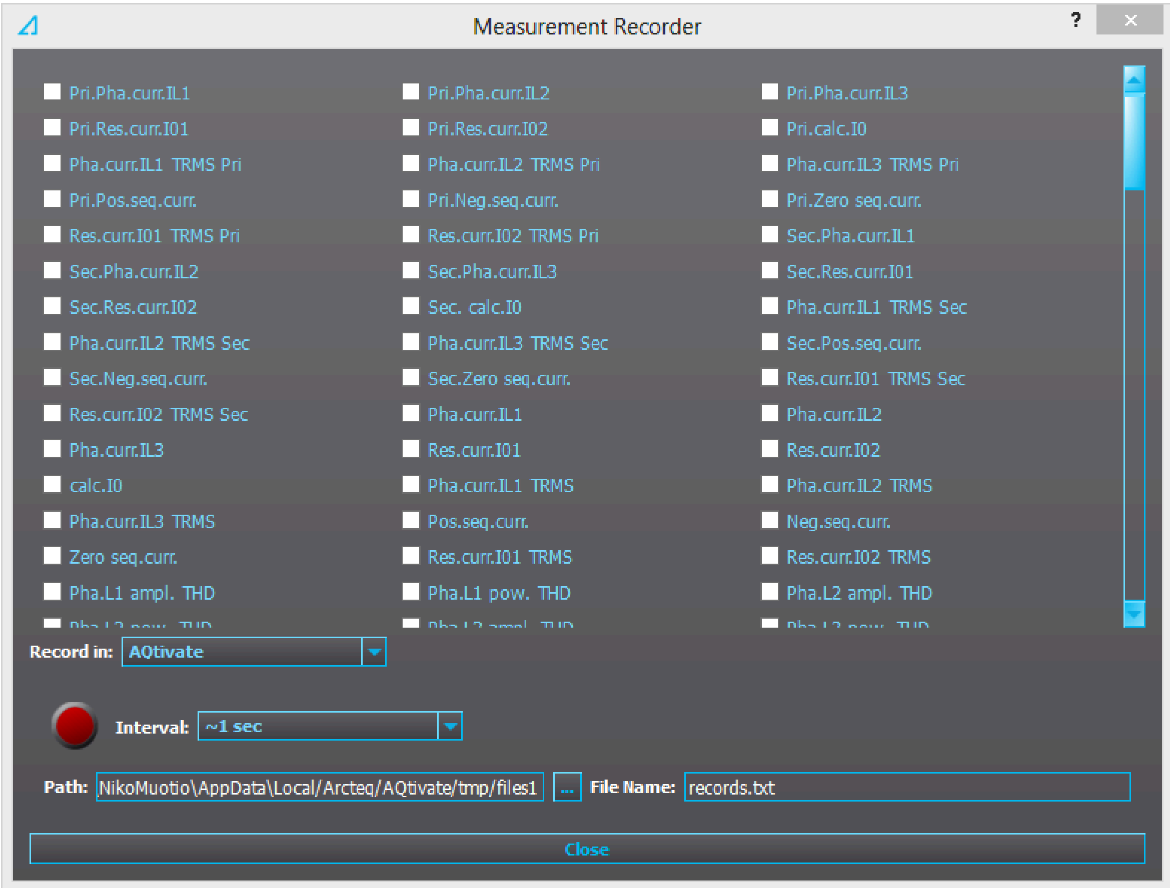
Events

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. 5.5.3 - 136. 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

5.5.4 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. 5.5.4 - 146. Measurement recorder values viewed with AQtivate PRO.

Table. 5.5.4 - 137. 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	

5.5.5 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 2nd h., 3rd h., 4th h., 5th h., 7th h., 9th h., 11th h., 13th h., 15th h., 17th h., 19th h.	The magnitudes of phase current components: Fundamental, 2nd harmonic, 3rd harmonic, 4th harmonic, 5th harmonic 7th, harmonic 9th, harmonic 11th, harmonic 13th, harmonic 15th, harmonic 17th, harmonic 19th 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. 5.5.5 - 138. 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: I0> TRIP 18: I0>> Trip 19: I0>>> Trip 20: I0>>>> Trip 21: I0Dir> Trip 22: I0Dir>> Trip 23: I0Dir>>> Trip 24: I0Dir>>>> 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. 5.5.5 - 139. 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 - 140. 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 - 141. 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 - 142. 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 - 143. 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 - 144. 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 - 145. 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 - 146. 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 - 147. 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 sequrity' 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 - 148. 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 - 149. 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")	0×0…0×3FFF	0×1	0×0	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 - 150. 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 *Communication → DNP3*.
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 - 151. 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 - 152. 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 - 153. 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 - 154. 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 - 155. 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 .aqs 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 - 156. Fault register settings.

Name	Range	Step	Default	Description
Select record source	0: Not in use 1…12: I>, I>>, I>>>, I>>>> (IL1, IL2, IL3) 13…24: Id>, Id>>, Id>>>, Id>>>> (IL1, IL2, IL3) 25…28: I0>, I0>>, I0>>>, I0>>>> (I0) 29…32: I0d>, I0d>>, I0d>>>, I0d>>>> (I0) 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 - 157. 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 - 158. 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 catecory of the chosen slot.
Slot X magnitude	Described in table above ("Available measured values")	-	-	Selects the magnituge 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-V211

Figure. 7.1 - 147. AQ-V211 variant without add-on modules.

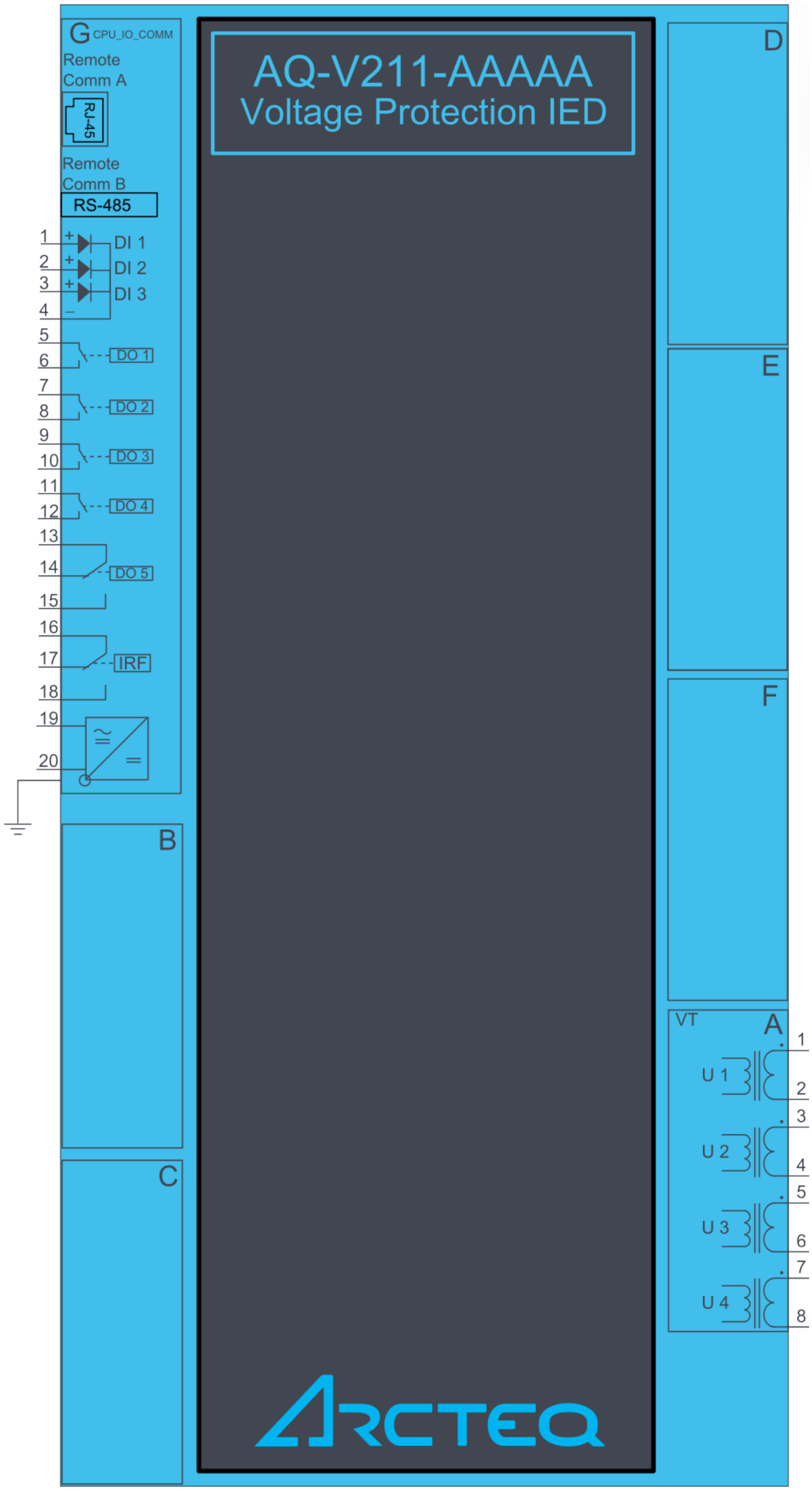


Figure. 7.1 - 148. AQ-V211 variant with digital input and output modules.

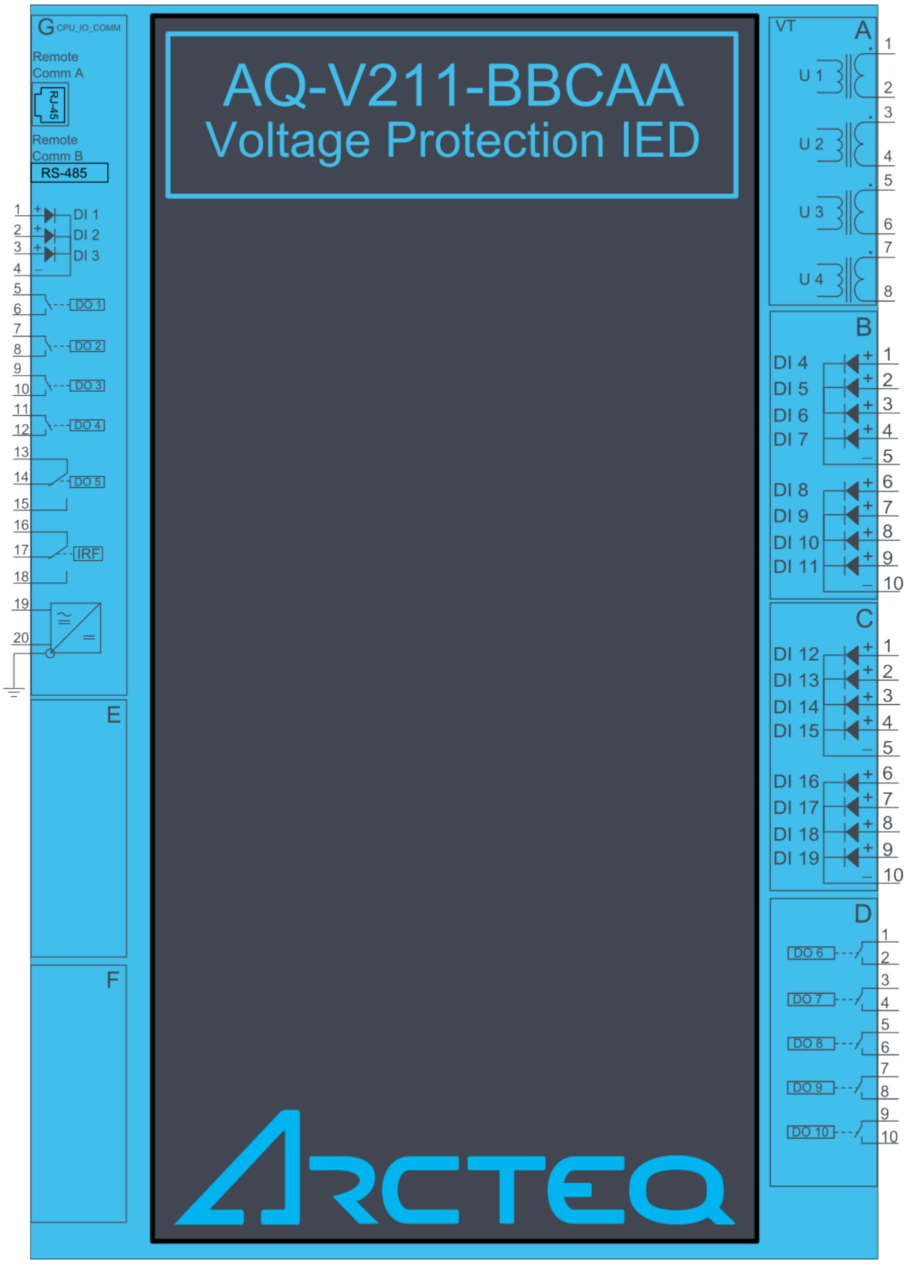
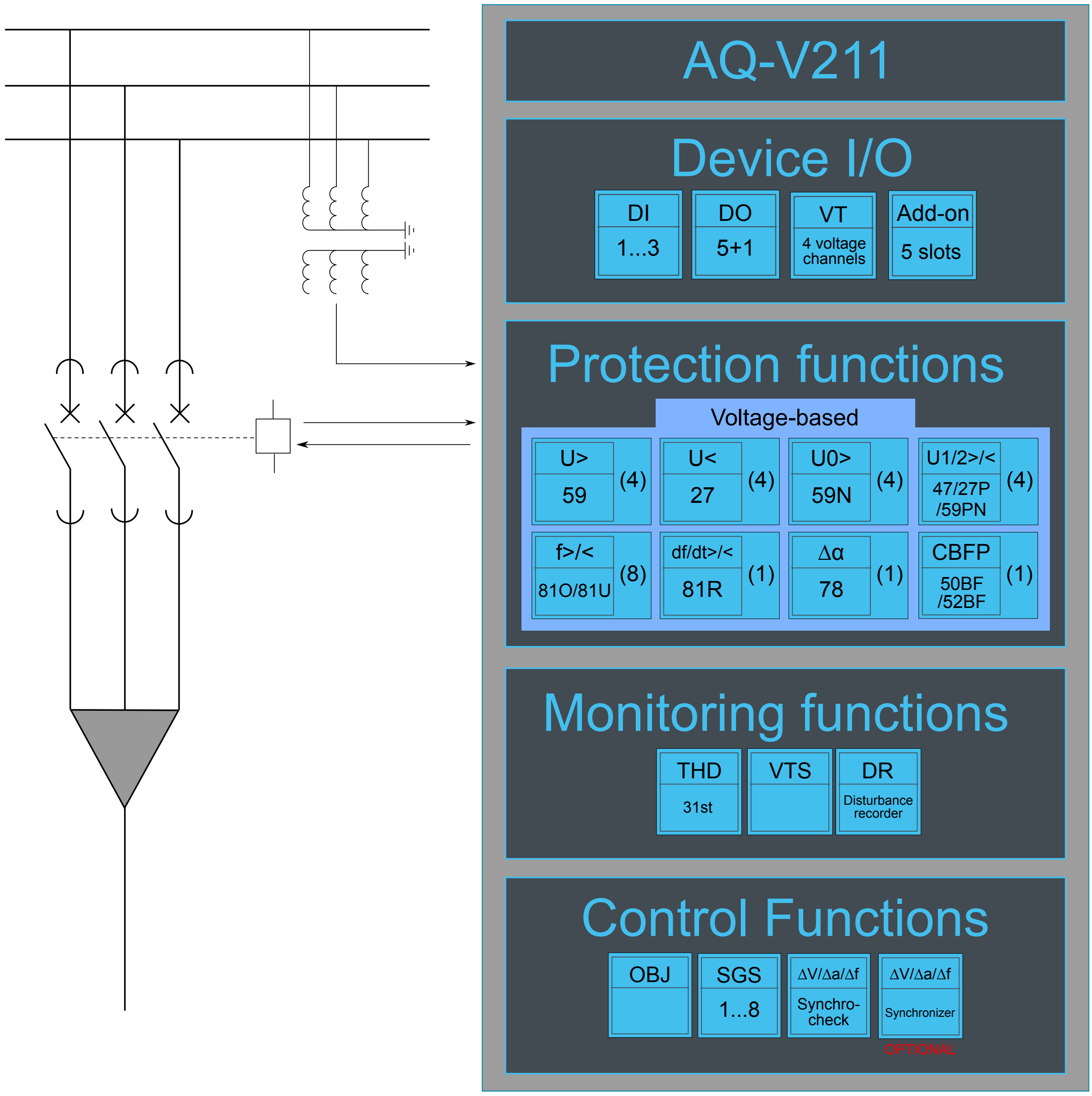


Figure. 7.1 - 149. AQ-V211 application example with function block diagram.

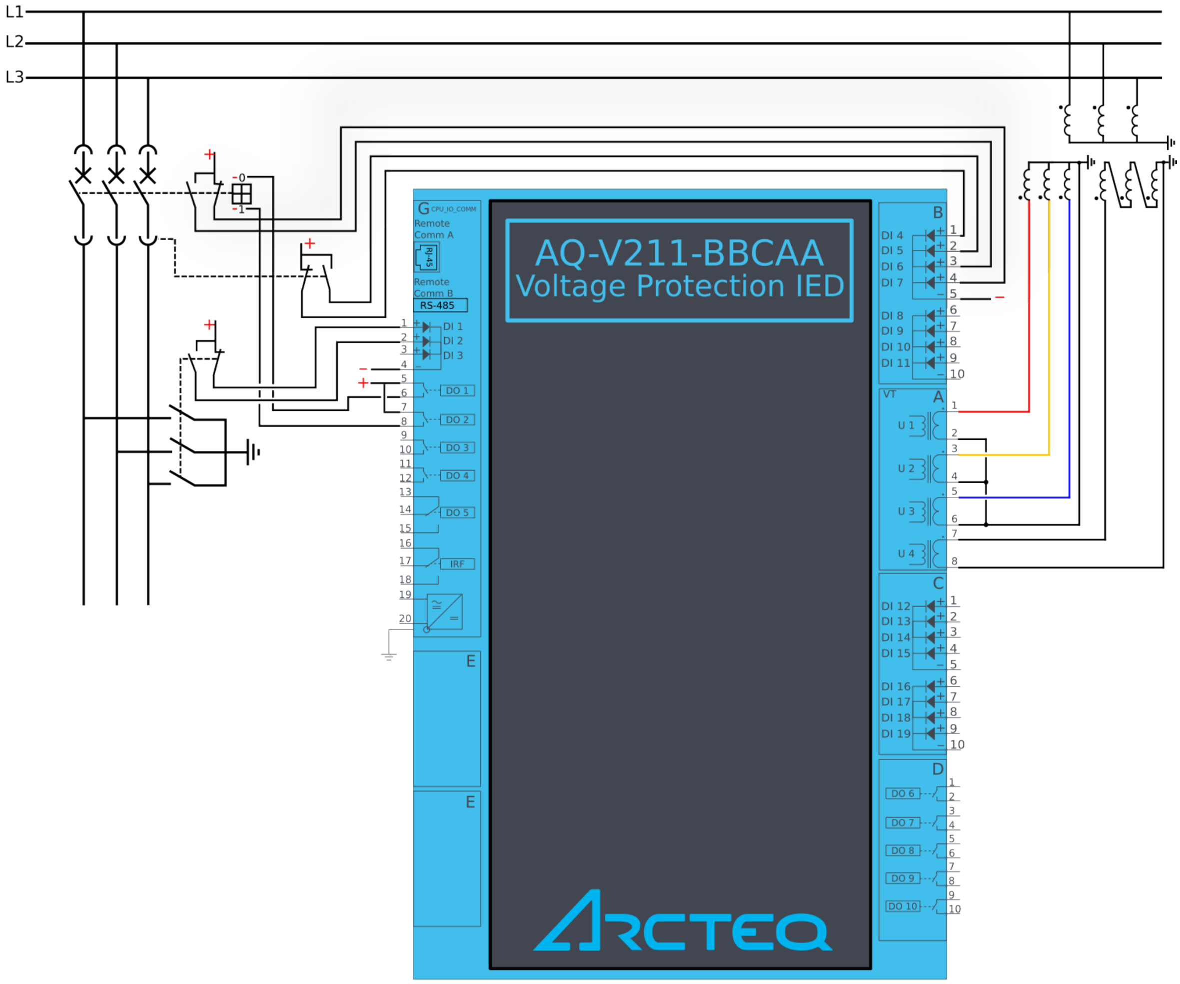


7.2 Application example and its connections

This chapter presents an application example for the voltage protection 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). The digital inputs are connected to indicate the breaker status, while the digital outputs are used for breaker control.

Figure. 7.2 - 150. Application example and its connections.



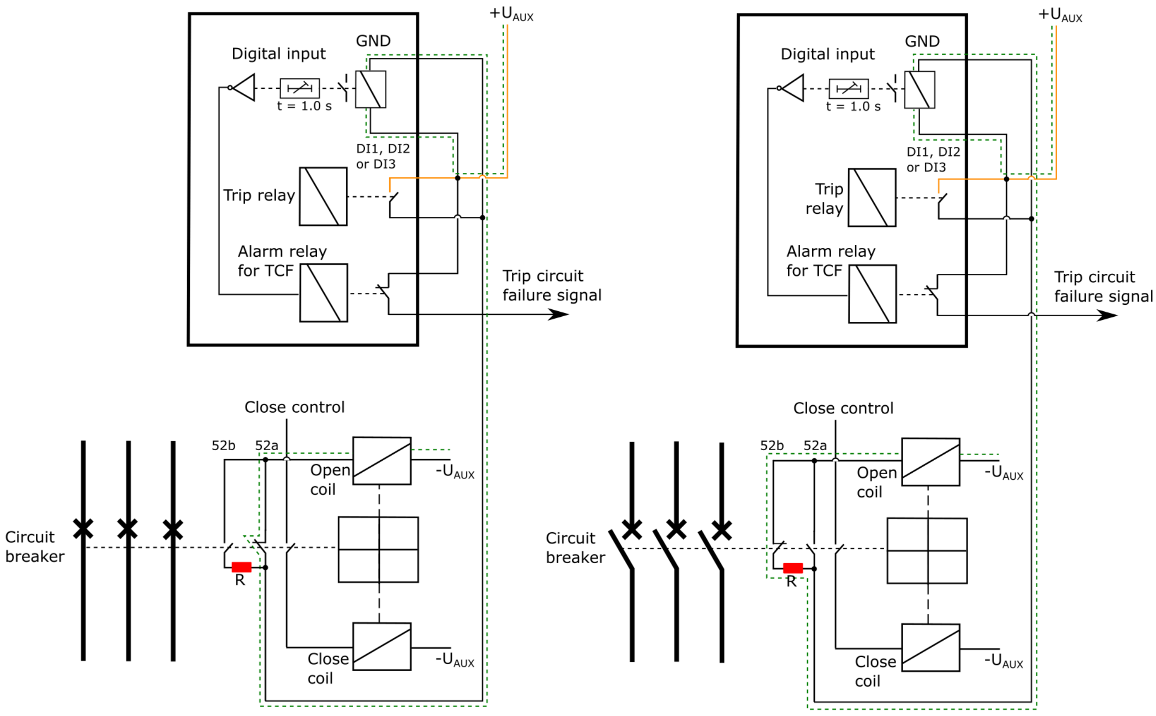
7.3 Trip circuit supervision (95)

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. 7.3 - 151. Trip circuit supervision with one DI and one non-latched trip output.

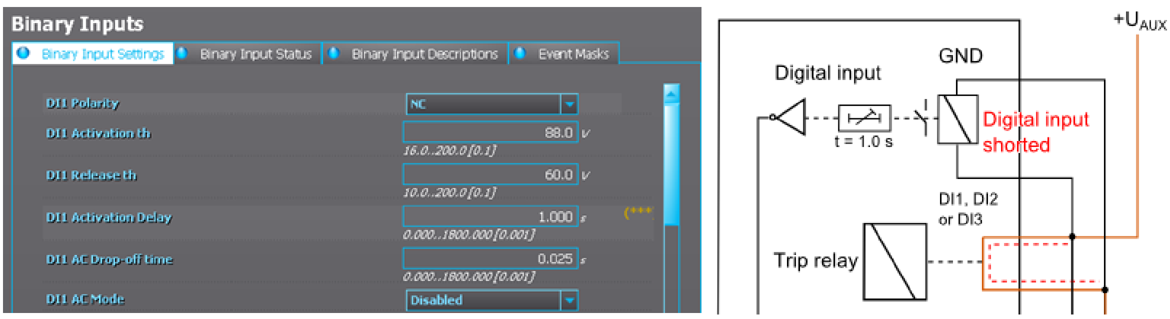


Note that the digital input that monitors the circuit is normally closed, and the same applies to the alarm relay if one is used. For monitoring and especially trip circuit supervision purposes it is recommended to use a normally closed contact to confirm the wiring's condition. An active digital input 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, $t_{DI} = t_{CB} + t_{IEDrelease} + t_{CBFP}$.

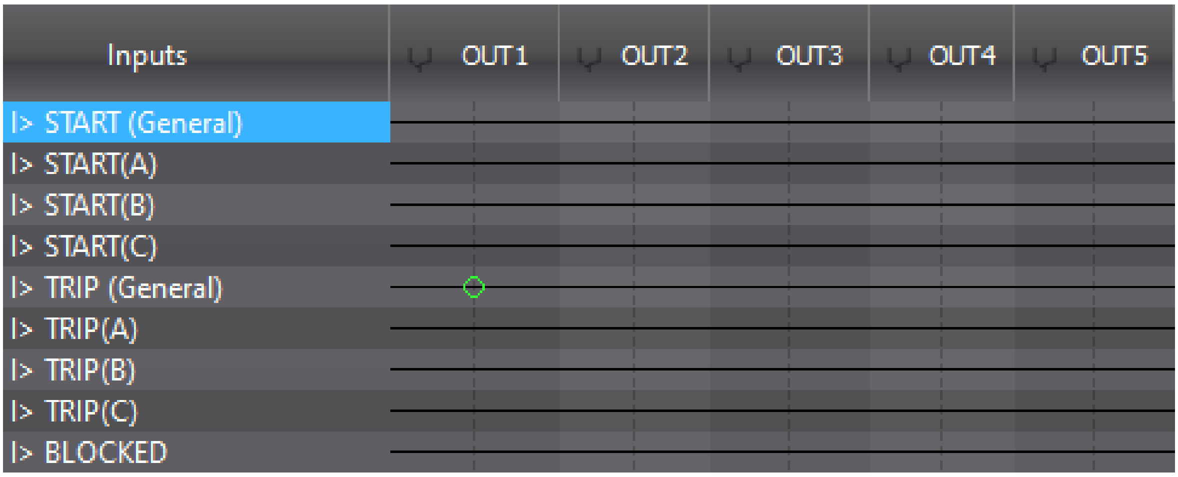
The image below presents the necessary settings when using a digital input for trip circuit supervision. The input's polarity must be NC (normally closed) and a one second delay is needed to avoid nuisance alarm while the circuit breaker is controlled open.

Figure. 7.3 - 152. 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. 7.3 - 153. Non-latched trip contact.



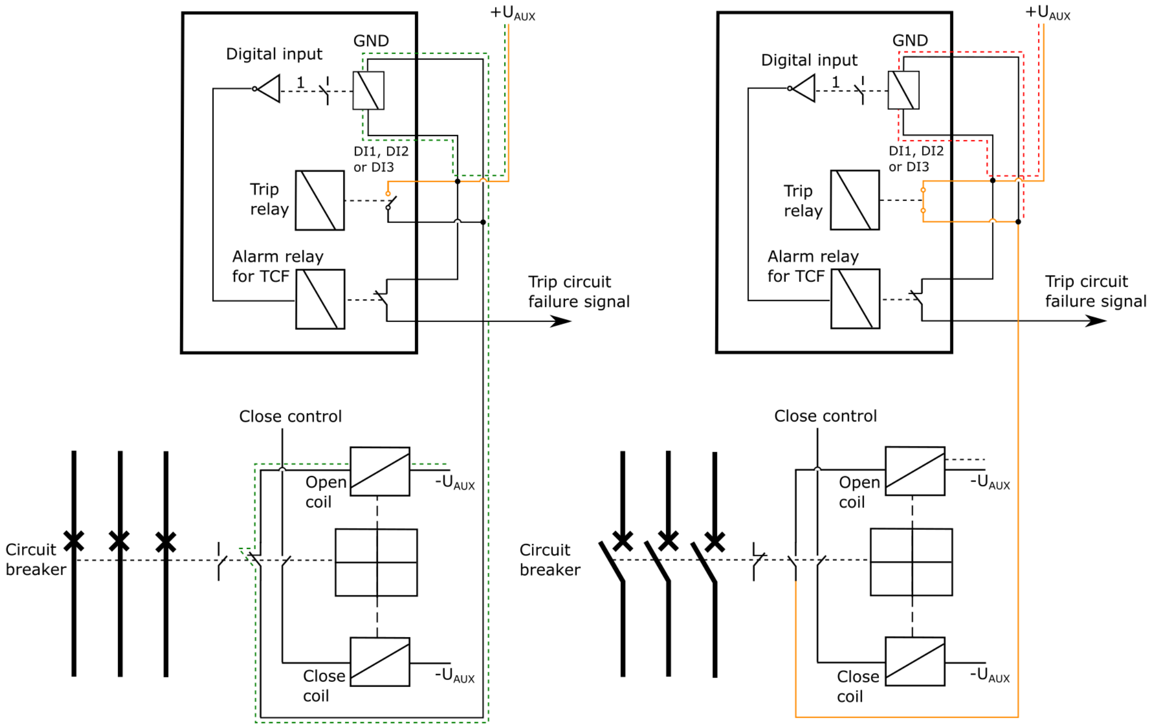
When the auto-reclosing function is used in feeder applications, the trip output contacts must be non-latched. Trip circuit supervision is generally easier and more reliable to build with non-latched outputs.

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. 7.3 - 154. Trip circuit supervision with one DI and one latched output contact.

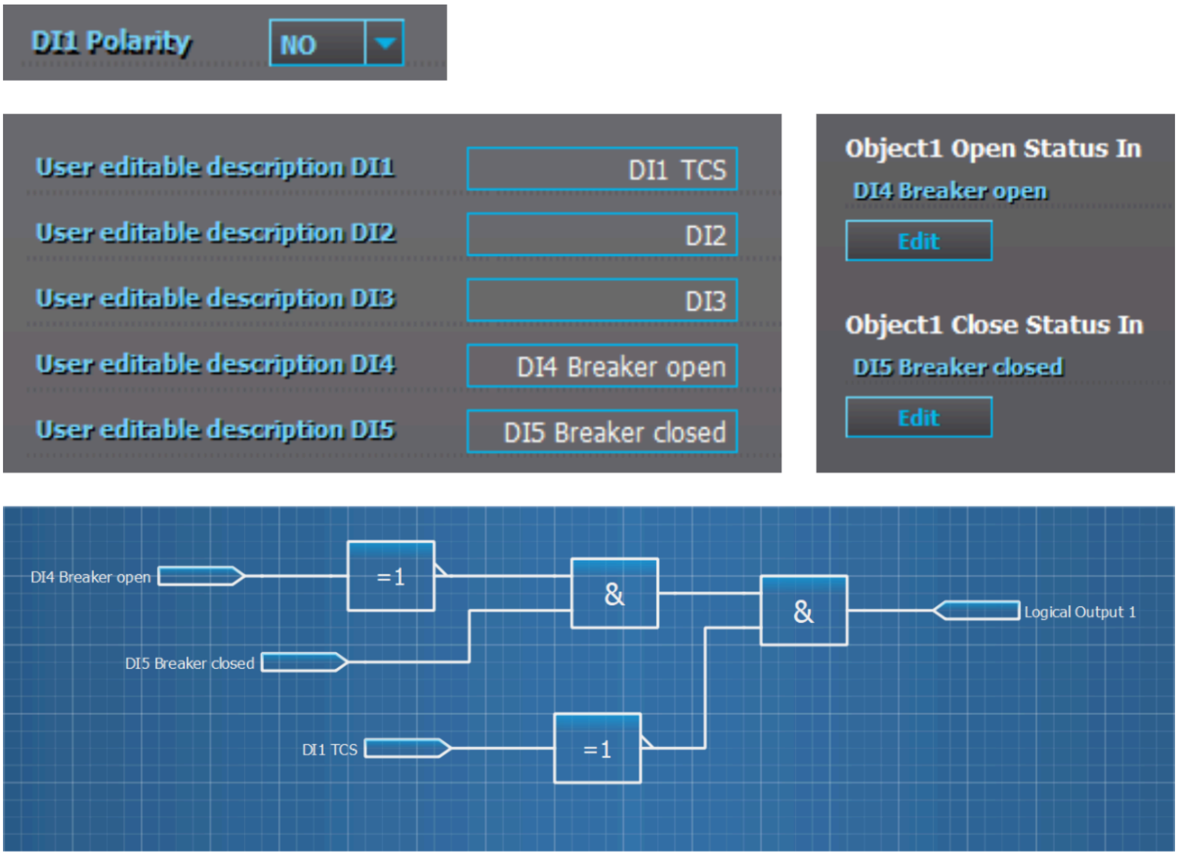


The trip circuit with a latched output contact can be monitored, but only when the circuit breaker's status is "Closed". Whenever the breaker is open, the supervision is blocked by an internal logic scheme. Its disadvantage is that the user does not know whether or not the trip circuit is intact when 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 signal ("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. 7.3 - 155. Example block scheme.



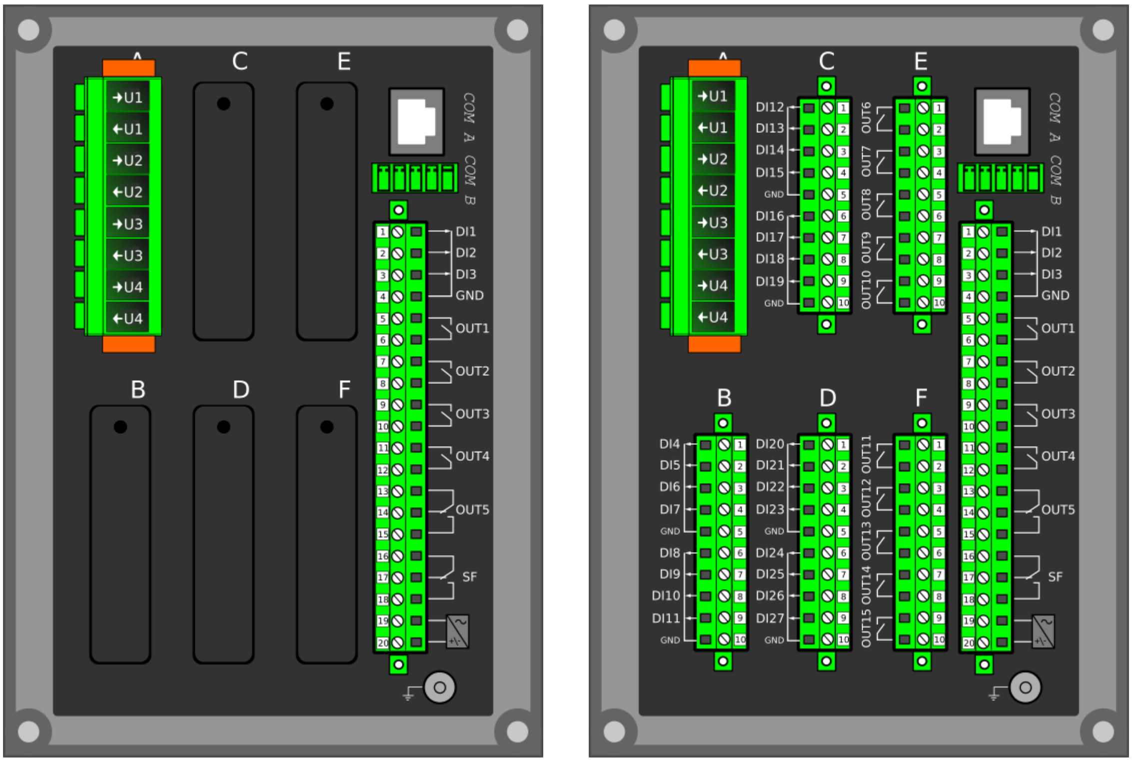
8 Construction and installation

8.1 Construction

AQ-X211 is a member of the modular and scalable AQ-200 series, and it includes five (5) 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.

The images below present the modules of both the non-optioned model (AQ-X211-XXXXXXX-AAAAA, on the left) and the fully optioned model (AQ-X211-XXXXXXX-BBBCC, on the right).

Figure. 8.1 - 156. Modular construction of AQ-X211.



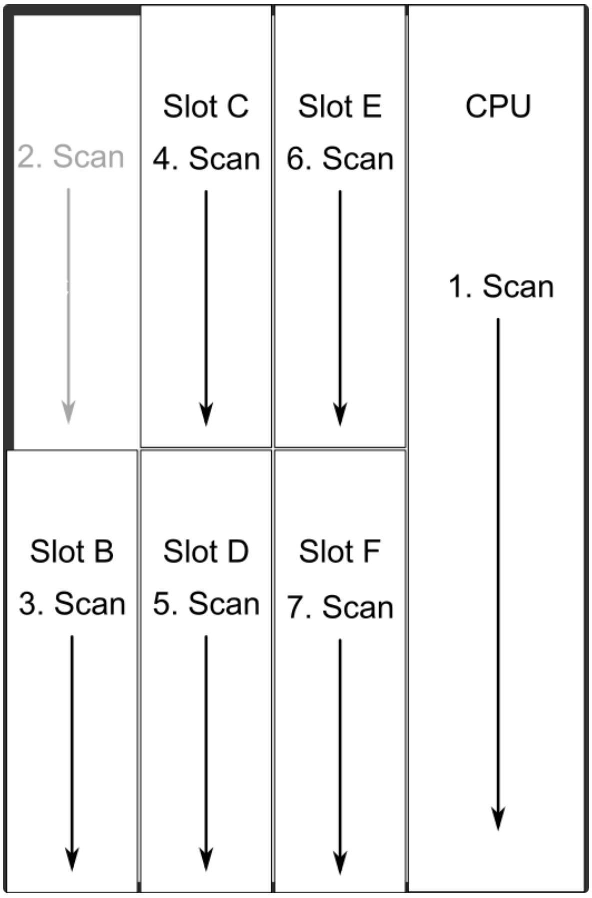
The modular structure of AQ-X211 allows for scalable solutions for different application requirements. In non-standard configurations Slots B, C, D, E and F accept all available add-on modules, such as digital I/O modules or another special module. The only difference between the slots affecting device 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 B, Slot C, Slot D, Slot E, 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 - 157. AQ-X211 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-X211). If the VTM is not found, the device issues an alarm.
3. Scan
   Scans Slot B, and moves to the next slot if Slot B 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.

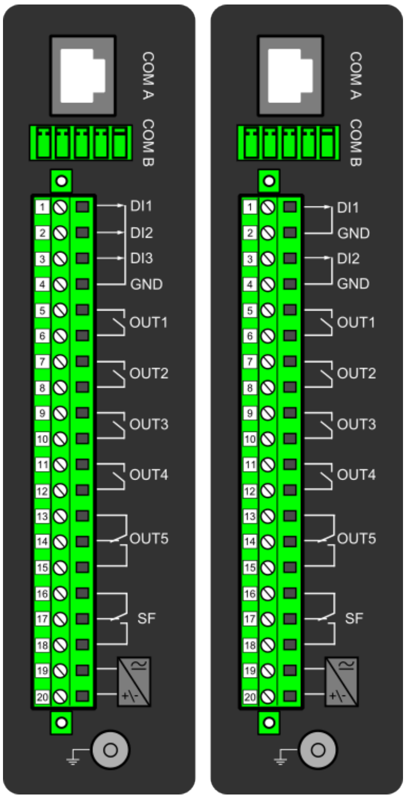
4. Scan
   Scans Slot C, and moves to the next slot if Slot C is empty. If the scan finds an 8DI module, it reserves the designations "DI4", "DI5", "DI6", "DI7", "DI8", "DI9", "DI10" and "DI11" to this slot. If Slot B also has an 8DI module (and therefore has already reserved these designations), the 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 B 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.
5. Scan
   A similar operation to Scan 4 (checks which designations have been reserved by modules in previous slots and numbers the new ones accordingly).
6. Scan
   A similar operation to Scan 4 (checks which designations have been reserved by modules in previous slots and numbers the new ones accordingly).
7. Scan
   A similar operation to Scan 4 (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-X211-XXXXXXX-BBBCC (the first image pair, on the right) has a total of 27 digital input channels available: three (DI1…DI3) in the CPU module, and the rest in Slots B…D in groups of eight. It also has a total of 15 digital output channels available: five (DO1…DO5) in the CPU module, and the rest in Slots E…F in groups of five. These same principles apply to all non-standard configurations in the AQ-X211 IED family.

8.2 CPU module

Figure. 8.2 - 158. CPU module.



Module connectors

Table. 8.2 - 159. 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 - 160. Digital input settings.

Name	Range	Step	Default	Description
DIx 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.
DIx Activation delay	0.000…1800.000 s	0.001 s	0.000 s	Defines the delay for the status change from 0 to 1.
DIx 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.
DIx AC mode	0: Disabled 1: Enabled	-	0: Disabled	Selects whether or not a 30-ms deactivation delay is added to account for alternating current.

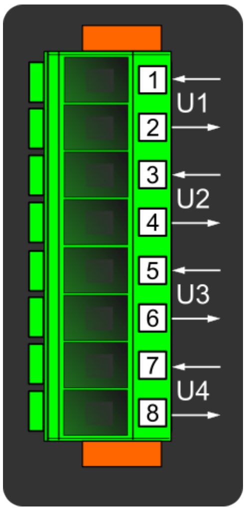
Scanning cycle

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 <u>not</u> included in these approximations.

8.3 Voltage measurement module

Figure. 8.3 - 159. 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 ± 0.2 % inaccuracy in the same range.

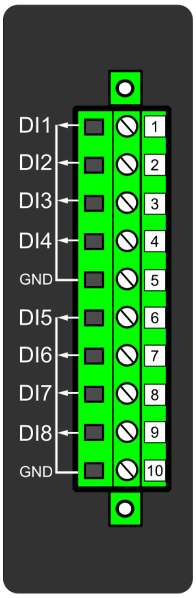
The voltage input characteristics are as follows:

- 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.

8.4 Digital input module (optional)

Figure. 8.4 - 160. Digital input module (DI8) with eight add-on digital inputs.



Connector	Description (x = the number of digital inputs in other modules that preceed this one in the configuration)
X 1	DIx + 1
X 2	DIx + 2
X 3	DIx + 3
X 4	DIx + 4
X 5	Common earthing for the first four digital inputs.
X 6	DIx + 5
X 7	DIx + 6
X 8	DIx + 7
X 9	DIx + 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 scannced 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.

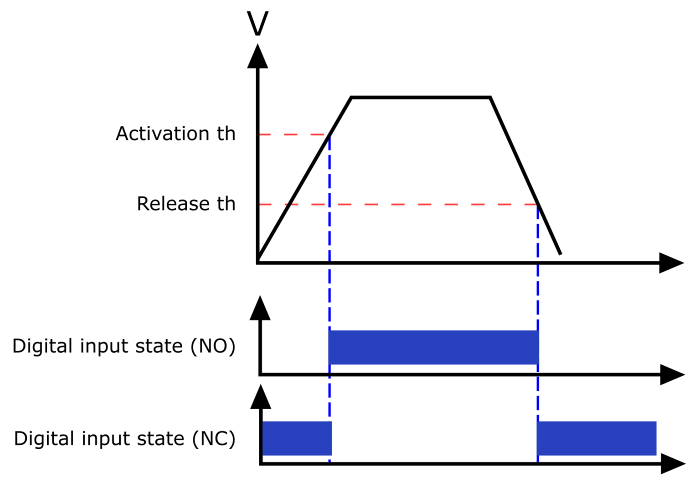
Table. 8.4 - 161. Digital input settings of DI8 module.

Name	Range	Step	Default	Description
DIx 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.
DIx 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.
DIx 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.
DIx Activation delay	0.000…1800.000 s	0.001 s	0.000 s	Defines the delay when the status changes from 0 to 1.
DIx 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.
DIx 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 "DIx Release threshold" parameter is hidden and forced to 10 % of the set "DIx Activation threshold" parameter.
DIx Counter	$0…2^{32}–1$	1	0	Displays the number of times the digital input has changed its status from 0 to 1.
DIx Clear counter	0: - 1: Clear	-	0: -	Resets the DIx 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. 8.4 - 161. Digital input state when energizing and de-energizing the digital input channels.



Digital input voltage measurements

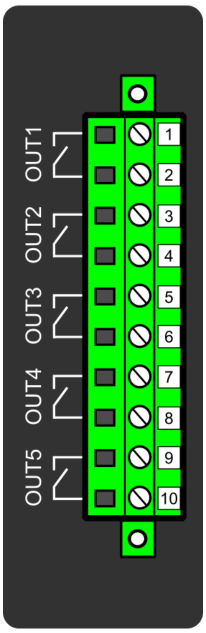
Digital input option card channels measure voltage on each channel. The measured voltage can be seen at *Control → Device IO → Digital inputs → Digital input voltages*.

Table. 8.4 - 162. Digital input channel voltage measurement.

Name	Range	Step	Description
DIx Voltage now	0.000...275.000 V	0.001 V	Voltage measurement of a digital input channel.

8.5 Digital output module (optional)

Figure. 8.5 - 162. Digital output module (DO5) with five add-on digital outputs.



Connector	Description
X 1–2	OUTx + 1 (1st and 2nd pole NO)
X 3–4	OUTx + 2 (1st and 2nd 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.

8.6 RTD input module (optional)

Figure. 8.6 - 163. RTD input module connectors.

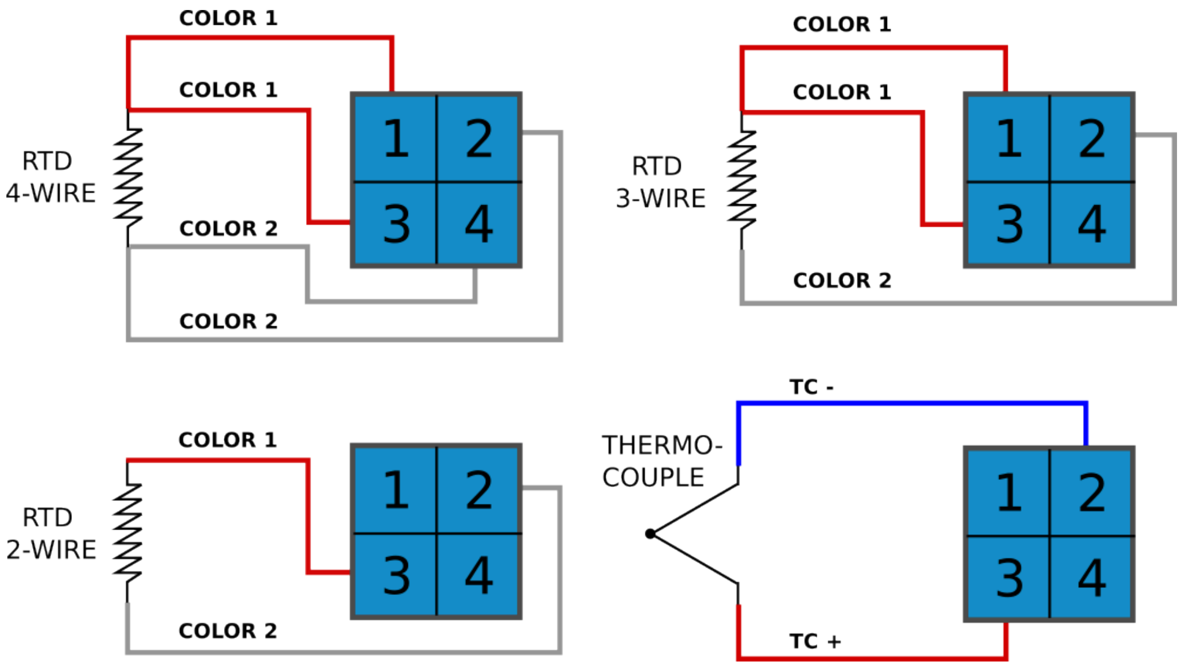
Channel	Connector			Connector
1	RTD1-1	1	2	RTD1-2
	RTD1-3	3	4	RTD1-4
2	RTD2-1	5	6	RTD2-2
	RTD2-3	7	8	RTD2-4
3	RTD3-1	9	10	RTD3-2
	RTD3-3	11	12	RTD3-4
4	RTD4-1	13	14	RTD4-2
	RTD4-3	15	16	RTD4-4
5	RTD5-1	17	18	RTD5-2
	RTD5-3	19	20	RTD5-4
6	RTD6-1	21	22	RTD6-2
	RTD6-3	23	24	RTD6-4
7	RTD7-1	25	26	RTD7-2
	RTD7-3	27	28	RTD7-4
8	RTD8-1	29	30	RTD8-2
	RTD8-3	31	32	RTD8-4

Channel	Connector			Connector
1		1	2	TC1-
	TC1+	3	4	
2		5	6	TC2-
	TC2+	7	8	
3		9	10	TC3-
	TC3+	11	12	
4		13	14	TC4-
	TC4+	15	16	
5		17	18	TC5-
	TC5+	19	20	
6		21	22	TC6-
	TC6+	23	24	
7		25	26	TC7-
	TC7+	27	28	
8		29	30	TC8-
	TC8+	31	32	

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:

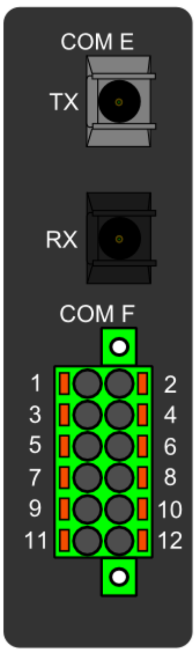
- Supported RTD sensors: Pt100, Pt1000
- Supported thermocouple sensors: type K (NiCh/NiAl), type J (Fe/constantan), type T (Cu/constantan) and type S (Cu/CuNi compensating).

Figure. 8.6 - 164. Different sensor types and their connections.



8.7 Serial RS-232 communication module (optional)

Figure. 8.7 - 165. Serial RS-232 module connectors.



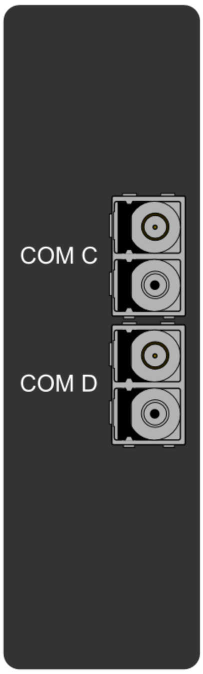
Connector	Name	Description
COM E	Serial fiber (GG/PP/GP/PG)	• Serial-based communications • Wavelength 660 nm • Compatible with 50/125 μm, 62.5/125 μm, 100/140 μm, and 200 μm Plastic-Clad Silica (PCS) fiber • Compatible with ST connectors

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.

8.8 LC 100 Mbps Ethernet communication module (optional)

Figure. 8.8 - 166. LC 100 Mbps Ethernet module connectors.

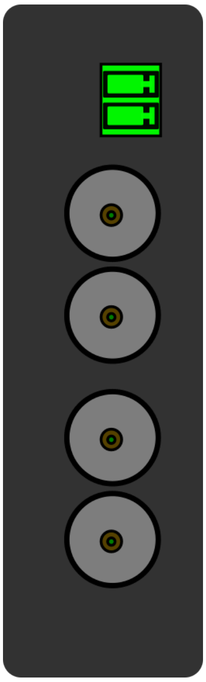


Connector	Description
COM C:	• Communication port C, LC fiber connector. • 62.5/125 µm or 50/125 µm multimode (glass). • Wavelength 1300 nm.
COM D:	• Communication port D, LC fiber connector. • 62.5/125 µm or 50/125 µm multimode (glass). • Wavelength 1300 nm.

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.

8.9 Double ST 100 Mbps Ethernet communication module (optional)

Figure. 8.9 - 167. Double ST 100 Mbps Ethernet communication module connectors.



Connector	Description
Two-pin connector	• IRIG-B input
ST connectors	• 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. 8.9 - 168. Example of a ring configuration.

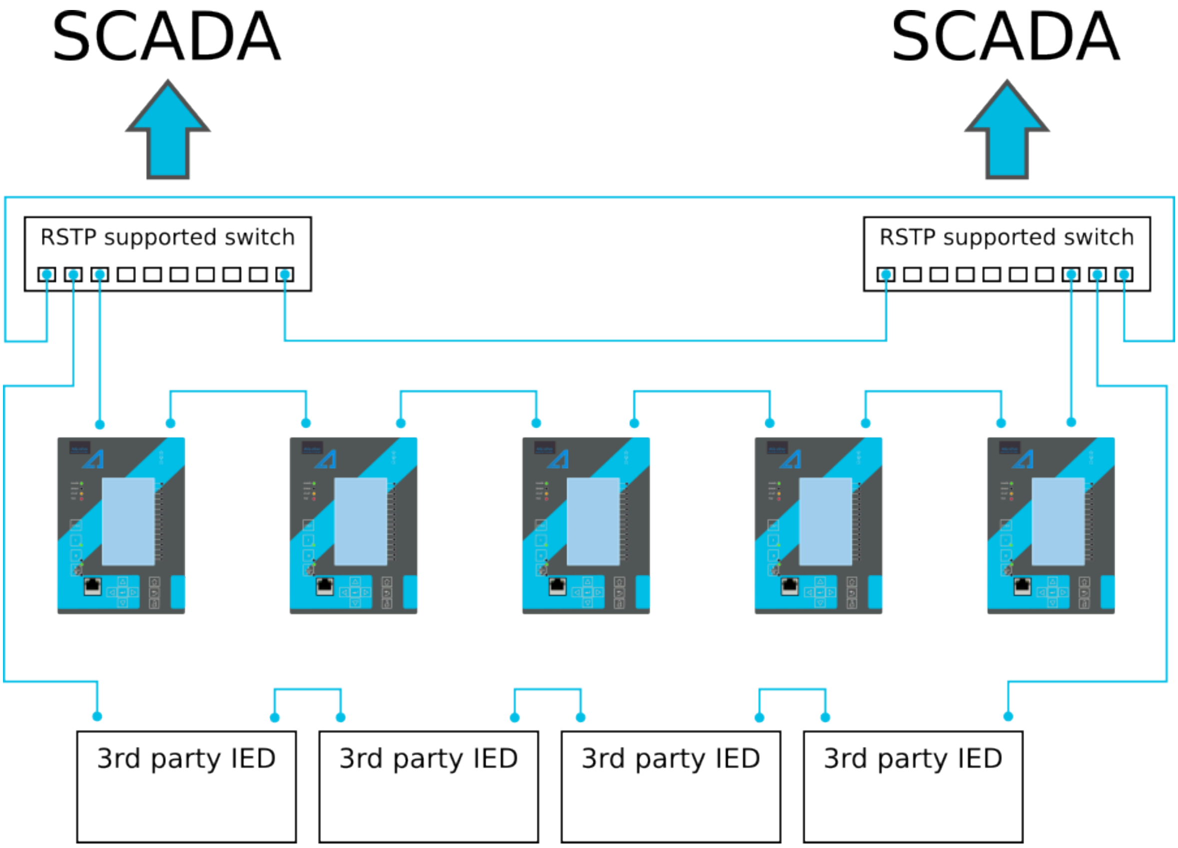
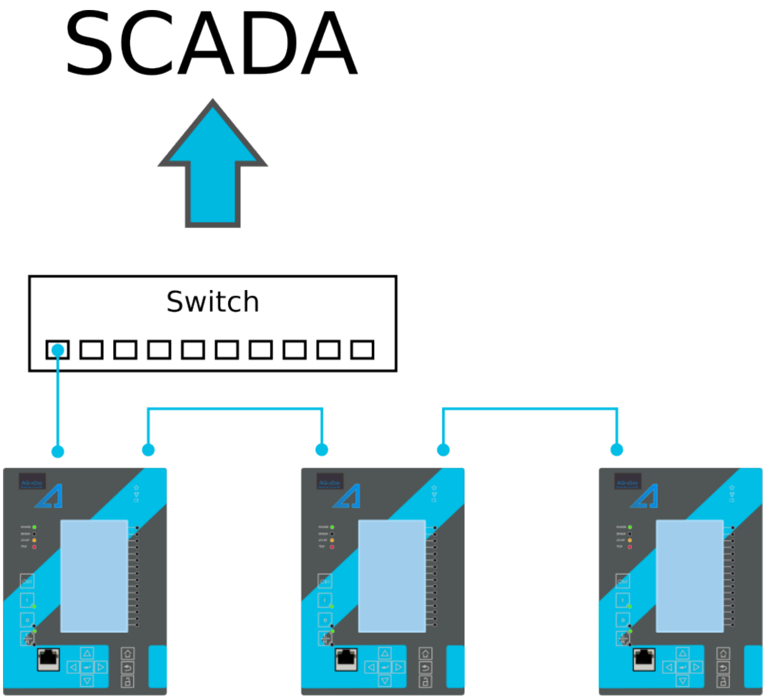
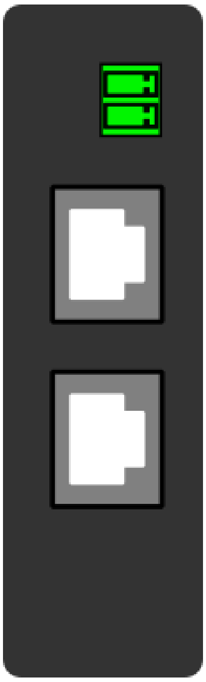


Figure. 8.9 - 169. Example of a multidrop configuration.



8.10 Double RJ-45 10/100 Mbps Ethernet communication module (optional)

Figure. 8.10 - 170. Double RJ-45 10/100 Mbps Ethernet communication module.



Connector	Description
Two-pin connector	• IRIG-B input

Connector	Description
RJ-45 connectors	• 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. 8.10 - 171. Example of a ring configuration.

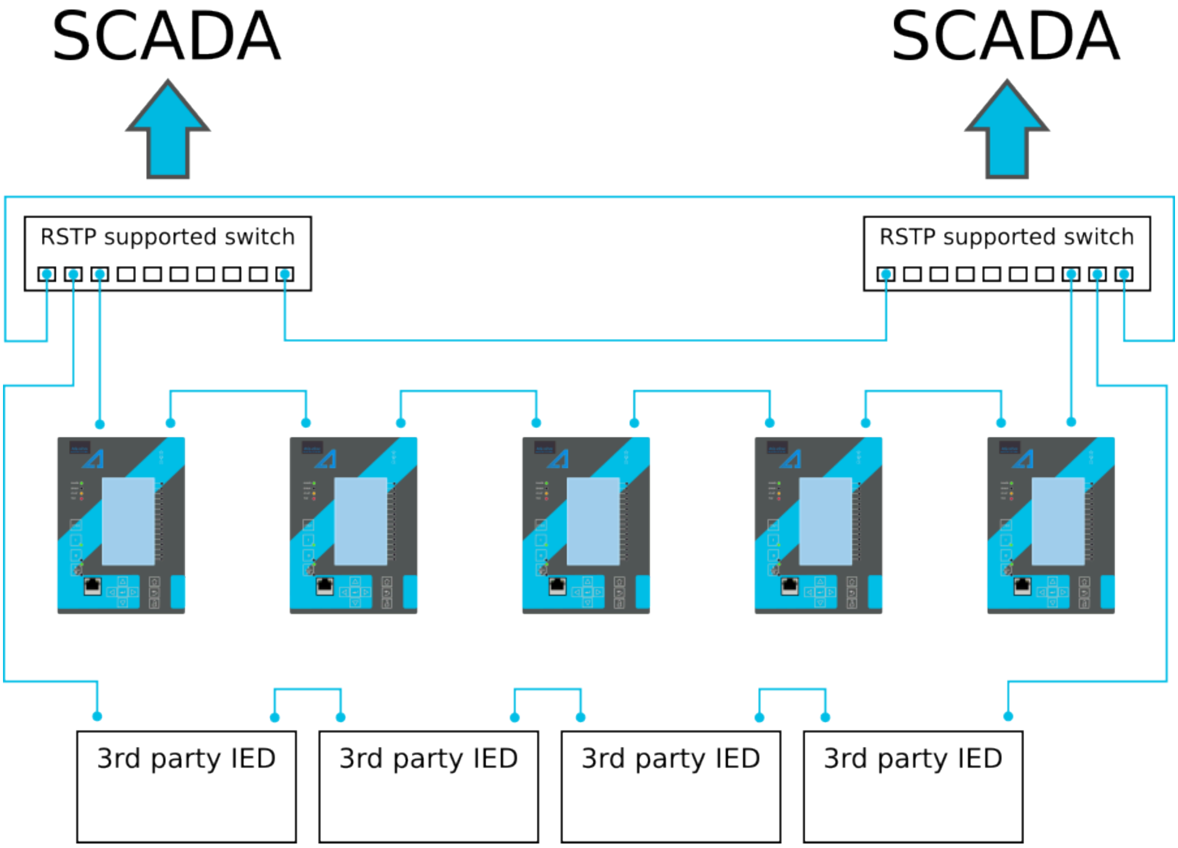
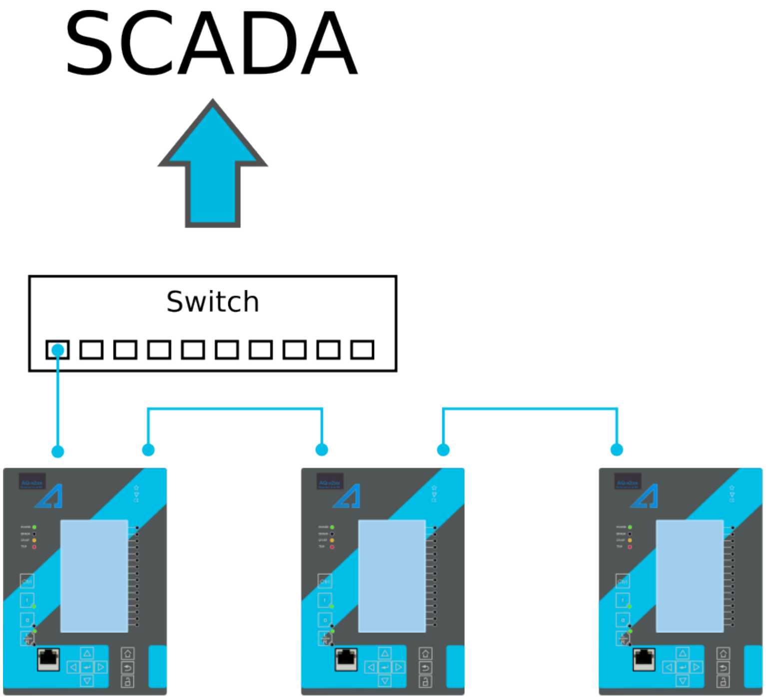
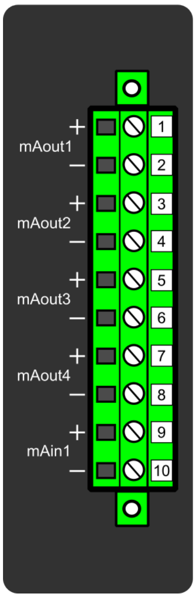


Figure. 8.10 - 172. Example of a multidrop configuration.



8.11 Milliampere (mA) I/O module (optional)

Figure. 8.11 - 173. 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.

8.12 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 (¼) 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. 8.12 - 174. Device dimensions.

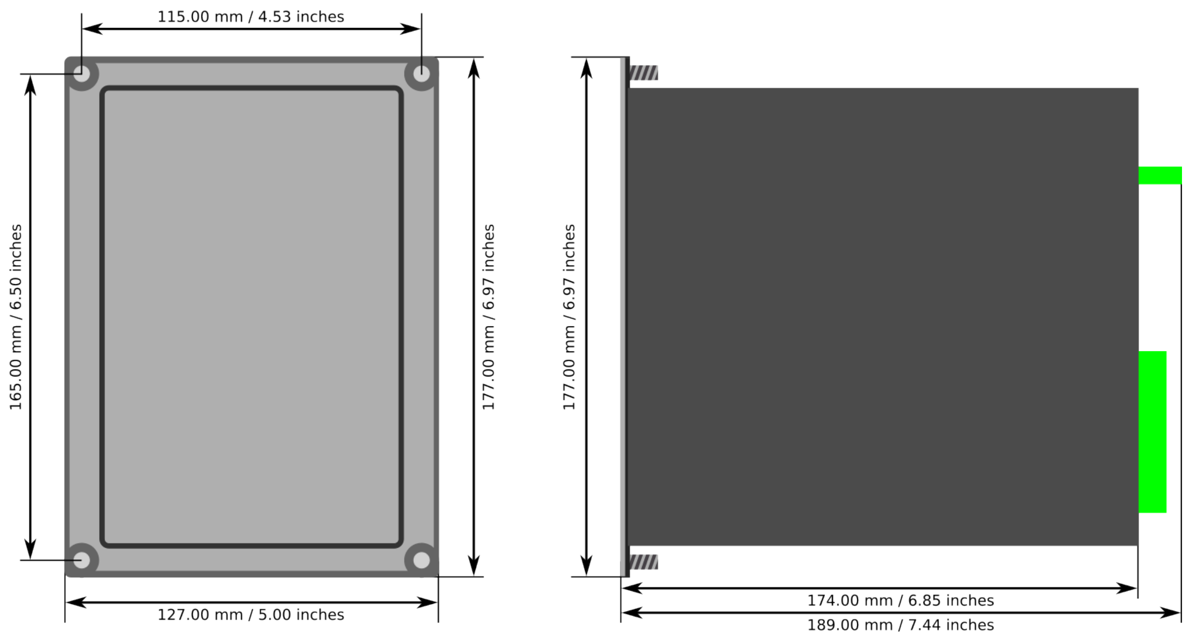


Figure. 8.12 - 175. Device installation.

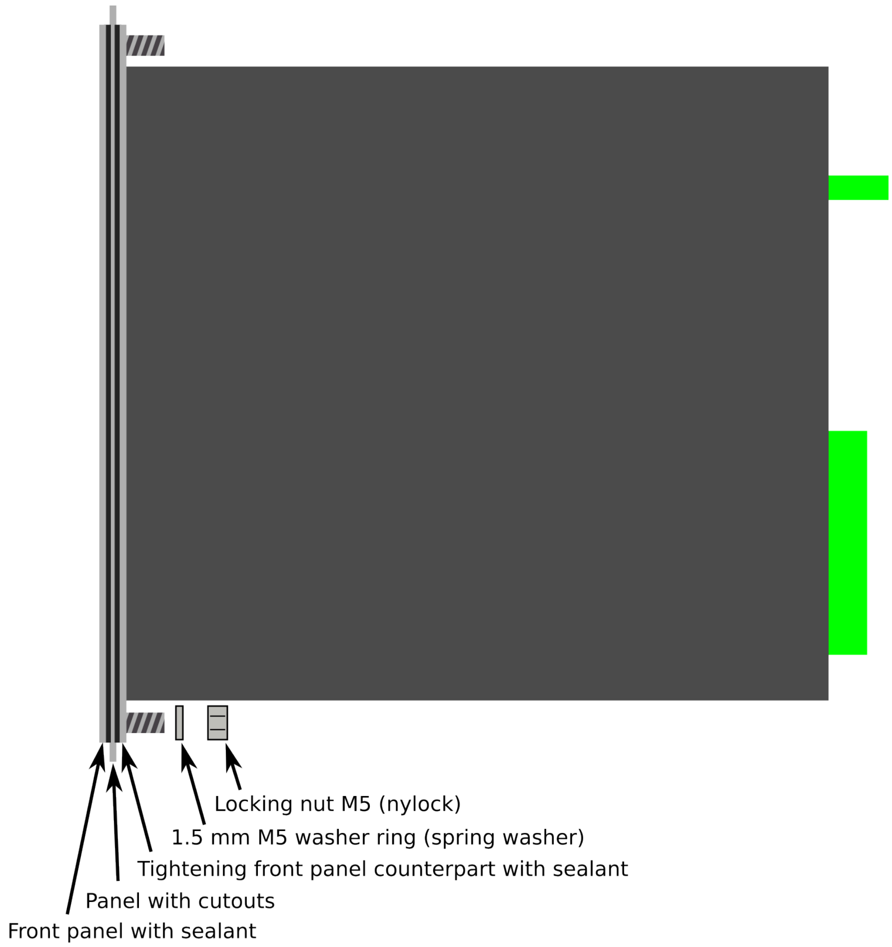
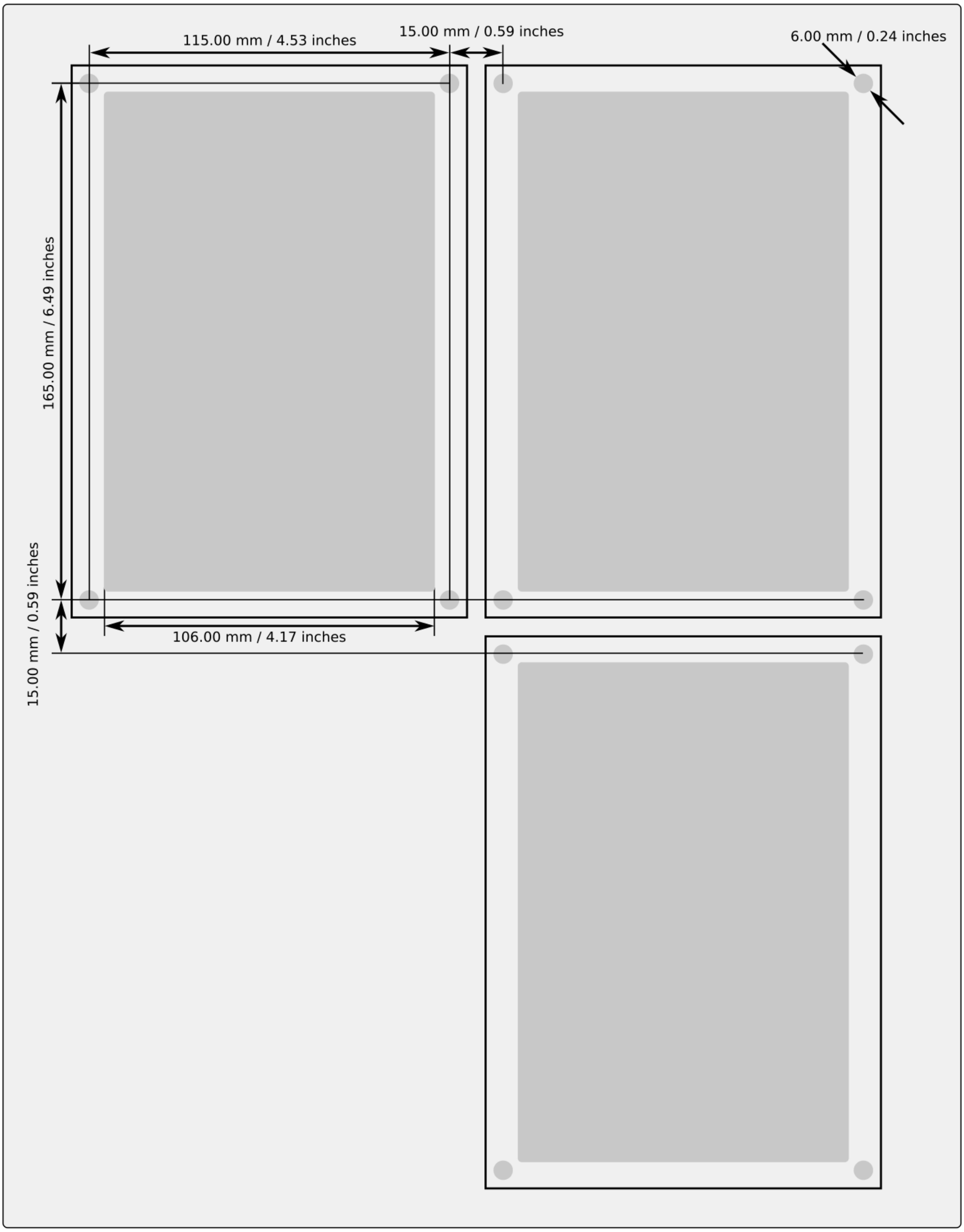


Figure. 8.12 - 176. Panel cutout dimensions and device spacing.



9 Technical data

9.1 Hardware

9.1.1 Measurements

9.1.1.1 Voltage measurement

Table. 9.1.1.1 - 163. 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 ±1.5 % 2…10 V ±0.5 % 10…480 V ±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 31st 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.

9.1.1.2 Frequency measurement

Table. 9.1.1.2 - 164. Frequency measurement accuracy.

Frequency measurement performance	
Frequency measuring range	6…75 Hz fundamental, up to the 31st harmonic current or voltage
Inaccuracy	10 mHz

9.1.2 CPU & Power supply

9.1.2.1 Auxiliary voltage

Table. 9.1.2.1 - 165. 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 - 166. 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 - 167. 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 - 168. 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 - 169. 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 - 170. 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 - 171. 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 - 172. 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 - 173. Technical data for the digital input module.

Rated values	
Rated auxiliary voltage	5…265 V (AC/DC)
Current drain	2 mA
Scanning rate Activation/release delay	5 ms 5...11 ms
Settings	
Pick-up threshold Release threshold	Software settable: 16…200 V, setting step 1 V 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 - 174. 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 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

9.1.3.3 Milliampere module (mA out & mA in)

Table. 9.1.3.3 - 175. Technical data for the milliampere module.

Signals

Output magnitudes Input magnitudes	4 × mA output signal (DC) 1 × mA input signal (DC)
mA input	
Range (hardware) Range (measurement) Inaccuracy	0...33 mA 0...24 mA ±0.1 mA
Update cycle Response time @ 5 ms cycle Update cycle time inaccuracy	5...10 000 ms, setting step 5 ms ~ 15 ms (13...18 ms) Max. +20 ms above the set cycle
mA input scaling range Output scaling range	0...4000 mA -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 Source signal scaling range	0...24 mA, setting step 0.001 mA -1 000 000.000…1 000 000.0000, setting step 0.0001

9.1.3.4 RTD input module

Table. 9.1.3.4 - 176. 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 - 177. 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 - 178. 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 - 179. 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 Protection functions

9.2.1.1 Circuit breaker failure protection (CBFP; 50BF/52BF)

Table. 9.2.1.1 - 180. Technical data for the circuit breaker failure protection function.

Measurement inputs	
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	RMS phase currents RMS residual current (I_{01}, I_{02} or calculated I_0)
Pick-up	
Monitored signals	Digital input status, digital output status, logical signals
Pick-up current setting: - IL1…IL3 - I01, I02, I0Calc	 0.10…40.00 × I_N, setting step 0.01 × I_N 0.005…40.00 × I_N, setting step 0.005 × I_N
Inaccuracy: - Starting phase current (5A) - Starting I01 (1 A) - Starting I02 (0.2 A) - Starting I0Calc (5 A)	 ±0.5 %I_{SET} or ±15 mA (0.10…4.0 × I_{SET}) ±0.5 %$I0_{SET}$ or ±3 mA (0.005…10.0 × I_{SET}) ±1.5 %$I0_{SET}$ or ±1.0 mA (0.005…25.0 × I_{SET}) ±1.0 %$I0_{SET}$ or ±15 mA (0.005…4.0 × I_{SET})
Operation time	
Definite time function operating time setting	0.050…1800.000 s, setting step 0.005 s
Inaccuracy: - Current criteria (I_M/I_{SET} ratio 1.05→) - DO or DI only	 ±1.0 % or ±55 ms ±15 ms
Reset	
Reset ratio	97 % of the pick-up current setting
Reset time	<50 ms

9.2.1.2 Overvoltage protection (U>; 59)

Table. 9.2.1.2 - 181. Technical data for the overvoltage function.

Measurement inputs	
Voltage inputs	U_{L1}, U_{L2}, U_{L3} U_{L12}, U_{L23}, U_{L31} (+ U_0)
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	50.00…150.00 %U_N, setting step 0.01 %U_N
Inaccuracy: - Voltage	 ±1.5 %U_{SET}
Operating time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy: - Definite time (U_M/U_{SET} ratio 1.05→)	 ±1.0 % or ±35 ms
IDMT setting parameters: k Time dial setting for IDMT A IDMT constant B IDMT constant C IDMT constant	 0.01…25.00, step 0.01 0…250.0000, step 0.0001 0…5.0000, step 0.0001 0…250.0000, step 0.0001
Inaccuracy: - IDMT operating time - IDMT minimum operating time	 ±1.5 % or ±20 ms ±20 ms
Instant operation time	
Start time and instant operation time (trip): - U_M/U_{SET} ratio 1.05→	 <50 ms
Reset	
Reset ratio	97 % of the pick-up voltage setting
Reset time setting Inaccuracy: Reset time	0.010…10.000 s, step 0.005 s ±1.0 % or ±45 ms
Instant reset time and start-up reset	<50 ms

9.2.1.3 Undervoltage protection (U<; 27)

Table. 9.2.1.3 - 182. Technical data for the undervoltage function.

Measurement inputs	
Voltage inputs	U_{L1}, U_{L2}, U_{L3} U_{L12}, U_{L23}, U_{L31} (+ U_0)
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	0.00…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
Inaccuracy: - Voltage	±1.5 %U_{SET} or ±30 mV
Operation time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy: - Definite time (U_M/U_{SET} ratio 1.05→)	±1.0 % or ±35 ms
IDMT setting parameters: k Time dial setting for IDMT A IDMT constant B IDMT constant C IDMT constant	0.01…25.00, step 0.01 0…250.0000, step 0.0001 0…5.0000, step 0.0001 0…250.0000, step 0.0001
Inaccuracy: - IDMT operating time - IDMT minimum operating time	±1.5 % or ±20 ms ±20 ms
Instant operation time	
Start time and instant operation time (trip): - U_M/U_{SET} ratio 1.05→	<65 ms
Retardation time (overshoot)	<30 ms
Reset	
Reset ratio	103 % of the pick-up voltage setting
Reset time setting Inaccuracy: Reset time	0.010…10.000 s, step 0.005 s ±1.0 % or ±45 ms
Instant reset time and start-up reset	<50 ms

Note!

- The low-voltage block is not in use when its pick-up setting is set to 0 %. The undervoltage function is in trip stage when the LV block is disabled and the device has no voltage injection.
- After the low voltage blocking condition, the undervoltage stage does not trip unless the voltage exceeds the pick-up setting first.

9.2.1.4 Neutral overvoltage protection (U0>; 59N)

Table. 9.2.1.4 - 183. Technical data for the neutral overvoltage function.

Measurement inputs	
Voltage input (selectable)	Residual voltage from U3 or 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 % $U0_N$, setting step 0.01 × I_N
Inaccuracy: - Voltage U0 - Voltage U0Calc	±1.5 %$U0_{SET}$ or ±30 mV ±150 mV
Operation time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s

Inaccuracy: - Definite time ($U0_M/U0_{SET}$ ratio 1.05→)	±1.0 % or ±45 ms
IDMT setting parameters: k Time dial setting for IDMT A IDMT constant B IDMT constant C IDMT constant	0.01…25.00, step 0.01 0…250.0000, step 0.0001 0…5.0000, step 0.0001 0…250.0000, step 0.0001
Inaccuracy: - IDMT operating time - IDMT minimum operating time	±1.5 % or ±20 ms ±20 ms
Instant operation time	
Start time and instant operation time (trip): - $U0_M/U0_{SET}$ ratio 1.05→	<50 ms
Reset	
Reset ratio	97 % of the pick-up voltage setting
Reset time setting Inaccuracy: Reset time	0.000 … 150.000 s, step 0.005 s ±1.0 % or ±50 ms
Instant reset time and start-up reset	<50 ms

9.2.1.5 Sequence voltage protection (U1/U2>/<; 47/27P/59NP)

Table. 9.2.1.5 - 184. Technical data for the sequence voltage function.

Measurement inputs	
Voltage inputs	U_{L1}, U_{L2}, U_{L3} U_{L12}, U_{L23}, U_{L31} (+ U_0)
Voltage input calculations	Positive sequence voltage (I1) Negative sequence voltage (I2)
Pick-up	
Pick-up setting	5.00…150.00 $\%U_N$, setting step 0.01 $\%U_N$
Inaccuracy: - Voltage	±1.5 $\%U_{SET}$ or ±30 mV
Low voltage block	
Pick-up setting	1.00…80.00 $\%U_N$, setting step 0.01 $\%U_N$
Inaccuracy: -Voltage	±1.5 $\%U_{SET}$ or ±30 mV
Operation time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy -Definite Time (U_M/U_{SET} ratio 1.05→)	±1.0 % or ±35 ms
IDMT setting parameters: k Time dial setting for IDMT A IDMT constant B IDMT constant C IDMT constant	0.01…25.00, step 0.01 0…250.0000, step 0.0001 0…5.0000, step 0.0001 0…250.0000, step 0.0001
Inaccuracy: - IDMT operating time - IDMT minimum operating time	±1.5 % or ±20 ms ±20 ms
Instant operation time	
Start time and instant operation time (trip): - U_M/U_{SET} ratio <0.95/1.05→	<65 ms

Reset	
Reset ratio	97 or 103 % of the pick-up voltage setting
Reset time setting Inaccuracy: Reset time	0.010…10.000 s, step 0.005 s ±1.0 % or ±35 ms
Instant reset time and start-up reset	<50 ms

9.2.1.6 Overfrequency and underfrequency protection (f>/<; 81O/81U)

Table. 9.2.1.6 - 185. Technical data for the overfrequency and underfrequency function.

Input signals	
Sampling mode	Fixed Tracking
Frequency reference 1 Frequency reference 2 Frequency reference 3	CT1IL1, CT2IL1, VT1U1, VT2U1 CT1IL2, CT2IL2, VT1U2, VT2U2 CT1IL3, CT2IL3, VT1U3, VT2U3
Pick-up	
f> pick-up setting f< pick-up setting	10.00…70.00 Hz, setting step 0.01 Hz 7.00…65.00 Hz, setting step 0.01 Hz
Inaccuracy (sampling mode): - Fixed - Tracking	±20 mHz (50/60 Hz fixed frequency) ±20 mHz (U > 30 V secondary) ±20 mHz (I > 30 % of rated secondary)
Operation time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy: - Definite time (I_M/I_{SET} ratio +/- 50 mHz)	±1.5 % or ±50 ms (max. step size: 100 mHz)
Instant operation time	
Start time and instant operation time (trip): - I_M/I_{SET} ratio +/- 50 mHz (Fixed) - I_M/I_{SET} ratio +/- 50 mHz (Tracking)	<70 ms (max. step size: 100 mHz) <3 cycles or <60 ms (max. step size: 100 mHz)
Reset	
Reset ratio	0.020 Hz
Instant reset time and start-up reset: - I_M/I_{SET} ratio +/- 50 mHz (Fixed) - I_M/I_{SET} ratio +/- 50 mHz (Tracking)	<110 ms (max. step size: 100 mHz) <3 cycles or <70 ms (max. step size: 100 mHz)

Note!

- The secondary voltage must exceed 2 volts or the current must exceed 0.25 amperes (peak-to peak) in order for the function to measure frequency.
- The frequency is measured two seconds after a signal is received.
- The fixed frequency mode: When the fixed mode is used, the system's nominal frequency should be set to 50 or 60 Hz.
- The tracked frequency mode: When tracked mode is used, the system's nominal frequency can be anything between 7...75 Hz.

9.2.1.7 Rate-of-change of frequency protection (df/dt>/<; 81R)

Table. 9.2.1.7 - 186. Technical data of the rate-of-change of frequency function.

Input signals

Sampling mode	Fixed Tracking
Frequency reference 1 Frequency reference 2 Frequency reference 3	CT1IL1, CT2IL1, VT1U1, VT2U1 CT1IL2, CT2IL2, VT1U2, VT2U2 CT1IL3, CT2IL3, VT1U3, VT2U3
Pick-up	
Df/dt>/< pick-up setting	0.15…1.00 Hz/s, setting step 0.01 Hz
f> limit	10.00…70.00 Hz, setting step 0.01 Hz
f< limit	7.00…65.00 Hz, setting step 0.01 Hz
Pick-up inaccuracy	
Df/dt	±5.0 %I_{SET} or ±20 mHz/s
Frequency	±15 mHz (U > 30 V secondary) ±20 mHz (I > 30 % of rated secondary)
Operation time	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy: - Definite time (I_M/I_{SET} ratio +/- 50 mHz)	±1.5 % or ±110 ms (max. step size: 100 mHz)
Start time and instant operation time (trip):	
f_M/f_{SET} ratio +/- 20 mHz (overreach)	<180 ms
f_M/f_{SET} ratio +/- 200 mHz (overreach)	<90 ms
Reset	
Reset ratio (frequency limit)	0.020 Hz
Instant reset time and start-up reset - f_M/f_{SET} ratio +/- 50 mHz	<2 cycles or <60 ms (max. step size: 100 mHz)

Note!

- The frequency is measured two seconds after a signal is received.

9.2.1.8 Resistance temperature detectors

Table. 9.2.1.8 - 187. Technical data of the resistance temperature detectors.

Inputs	
Resistance input magnitudes	Measured temperatures measured by RTD sensors
Alarm channels	12 individual alarm channels
Settable alarms	24 alarms available (two per each alarm channel)
Pick-up	
Alarm setting range Inaccuracy Reset ratio	101.00…2000.00 deg, setting step 0.1 deg (either < or > setting) ±3 % of the set pick-up value 97 % of the pick-up setting
Operation	
Operating time	Typically <500 ms

9.2.2 Control functions

9.2.2.1 Setting group selection

Table. 9.2.2.1 - 188. 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 - 189. 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.

9.2.2.3 Vector jump (Δφ; 78)

Table. 9.2.2.3 - 190. Technical data for the vector jump protection function.

Measurement inputs	
Voltage inputs	U_{L1}, U_{L2}, U_{L3} U_{L12}, U_{L23}, U_{L31} + U_0
Monitored voltages	Any or all system line-to-line voltage(s) Any or all system line-to-neutral voltage(s) Specifically chosen line-to-line or line-to-neutral voltage U4 channel voltage
Pick-up	
Pick-up setting	0.05…30.00°, setting step 0.01°
Inaccuracy: - Voltage angle	±30% overreach or 1.00 °

Low-voltage blocking	
Pick-up setting	0.01…100.00 $\%U_N$, setting step 0.01 $\%U_N$
Inaccuracy: - Voltage	±1.5 $\%U_{SET}$ or ±30 mV
Instant operation time	
Alarm and trip operation time: - (Im/Iset ratio > ±30% overreach or 1.00 °)	<40 ms (typically 30 ms) 50/60 Hz <50 ms (typically 40 ms) 16.67 Hz
Reset	
Trip pulse	~5-10ms

9.2.2.4 Synchrocheck (ΔV/Δa/Δf; 25)

Table. 9.2.2.4 - 191. Technical data for the synchrocheck function.

Input signals	
Voltage inputs	U1, U2, U3 or U4 voltage channel
Voltage input magnitudes	RMS line-to-line or line-to-neutral voltages U3 or U4 voltage channel RMS
Pick-up	
U diff < setting	2.00…50.00 $\%U_N$, setting step 0.01 $\%U_N$
Angle diff < setting	3.0…90.0 deg, setting step 0.10 deg
Freq diff < setting	0.05…0.50 Hz, setting step 0.01 Hz
Inaccuracy: - Voltage - Frequency - Angle	±3.0 $\%U_{SET}$ or ±0.3 $\%U_N$ ±25 mHz (U> 30 V secondary) ±1.5° (U> 30 V secondary)
Reset	
Reset ratio: - Voltage - Frequency - Angle	99 % of the pick-up voltage setting 20 mHz ±2.0°
Activation time	
Activation (to LD/DL/DD) Activation (to Live Live)	<35 ms <60 ms
Reset	<40 ms
Bypass modes	
Voltage check mode (excluding LL)	LL+LD, LL+DL, LL+DD, LL+LD+DL, LL+LD+DD, LL+DL+DD, bypass
U live > limit U dead < limit	0.10…100.00 $\%U_N$, setting step 0.01 $\%U_N$ 0.00…100.00 $\%U_N$, setting step 0.01 $\%U_N$

Note!

- Voltage is scaled to the primary amplitude; therefore, the different sized PT secondaries are possible.
- The minimum voltage for direction and frequency solving is 20.0 $\%U_N$.
- U< dead limit is not in use when set to 0 $\%U_N$.
- When SYN3 is used, SYN1 and SYN2 must have the same reference voltage.
- In 3LN mode the synchronization to the L-N and L-L voltages is possible. In 3LL/2LL modes the synchronization is only supported to the L-L voltage.

9.2.3 Monitoring functions

9.2.3.1 Voltage transformer supervision (60)

Table. 9.2.3.1 - 192. 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…0.50 × U_N, setting step 0.01 × U_N 0.50…1.10 × U_N, setting step 0.01 × U_N 2.00…90.00 deg, setting step 0.10 deg
Inaccuracy: - Voltage - U angle (U> 1 V)	 ±1.5 %U_{SET} ±1.5°
External line/bus side pick-up (optional)	0 → 1
Time delay for alarm	
Definite time function operating time setting	0.00…1800.00 s, setting step 0.005 s
Inaccuracy: - Definite time (U_M/U_{SET} ratio > 1.05/0.95)	 ±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…10.000 s, step 0.005 s ±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 Disturbance recorder

Table. 9.2.3.2 - 193. 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 - 194. 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 µs Between wire and earth 4 kV, 1.2/50 µs
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 - 195. 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 µs, 0.5 J

Physical environment compatibility

Table. 9.3 - 196. Mechanical tests.

Vibration test	
EN 60255-1, EN 60255-27, IEC 60255-21-1 Class 1	2…13.2 Hz, ± 3.5 mm 13.2…100 Hz, ± 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 - 197. 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 - 198. 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 - 199. 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 - V 2 1 1 X - P X 8 A A X A - X X X X X

Model
V Voltage protection

Device size
1 1/4 of 19" rack

Analog measurement
1 4 Voltage measurement channels

Functionality package
A Normal functional package
B With synchronizer function

Mounting
P Panel mounting

Auxiliary voltage
H 80...265 VAC/DC
L 18...72 VDC

Measurement accuracy class
8 N/A

Terminals
A N/A

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 B, C, D, E, F (5 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

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Contacts

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