

# AQ-P215

Power monitoring device

## Instruction manual



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## Disclaimer

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

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# 1 Document information

## 1.1 Version 2 revision notes

Table. 1.1 - 1. Version 2 revision notes

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

Changes	<ul style="list-style-type: none"> <li>- Terminology consistency improved (e.g. binary inputs are now always called digital inputs).</li> <li>- 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.).</li> <li>- Improvements to many drawings and formula images.</li> <li>- Improved and updated device user interface display images.</li> <li>- AQ-P215 Functions included list Added: Voltage memory, running hour counter, programmable control switch and mA output control.</li> <li>- Changed disturbance recorder maximum digital channel amount from 32 to 95.</li> <li>- Added residual current coarse and fine measurement data to disturbance recorder description.</li> <li>- Updated I01 and I02 rated current range.</li> <li>- Added inches to Dimensions and installation chapter.</li> <li>- Added raising frames, wall mounting bracket, combiflex frame to order code.</li> <li>- Added logical input and logical output function descriptions.</li> <li>- Additions to Abbreviations chapter.</li> <li>- Added button test description to Local panel structure chapter.</li> <li>- Added parameter descriptions to General menu Device user interface chapter.</li> <li>- Added new parameter descriptions to Monitoring menu device user interface chapter.</li> <li>- Added note to Configuring user levels and passwords chapter that user level with a password automatically locks itself after 30 minutes of inactivity.</li> <li>- Added more "Tripped stage" indications and fault types to Measurement value recorder function.</li> <li>- Updated: Digital input activation and release threshold setting ranges and added drop-off delay setting.</li> <li>- Added sample rate to voltage and current measurement tech data.</li> </ul>
Revision	2.04
Date	8.6.2021
Changes	<ul style="list-style-type: none"> <li>- Removed the 0.2S energy measurement class from the unit description</li> <li>- Increased the consistency in terminology</li> <li>- Various image upgrades</li> <li>- Visual update to the order codes</li> </ul>
Revision	2.05
Date	22.6.2021
Changes	<ul style="list-style-type: none"> <li>- Fixed phase current measurement continuous thermal withstand from 30A to 20A.</li> <li>- Fixed lots of timing errors written to registers table. "Prefault" is -200 ms from Start event, "Pretrigger" is -20 ms from trip (or start if fault doesn't progress to trip), "Fault" is start (or trip if fault doesn't progress to trip).</li> <li>- Added event history technical data</li> </ul>
Revision	2.06
Date	21.6.2022
Changes	<ul style="list-style-type: none"> <li>- Improved descriptions generally in many chapters.</li> <li>- Improved readability of a lot of drawings and images.</li> <li>- Order codes have been revised.</li> <li>- Added new trip detections and fault types to measurement value recorder.</li> <li>- Added user description parameter descriptions for digital inputs, digital outputs, logical inputs, logical outputs and GOOSE inputs.</li> <li>- Added spare part codes and compatibilities to option cards.</li> </ul>
Revision	2.07

Date	7.7.2022
Changes	- Added THD voltage measurements.
Revision	2.08
Date	8.9.2022
Changes	<ul style="list-style-type: none"> <li>- Added stage forcing parameter to function descriptions.</li> <li>- Fixes to "<a href="#">Real time signals to comm</a>" description.</li> <li>- Added "Ethernet port" parameter description to <a href="#">IEC61850</a>, <a href="#">IEC104</a> and <a href="#">Modbus TCP</a> descriptions.</li> <li>- Removed "Measurement update interval" settings from Modbus description. No longer in use.</li> <li>- Renamed "System integration" chapter to "<a href="#">Communication</a>" and restructured the chapters to be closer to how they are in the menus.</li> <li>- Added "<a href="#">Event logger</a>" chapter.</li> </ul>
Revision	2.09
Date	14.3.2023
Changes	<ul style="list-style-type: none"> <li>- Updated the Arcteq logo on the cover page and refined the manual's visual look.</li> <li>- Added the "<a href="#">Safety information</a>" chapter and changed the notes throughout the document accordingly.</li> <li>- Changed the "IED user interface" chapter's title to "Device user interface" and replaced all 'IED' terms with 'device' or 'unit'.</li> <li>- Updated the rated values for the change-over CPU digital outputs in "Technical data".</li> <li>- Added the maximum and minimum allowed tracking frequencies to the settings table of the "<a href="#">Frequency tracking and scaling</a>" chapter (under "Measurements").</li> <li>- Updated the input impedance for the voltage measurement module in "<a href="#">Technical data</a>".</li> </ul>
Revision	2.10
Date	19.6.2023
Changes	<ul style="list-style-type: none"> <li>- Updated order codes.</li> <li>- Added mention of 5 ms measurement update cycle in the <a href="#">Fast Modbus</a> description.</li> </ul>
Revision	2.11
Date	29.11.2023
Changes	<ul style="list-style-type: none"> <li>- Added the 5 ms update time in the measurement chapters.</li> <li>- Added spring lock cage options for connectors. See the "<a href="#">Ordering information</a>" chapter.</li> <li>- Updated the contact address for technical support in the "<a href="#">Contact and reference information</a>" chapter.</li> </ul>
Revision	2.12
Date	January 2024
Changes	<ul style="list-style-type: none"> <li>- Added voltage input thresholds to "<a href="#">Voltage measurement and scaling</a>".</li> <li>- Added Chinese and Kazakh languages as language options in "<a href="#">General menu</a>".</li> </ul>

## 1.2 Version 1 revision notes

Table. 1.2 - 2. Version 1 revision notes

Revision	1.00
Date	8.4.2013
Changes	<ul style="list-style-type: none"> <li>The first revision for AQ-P215.</li> </ul>
Revision	1.01
Date	26.1.2015
Changes	<ul style="list-style-type: none"> <li>Added the RTD &amp; mA input module, the double LC 100Mb Ethernet card module, and the serial RS-232 &amp; serial fiber module hardware descriptions</li> <li>Order code updated.</li> </ul>
Revision	1.02
Date	30.5.2015
Changes	<ul style="list-style-type: none"> <li>Added the PCB and Terminal options to the order code.</li> </ul>
Revision	1.03
Date	30.8.2016
Changes	<ul style="list-style-type: none"> <li>Added the password set-up guide (previously only in the AQtivate 200 user guide).</li> </ul>
Revision	1.04
Date	9.2.2017
Changes	<ul style="list-style-type: none"> <li>Added the programmable stage description.</li> <li>Order code updated.</li> </ul>
Revision	1.05
Date	20.12.2017
Changes	<ul style="list-style-type: none"> <li>Measurement value recorder description added.</li> <li>ZCT connection added to the current measurement description.</li> <li>Event lists revised on several functions.</li> <li>RTD &amp; mA card description improvements.</li> <li>Ring-lug CT card option description added.</li> <li>Order code revised.</li> </ul>
Revision	1.06
Date	29.5.2018
Changes	<ul style="list-style-type: none"> <li>Added the fast Modbus/TCP setup description.</li> </ul>
Revision	1.07
Date	14.8.2018
Changes	<ul style="list-style-type: none"> <li>Added the mA output option card description and updated the order code.</li> </ul>

Revision	1.08
Date	12.12.2018
Changes	<ul style="list-style-type: none"><li>• Added the running hour counter function description.</li><li>• HMI display technical data added.</li></ul>

## 1.3 Safety information

This document contains important instructions that should be saved for future use. Read the document carefully before installing, operating, servicing, or maintaining this equipment. Please read and follow all the instructions carefully to prevent accidents, injury and damage to property.

Additionally, this document contains four (4) types of special messages to call the reader's attention to useful information as follows:



### NOTICE!

"Notice" messages indicate relevant factors and conditions to the the concept discussed in the text, as well as to other relevant advice.



### CAUTION!

"Caution" messages indicate a potentially hazardous situation which, if not avoided, **could** result in minor or moderate personal injury, in equipment/property damage, or software corruption.



### WARNING!

"Warning" messages indicate a potentially hazardous situation which, if not avoided, **could** result in death or serious personal injury as well as serious damage to equipment/property.



### DANGER!

"Danger" messages indicate an imminently hazardous situation which, if not avoided, **will** result in death or serious personal injury.

These symbols are added throughout the document to ensure all users' personal safety and to avoid unintentional damage to the equipment or connected devices.

Please note that although these warnings relate to direct damage to personnel and/or equipment, it should be understood that operating damaged equipment may also lead to further, indirect damage to personnel and/or equipment. Therefore, we expect any user to fully comply with these special messages.

## 1.4 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

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



## 2 General

The AQ-P215 power monitoring unit 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-P215 power monitoring unit. For other AQ 200 and AQ 250 series products please consult their respective device manuals.

AQ-P215 is a novel power monitoring unit for any demanding metering and power monitoring applications. AQ-P215 offers a unique combination of high accuracy power and energy measurement of 0.2 % down to 1 A RMS with dynamic measurement range up to 250 A secondary current. Freely configurable data logging, programmable logic and disturbance recorder features allow for a variety of power quality monitoring applications. There are up to three (3) option card slots available for additional I/O or communication cards for more comprehensive monitoring and control applications. AQ-P215 communicates using various protocols including the IEC 61850 substation communication standard.

## 3 Device user interface

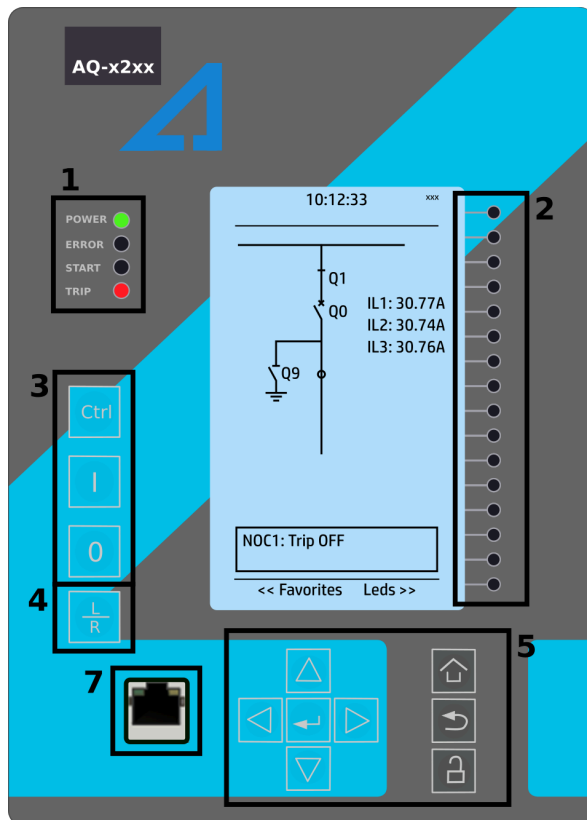
### 3.1 Panel structure

The user interface section of an AQ 200 or AQ 250 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 200 freeware software suite.

#### 3.1.1 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.

Figure. 3.1.1 - 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 device 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 device configuration.



#### NOTICE!

The object control buttons are not in use in AQ-P215.

When the unit is powered on, the green "Power" LED is lit. When the red "Error" LED is lit, the device 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.

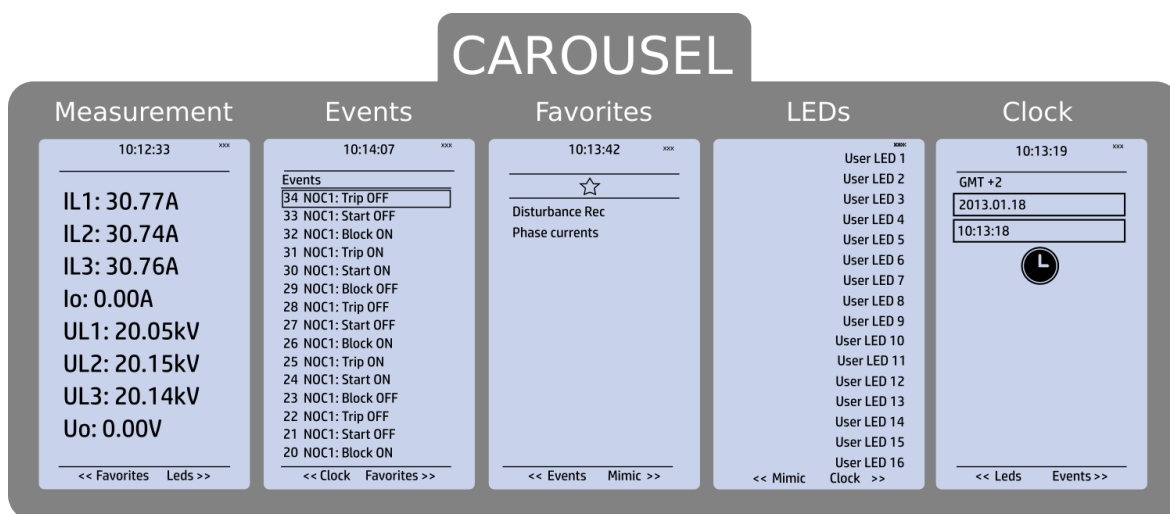
Holding the I (object control) button down for five seconds brings up the button test menu. It displays all the physical buttons on the front panel. Pressing any of the listed buttons marks them as tested. When all buttons are marked as having been tested, the device will return back to the default view.

## 3.2 Mimic and main menu

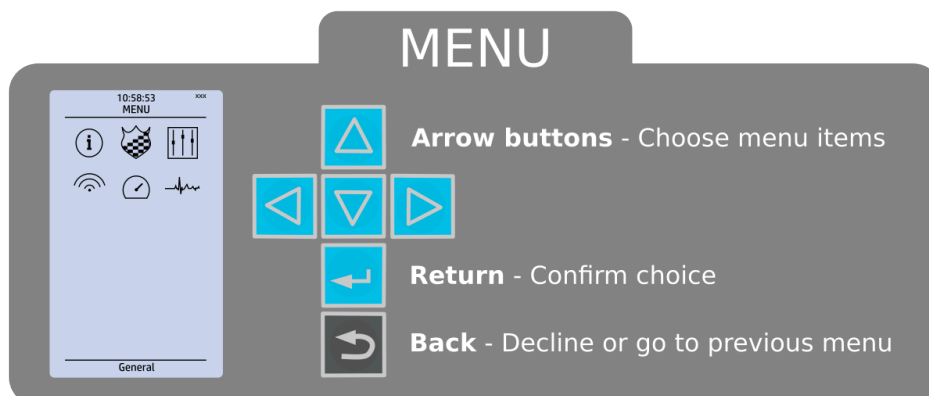
### 3.2.1 Basic configuration

The user interface is divided into five (5) quick displays: "Measurements", "Events", "Favorites", "LEDs" and "Clock". 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. 3.2.1 - 2. Basic navigation for AQ-P215.



**Home** - Switch between MENU and CAROUSEL view



The **Home** button switches between the quick display carousel and the main display with the six (6) main configuration menus. The AQ-P215 power monitoring device has the following six configuration menus: *General*, *PMU functions*, *Control*, *Communication*, *Measurements* and *Monitoring*. You can switch between these menus by using the four navigational arrow keys and confirming your selection with the **Enter** button in the middle. Please note that the menu's name appears at the bottom of the display when selected. 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 latched LEDs in "LEDs" and "Favorites" displays. 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).

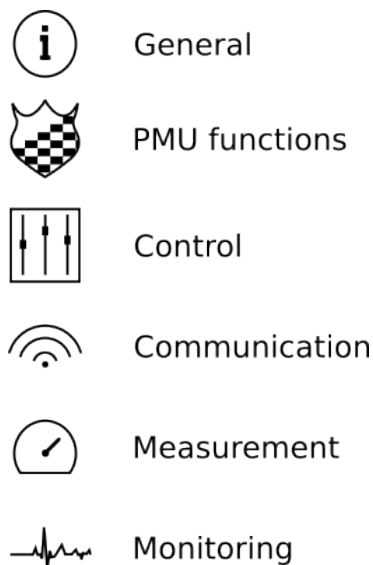
### 3.2.2 Navigation in the main configuration menus

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

- General
- PMU functions
- Control
- Communication
- Measurement
- Monitoring.

They are presented in the image below.

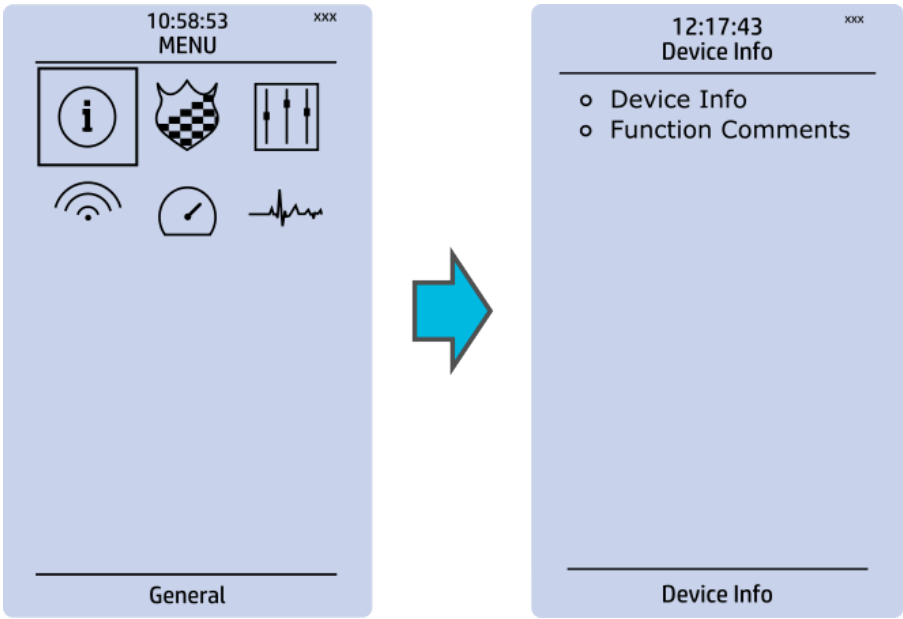
Figure. 3.2.2 - 3. Main configuration menus.



### 3.3 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. 3.3 - 4. General menu structure.



Device info

Figure. 3.3 - 5. Device info.

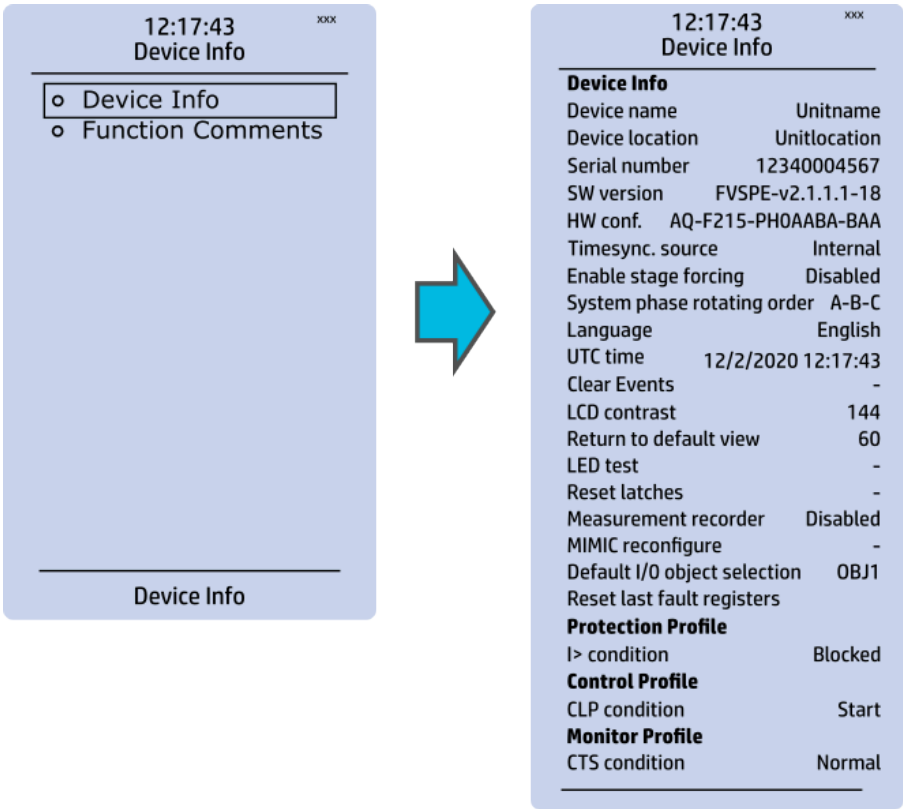


Table. 3.3 - 3. Parameters and indications in the *General* menu.

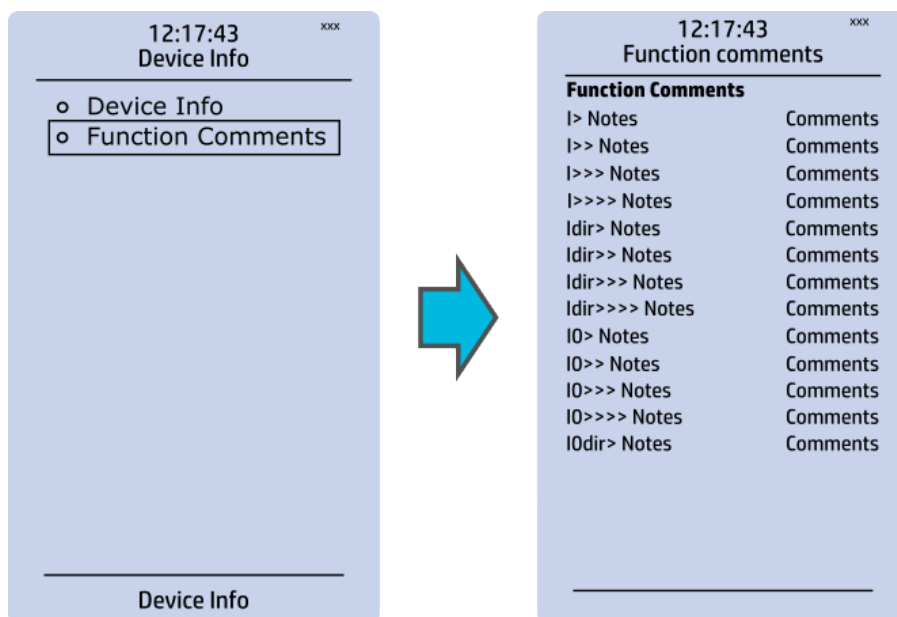
Name	Range	Step	Default	Description
Device name	-	-	Unitname	The file name uses these fields when loading the .aqs configuration file from the AQ-200 unit.
Device location	-	-	Unitlocation	
Serial number	-	-	-	Displays the unit's unique serial number. The serial number is also printed on the sticker 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	<ul style="list-style-type: none"> <li>• Internal</li> <li>• External NTP</li> <li>• External Serial</li> <li>• IRIG-B</li> </ul>	-	<ul style="list-style-type: none"> <li>• Internal</li> </ul>	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	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Enabled</li> </ul>	-	<ul style="list-style-type: none"> <li>• Disabled</li> </ul>	When this parameter is enabled it is possible for the user to force the protection, control and monitoring functions to different statuses like START and TRIP. This is done in the function's <i>Info</i> page with the <i>Force status to</i> parameter.
System phase rotating order	<ul style="list-style-type: none"> <li>• A-B-C</li> <li>• A-C-B</li> </ul>	-	<ul style="list-style-type: none"> <li>• A-B-C</li> </ul>	Allows the user to switch the expected order in which the voltage and current phases are wired to the unit.
Language	<ul style="list-style-type: none"> <li>• User defined</li> <li>• English</li> <li>• Finnish</li> <li>• Chinese</li> <li>• Spanish</li> <li>• French</li> <li>• German</li> <li>• Russian</li> <li>• Ukrainian</li> <li>• Kazakh</li> </ul>	-	<ul style="list-style-type: none"> <li>• English</li> </ul>	Changes the language of the parameter descriptions in the HMI. If the language has been set to "Other" in the settings of the AQtivate 200 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	<ul style="list-style-type: none"> <li>• -</li> <li>• Clear</li> </ul>	-	<ul style="list-style-type: none"> <li>• -</li> </ul>	Clears the event history recorded in the device.
LCD Contrast	0...255	1	120	Changes the contrast of the LCD display.

Name	Range	Step	Default	Description
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	<ul style="list-style-type: none"> <li>-</li> <li>Activated</li> </ul>	-	<ul style="list-style-type: none"> <li>-</li> </ul>	When activated, all LEDs are lit up. LEDs with multiple possible colors blink each color.
Reset latches	<ul style="list-style-type: none"> <li>-</li> <li>Reset</li> </ul>	-	<ul style="list-style-type: none"> <li>-</li> </ul>	Resets the latched signals in the logic and the matrix. When a reset command is given, the parameter automatically returns back to "-".
Measurement recorder	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	<ul style="list-style-type: none"> <li>Disabled</li> </ul>	Enables the measurement recorder tool, further configured in <i>Tools</i> → <i>Misc</i> → <i>Measurement recorder</i> .
Reconfigure mimic	<ul style="list-style-type: none"> <li>-</li> <li>Reconfigure</li> </ul>	-	<ul style="list-style-type: none"> <li>-</li> </ul>	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.

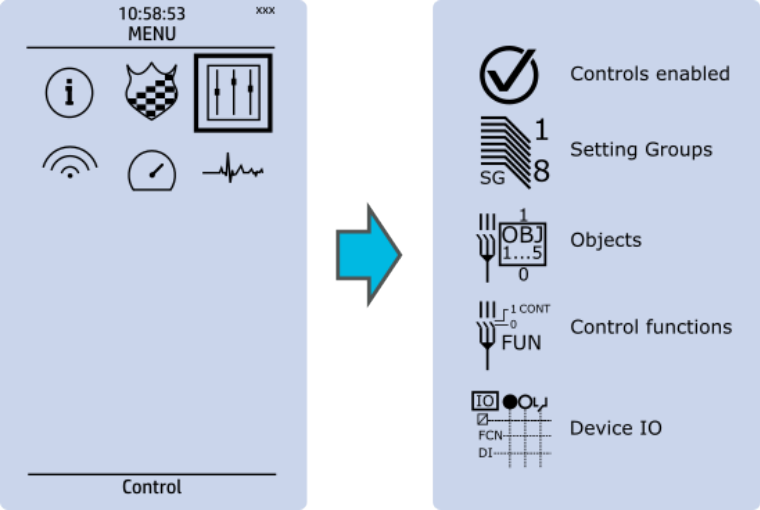
Figure. 3.3 - 6. Function comments.



### 3.4 Control menu

#### Main menu

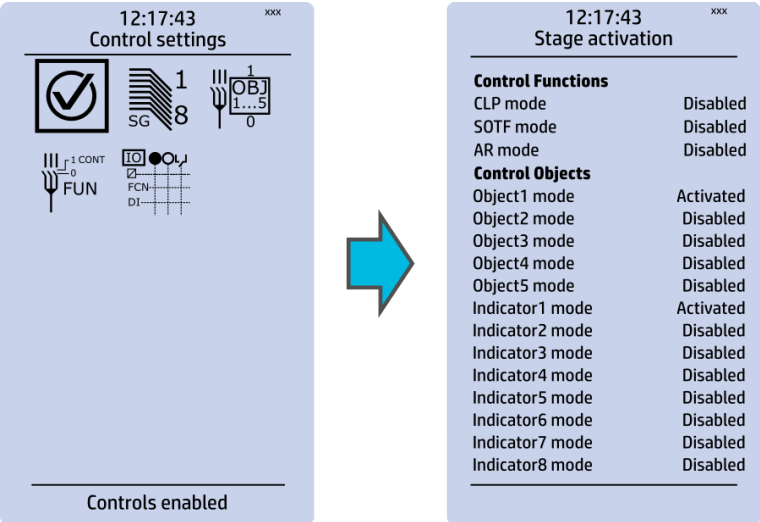
Figure. 3.4 - 7. Main menu structure.



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. 3.4 - 8. Controls enabled submenu.



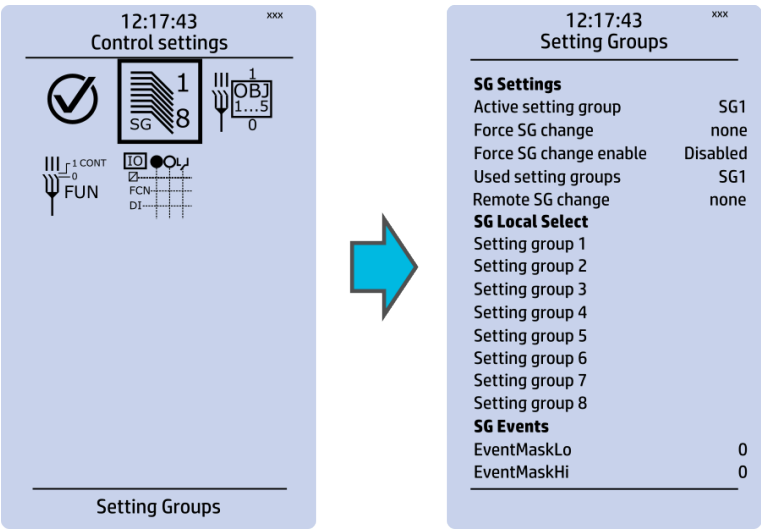
You can activate the selected control functions in the *Controls enabled* submenu. By default all the control functions are disabled. All activated functions can be viewed in the *Control functions* submenu (see the section "Control functions" below for more information).

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. 3.4 - 9. Setting groups submenu.

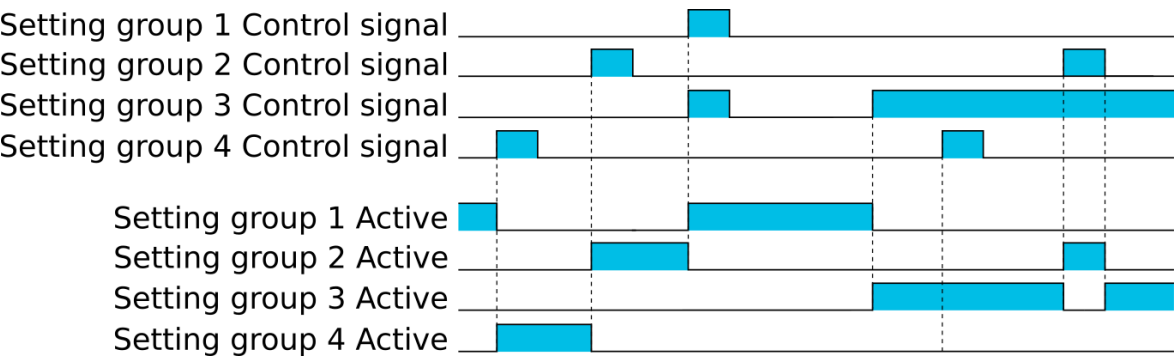


The *Setting groups* submenu displays all the information related to setting group changing, such as the following:

- **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).

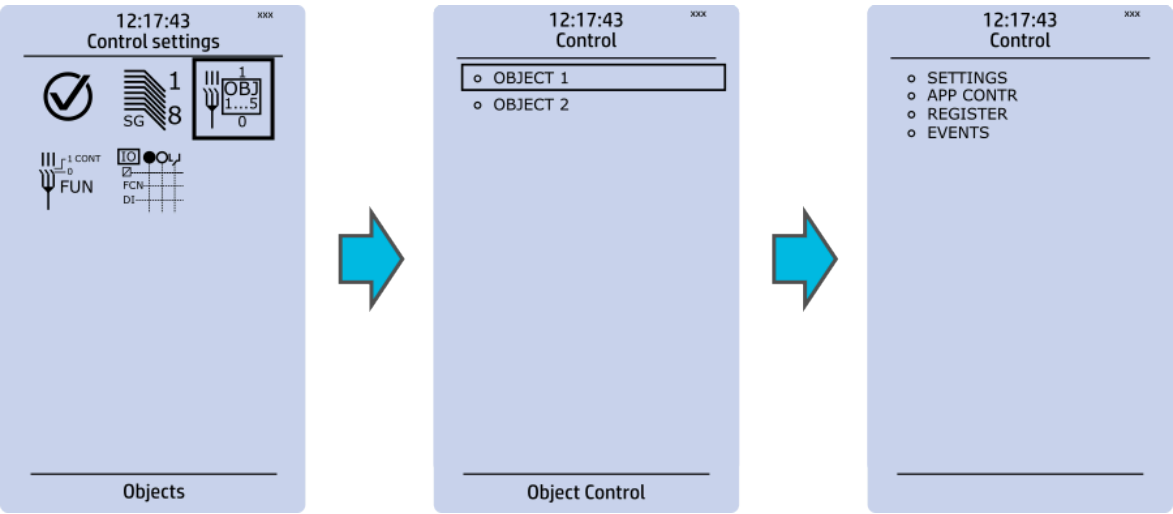
Setting group 1 (SG1) has the highest priority, while Setting group 8 (SG8) has the lowest priority. Setting groups can be controlled with pulses or with both pulses and static signals (see the image below).

Figure. 3.4 - 10. Example of setting group (SG) changing.



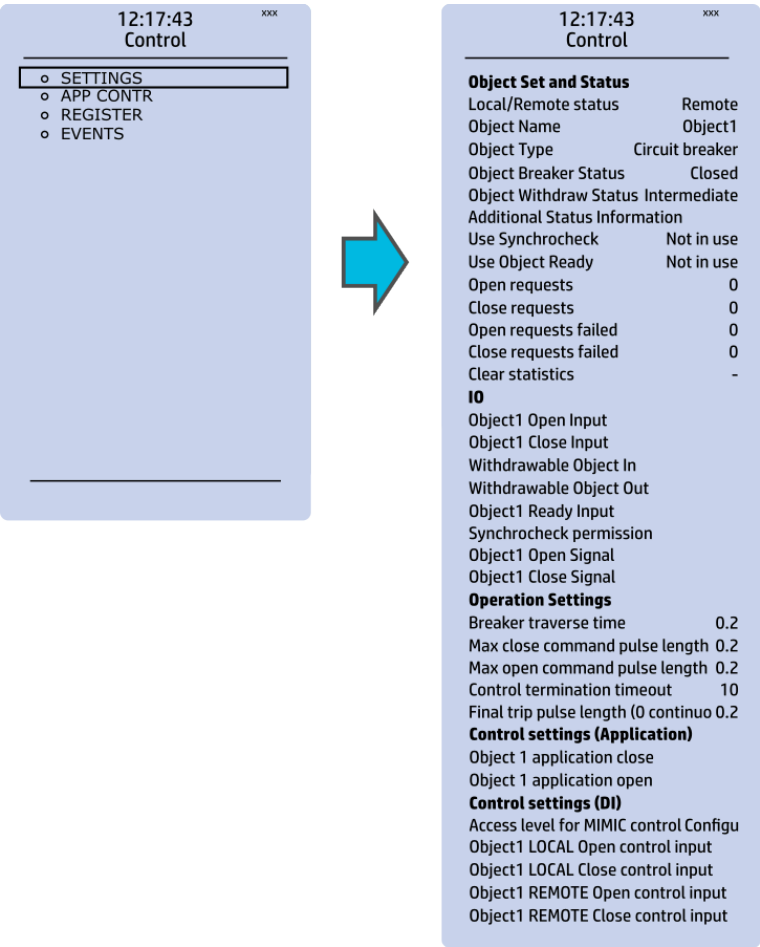
Objects

Figure. 3.4 - 11. 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. 3.4 - 12. 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 Intermediate. The status "Intermediate" 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 device 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 intermediate 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.

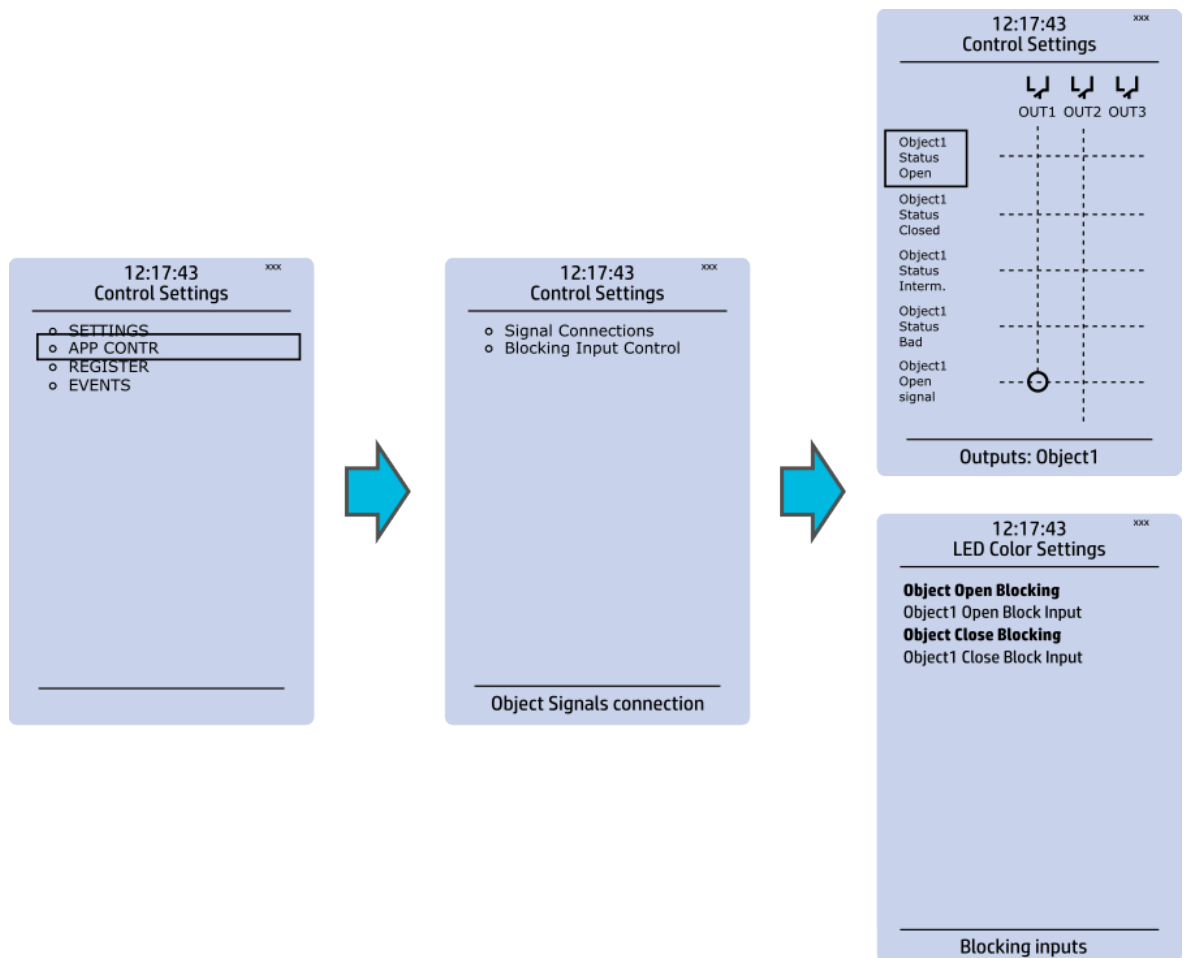
## CONTROL SETTINGS (APPLICATION)

- **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 device.

## 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.

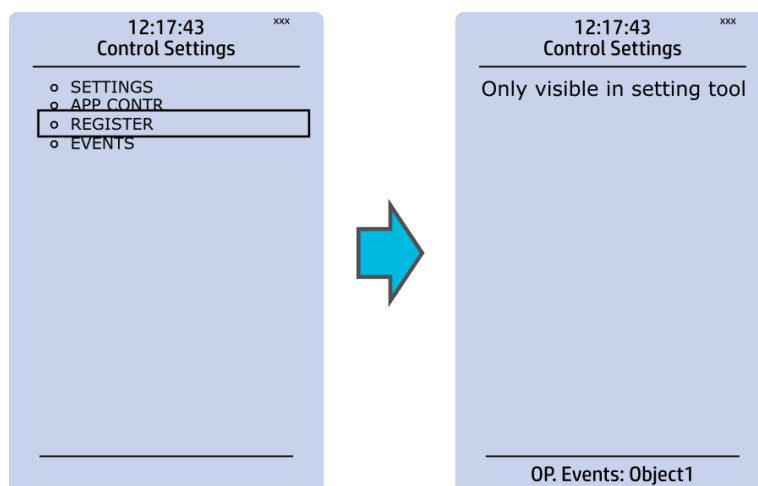
Figure. 3.4 - 13. Application control section.



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. 3.4 - 14. 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. 3.4 - 15. Events section.

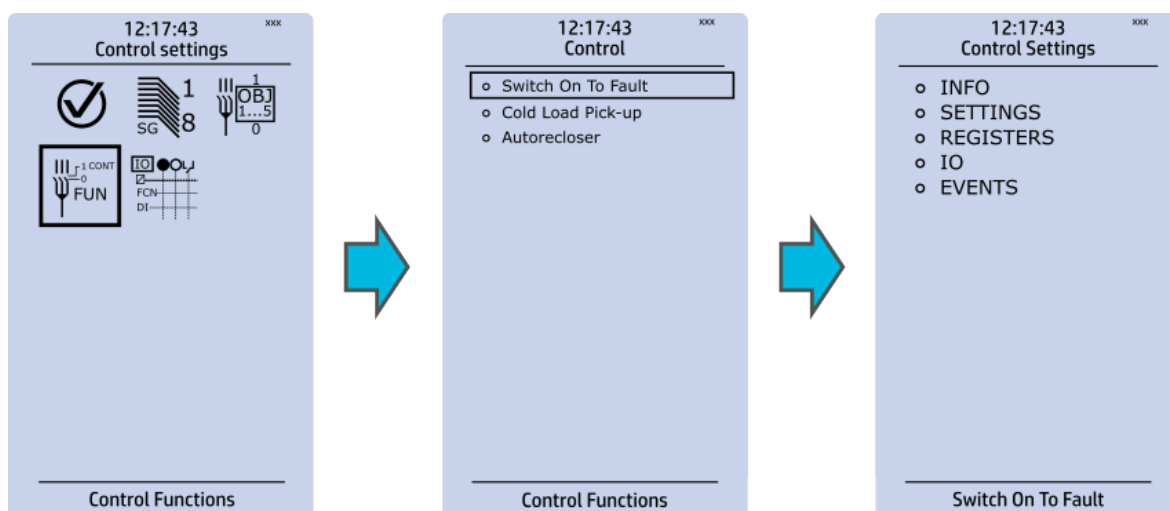


You can mask on and mask off events related to an object's stage in "Event mask". By default all events are masked off. You can activate the desired events by masking them ("x"). Please remember to save your maskings by confirming the changes with the check mark icon. If you want to cancel the changes, 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

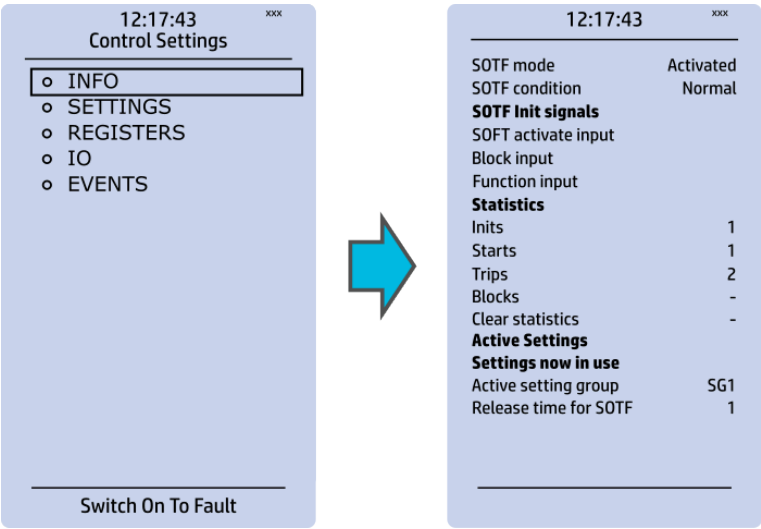
Once a control function has been activated in the *Controls* → *Controls enabled* submenu, its own submenu can be opened. In the image series below, the user has activated three control functions. The user accesses the list of activated control stages through the "Control functions" module, and selects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

Figure. 3.4 - 16. 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. 3.4 - 17. Info section.

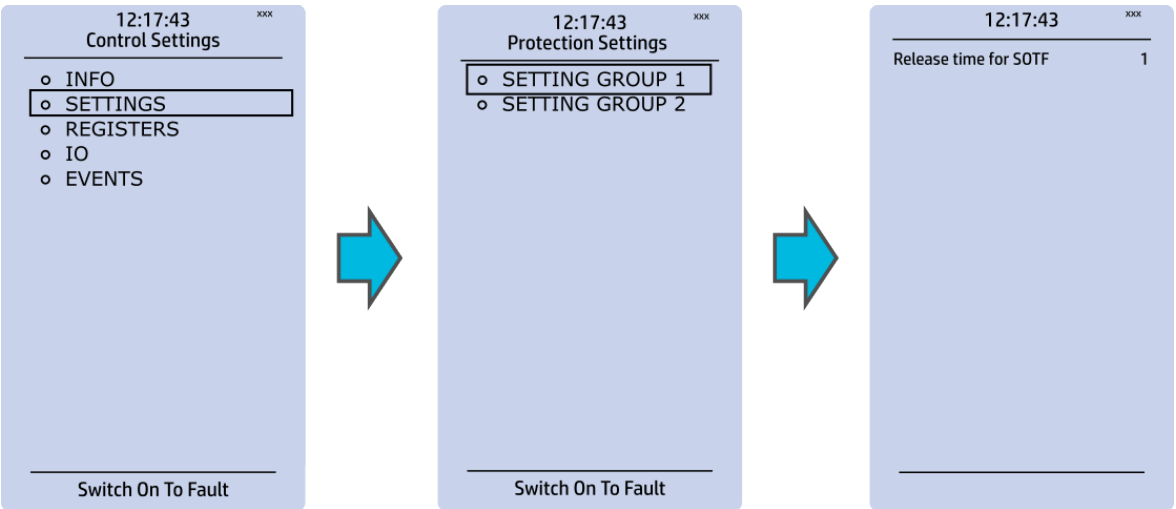


The "Info" section offers many details concerning the function and its status:

- **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).

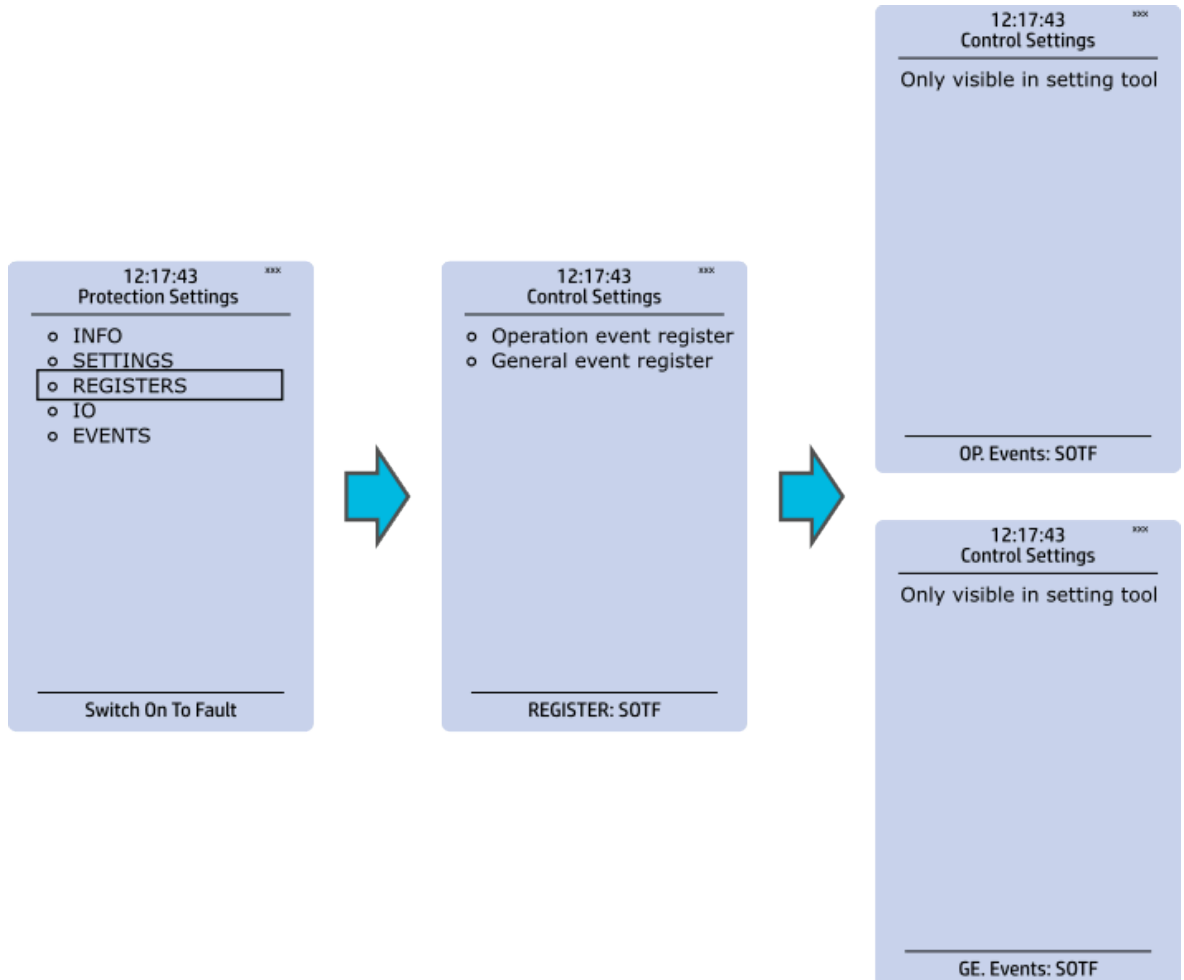
While the function is activated and disabled in the *Control* → *Controls enabled* submenu, you can disable the function through the "Info" section (the [function name] mode at the top of the section).

Figure. 3.4 - 18. 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. 3.4 - 19. Registers section.

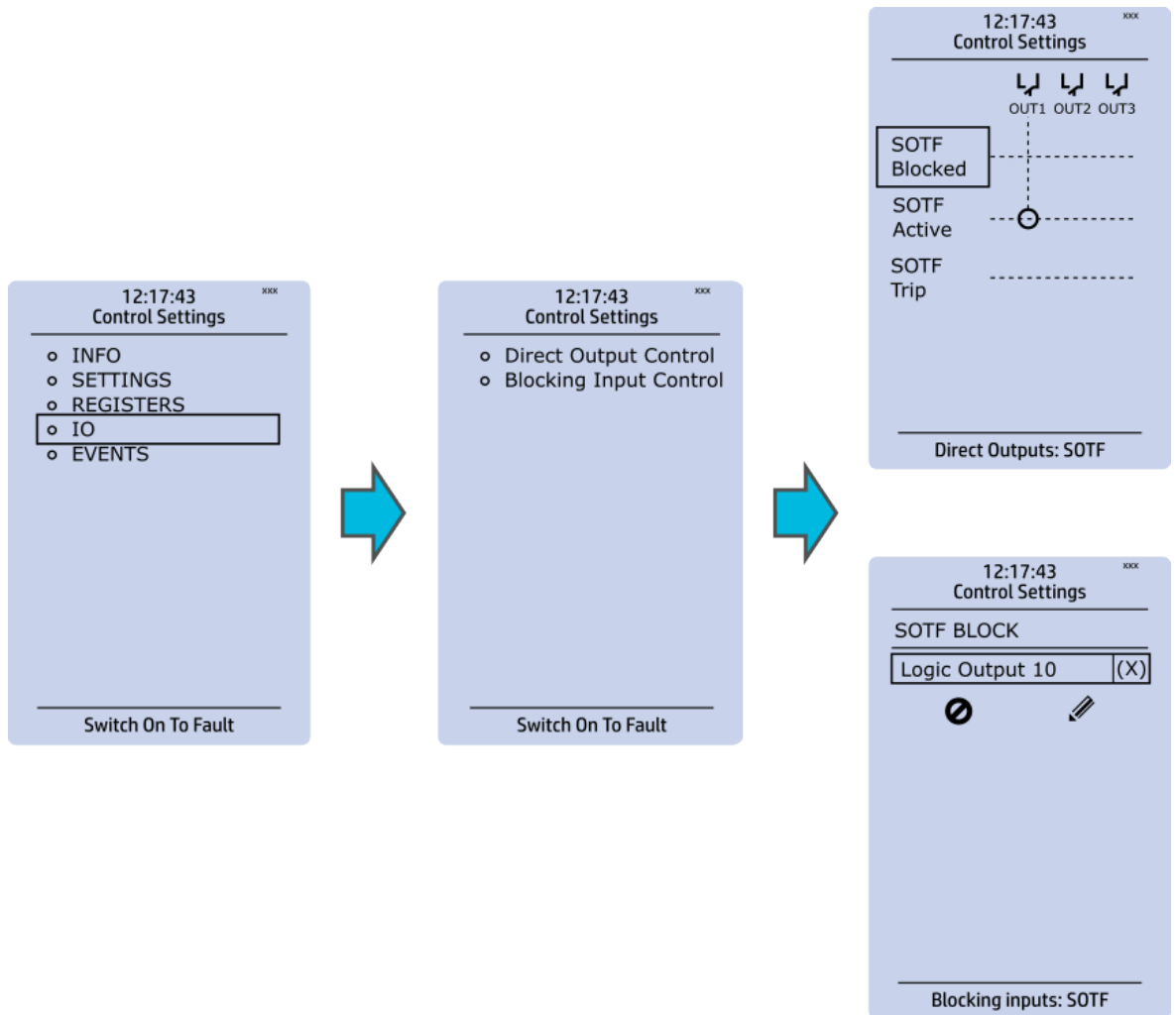


Please note that the content of the "Registers" section is not available in the HMI. It can only be accessed via the AQtivate setting tool. Stored in the "Registers" section you can find both "Operation event register" and "General event register".

"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. 3.4 - 20. I/O section.



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

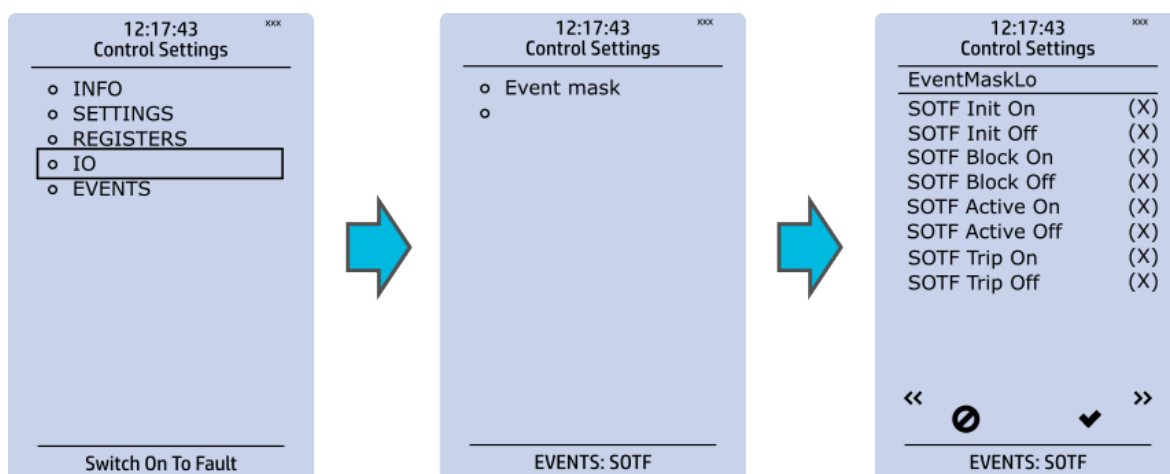
In "Direct output control" you can connect the stage's signals to physical outputs, either to an output relay or an LED (START or TRIP LEDs or one of the 16 user configurable LEDs). If the stage is blocked internally (by a digital input or another signal), you can configure an output to indicate the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



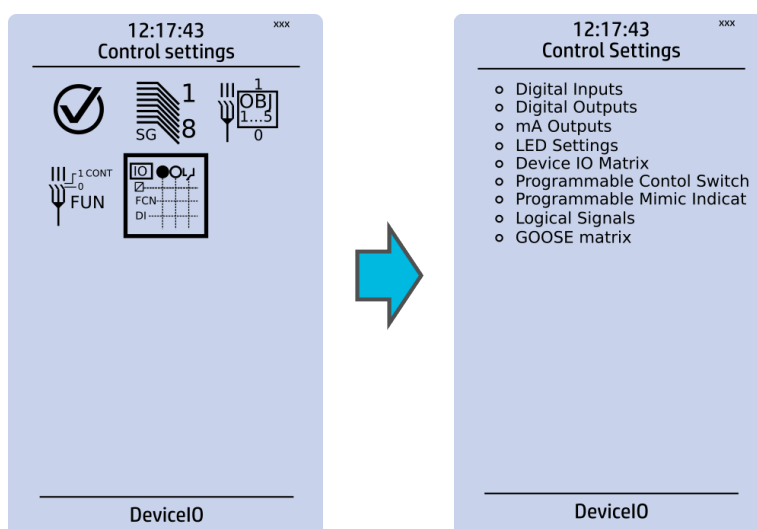
Figure. 3.4 - 21. Events section.



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).

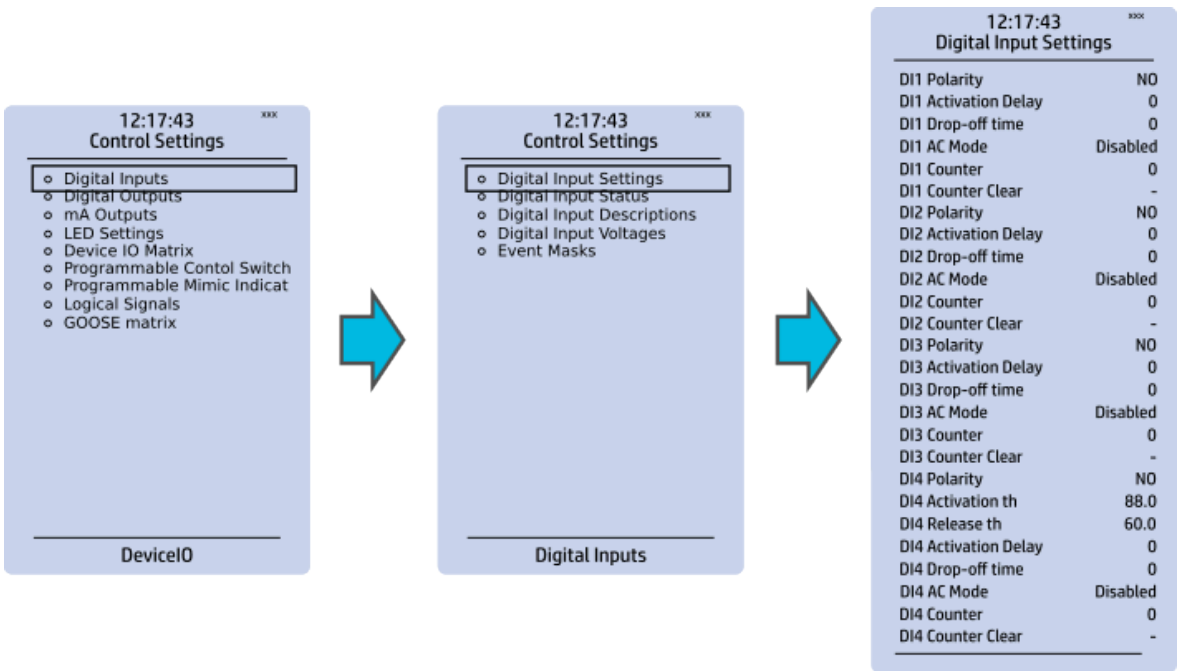
## Device I/O

Figure. 3.4 - 22. 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. 3.4 - 23. Digital input section.

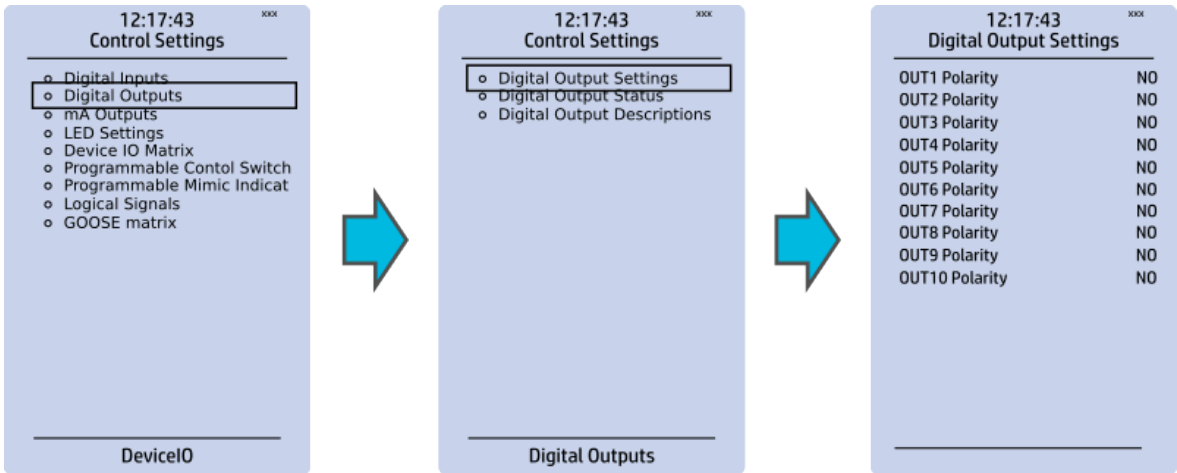


All settings related to digital inputs can be found in the "Digital inputs" section.

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. 3.4 - 24. Digital outputs section.



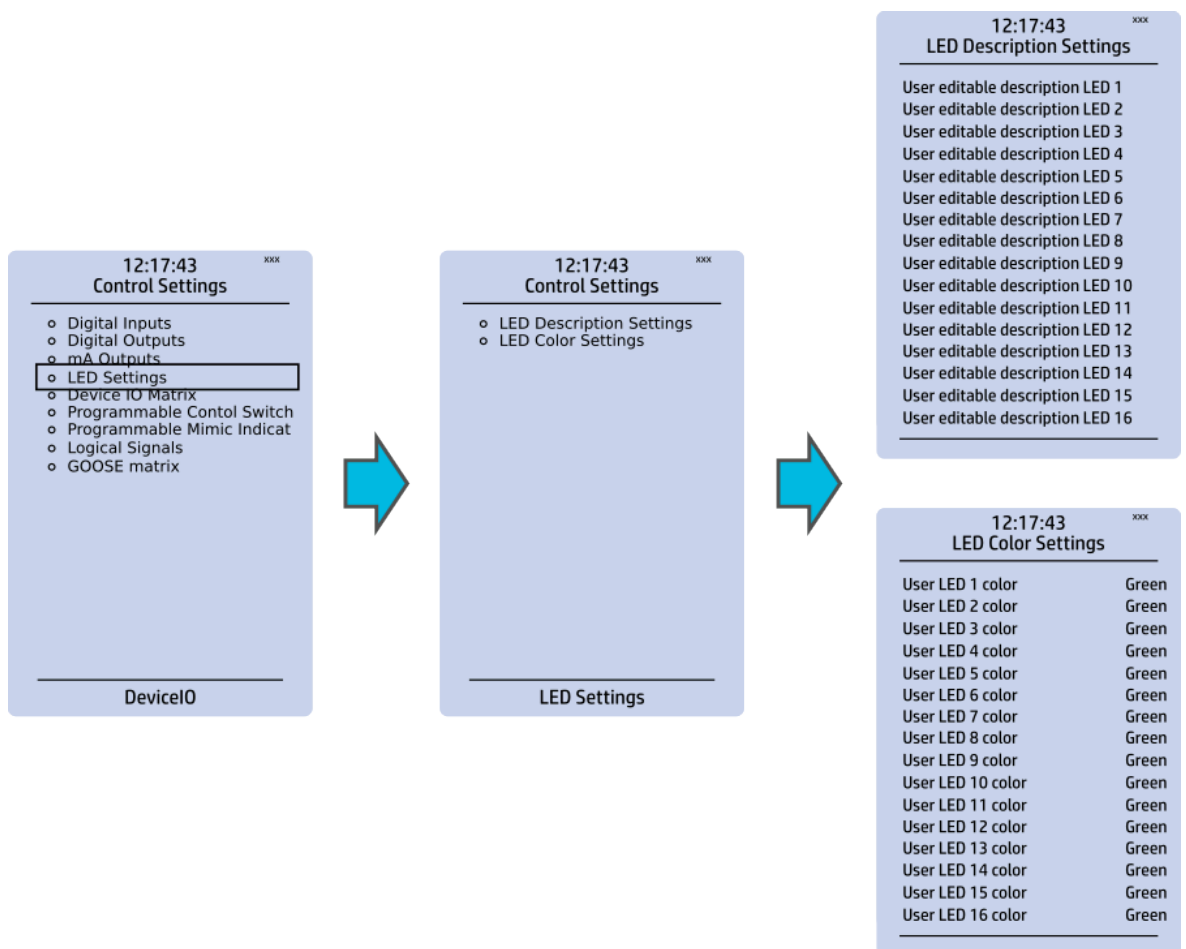
All settings related to digital outputs can be found in the "Digital outputs" section.

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.

**NOTICE!**

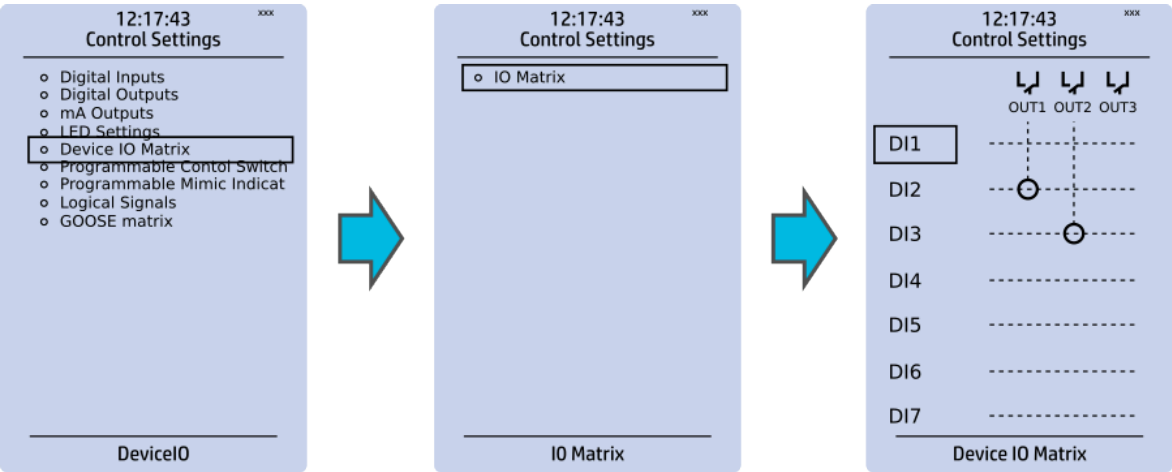
An NC signal goes to the default position (NO) if the device loses the auxiliary voltage or if the system is fully reset. However, an NC signal does not open during voltage or during System full reset. An NC output signal does not open during a Communication or Protection reset.

Figure. 3.4 - 25. 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.

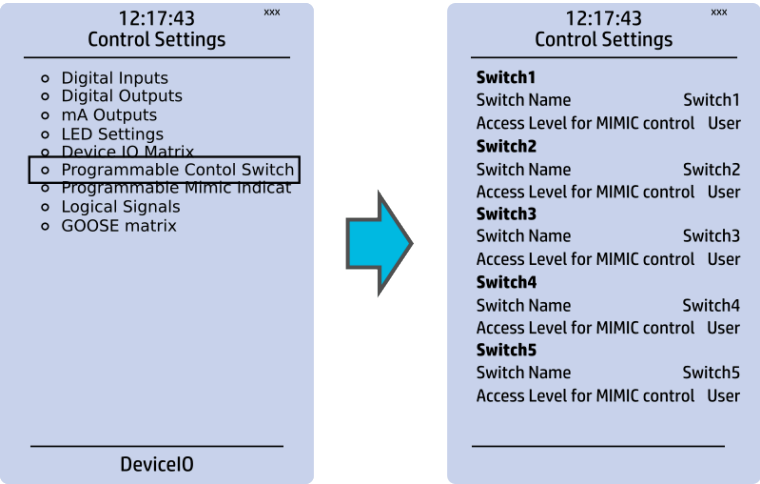
Figure. 3.4 - 26. Device I/O matrix section.



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.

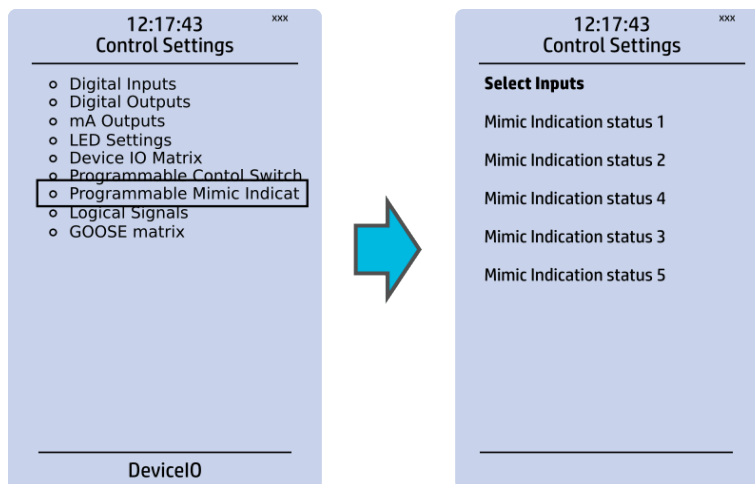
You can clear latched signals by entering the mimic display and the pressing the **Back** button on the panel.

Figure. 3.4 - 27. Programmable control switch section.



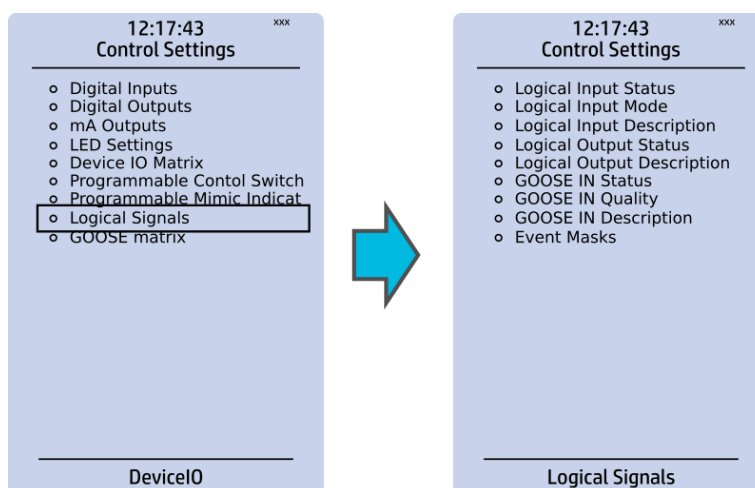
Programmable control switches (PCSs) are switches that can be used to control signals while in the mimic view. These signals can be used in a variety of situations, such as for controlling the logic program, for function blocking, etc. You can name each switch and set the access level to determine who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

Figure. 3.4 - 28. 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 200 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. 3.4 - 29. Logical signals section.



All AQ 200 series units have the following 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 200 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 200 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).

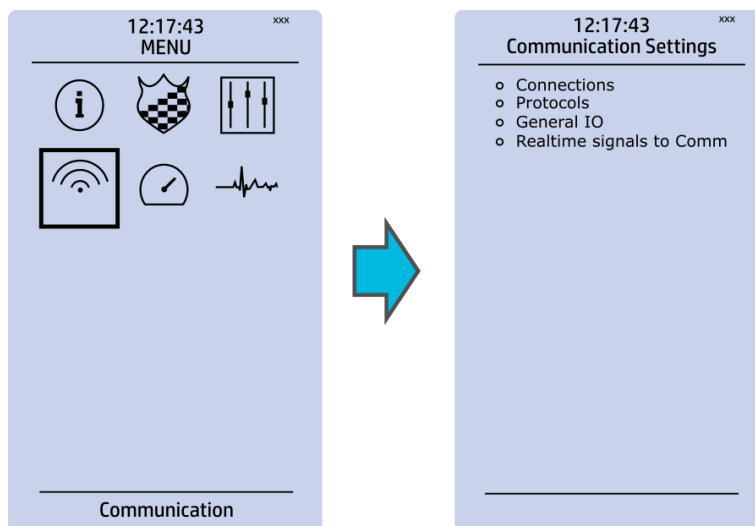


**NOTICE!**

Please refer to the "[Communication](#)" chapter for a more detailed description of the use of logical signals.

## 3.5 Communication menu

Figure. 3.5 - 30. Communication menu.

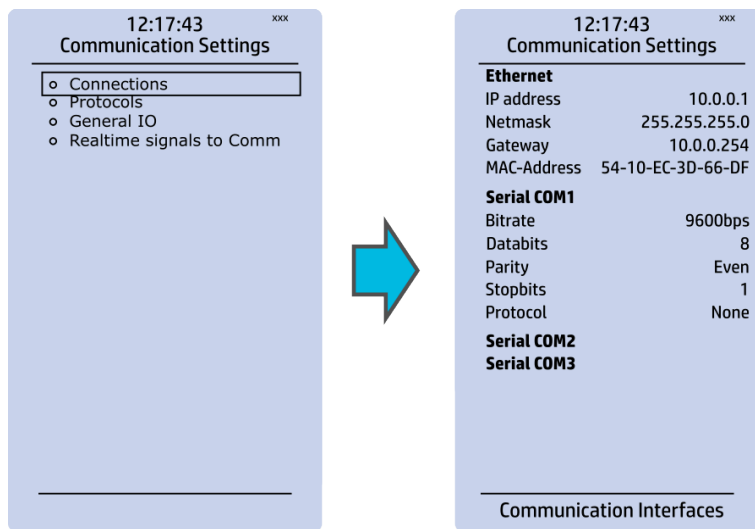


The *Communication* main menu includes four submenus (as seen in the figure above): *Connections*, *Protocols*, *General IO* and *Realtime signals to Comm*. All devices can be configured through the Ethernet connection in the back panel with the AQtivate 200 setting tool software. Connecting to AQtivate requires knowing the IP address of your device: this 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
- ModbusIO.

## Connections

Figure. 3.5 - 31. View of the Connections submenu.



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

### ETHERNET

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

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

### SERIAL COM

This section defines the basic settings of the 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 it can be changed to 19,200 bps or to 38,400 bps if an external device supports the faster speed).
- Databits, Parity and Stopbits: these can be set according to 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.



#### NOTICE!

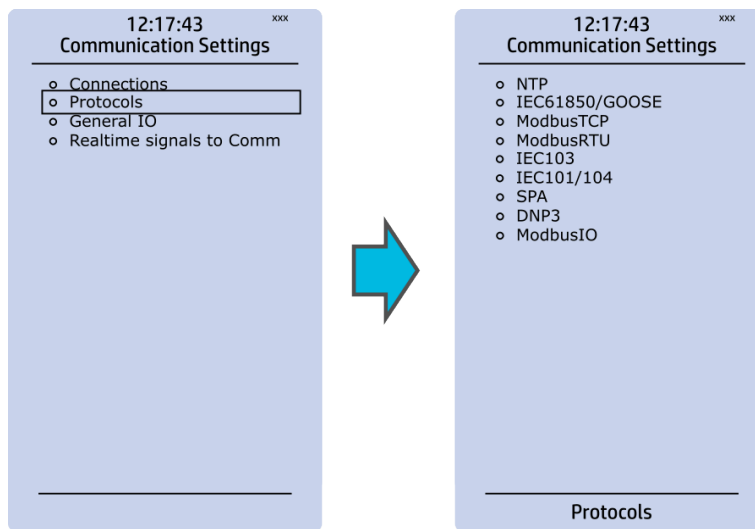
When communicating with a device via the front Ethernet port connection, the IP address is always 192.168.66.9.

### SERIAL COM1 & COM2

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

## Protocols

Figure. 3.5 - 32. 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 in AQ 200 series units by default, or with a 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 Ethernet-based communication protocols.
- IEC 61850: an Ethernet-based communication protocol.
- Modbus/TCP: an Ethernet-based communication protocol.
- Modbus/RTU: a serial communication protocol.
- IEC-103: a serial communication protocol.
- IEC-101/104: since the standards IEC 60870-5-101 and IEC 60870-5-104 are closely related, the IEC-101 protocol uses serial communication on the physical layer, whereas the IEC-104 protocol uses Ethernet communication.
- SPA: a serial communication protocol.
- DNP3: supports both serial and Ethernet communication.
- ModbusIO: used for connecting external devices like ADAM RTD measurement units.



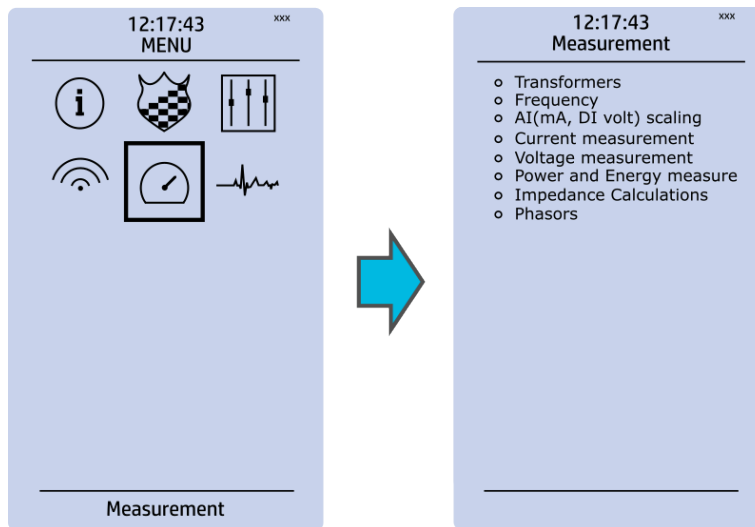
### NOTICE!

Please refer to the "[Communication](#)" chapter for a more detailed text on the various communication options.



## 3.6 Measurement menu

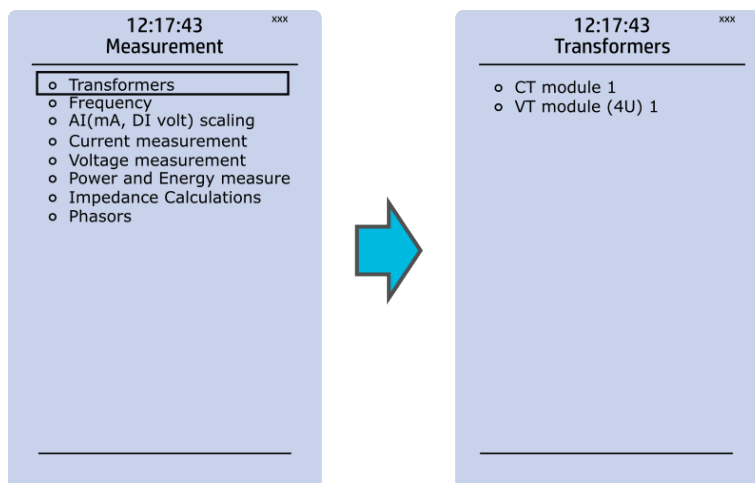
Figure. 3.6 - 33. Measurement section.



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 device 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

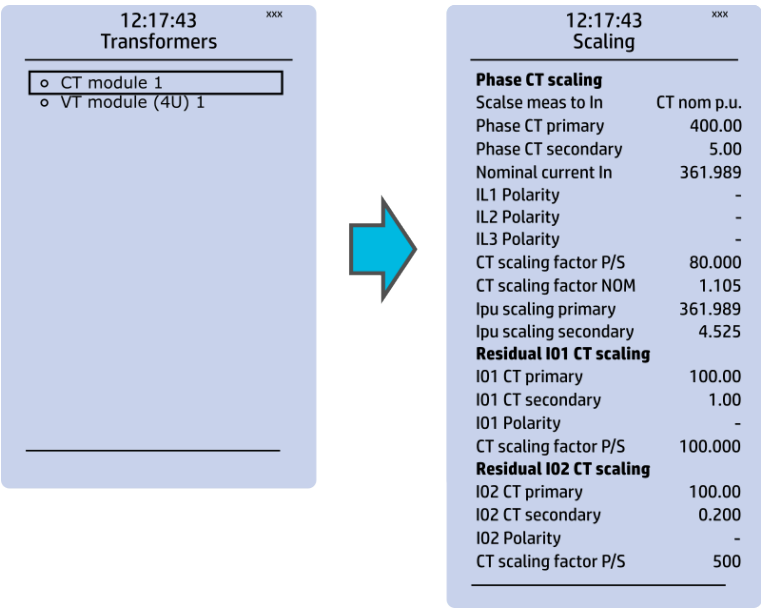
Figure. 3.6 - 34. Transformers section.



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

CT module

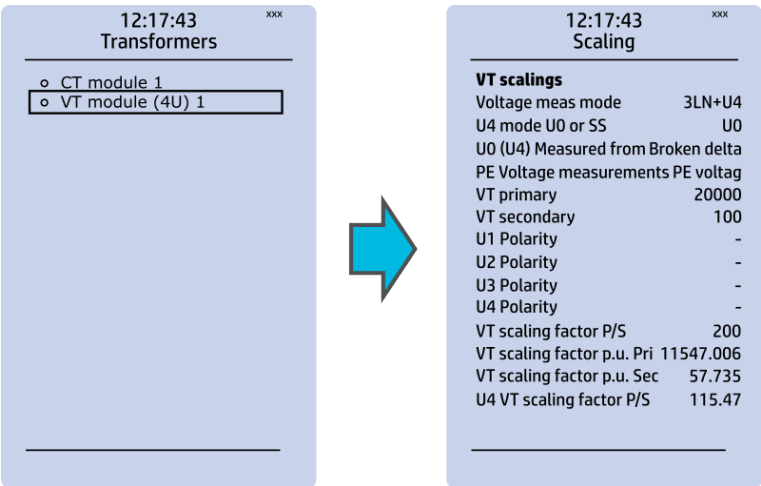
Figure. 3.6 - 35. CT module section.



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

VT module

Figure. 3.6 - 36. VT module section.

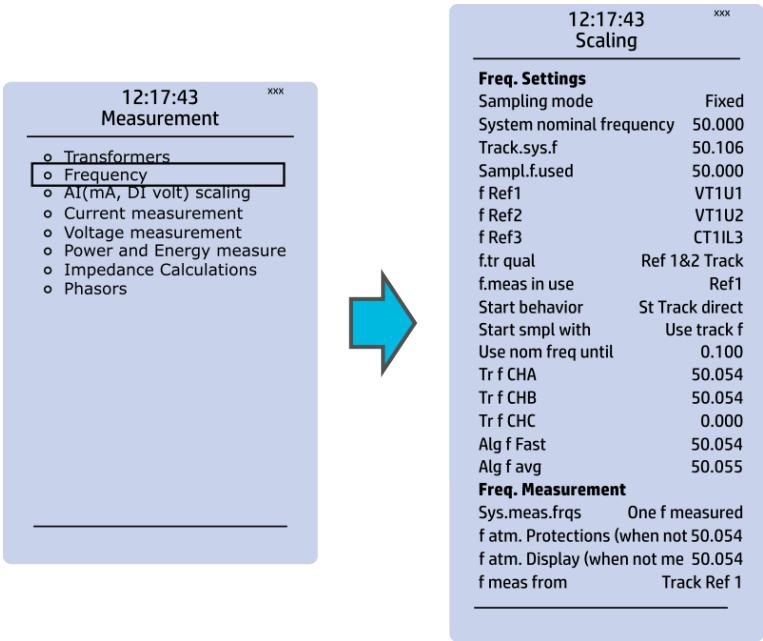


Voltage transformer settings include voltage measurement mode selection, voltage transformer nominal settings and voltage channel polarity switching. Voltage transformer setting defines what kind of voltages are connected to the VT module card. The voltages are: three line-to-line voltages, three line-to-neutral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

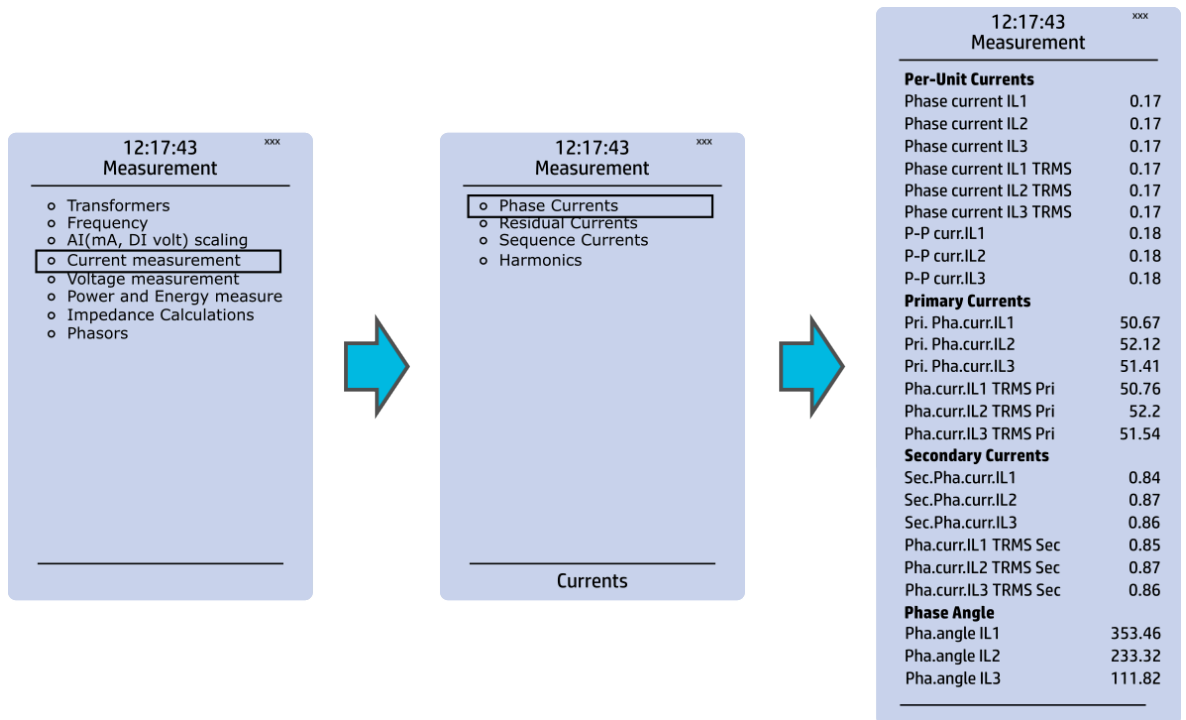
Figure. 3.6 - 37. Frequency submenu.



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

## Current measurement

Figure. 3.6 - 38. Current measurement submenu.



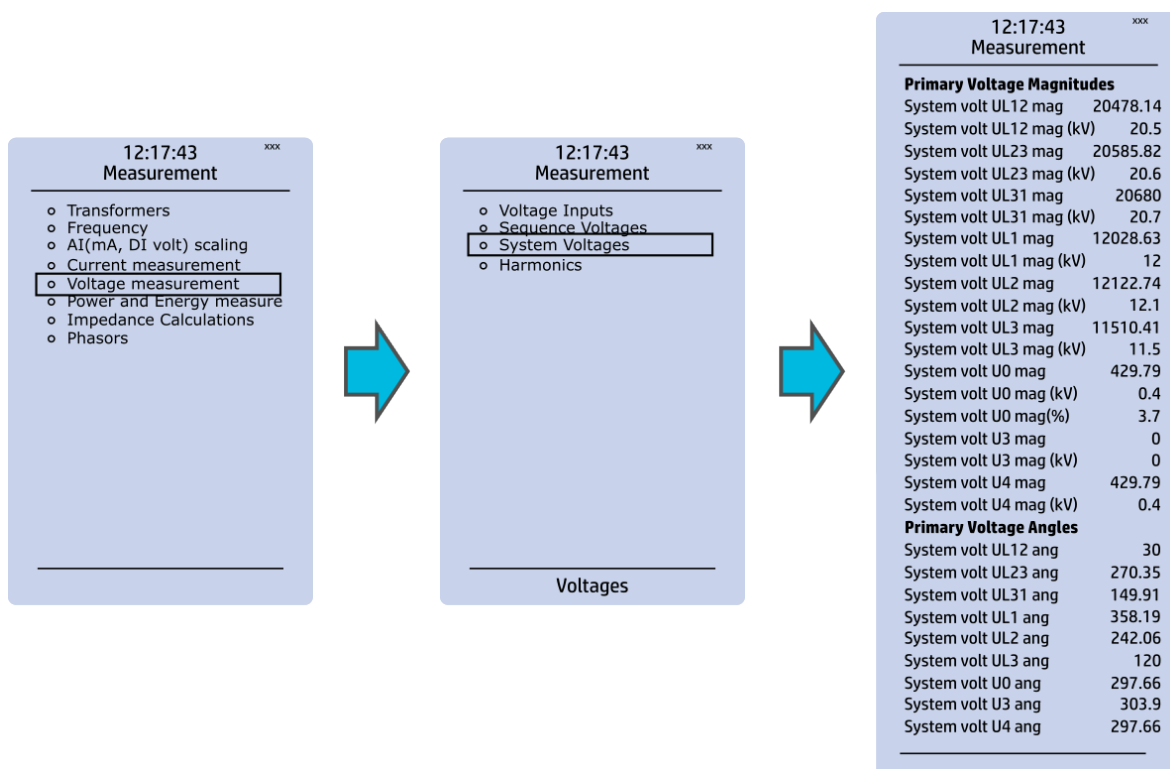
*Current measurement* submenu includes various individual measurements for each phase or phase-to-phase measurement.

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

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

## Voltage measurement

Figure. 3.6 - 39. Voltage measurement submenu and System Voltages menu.



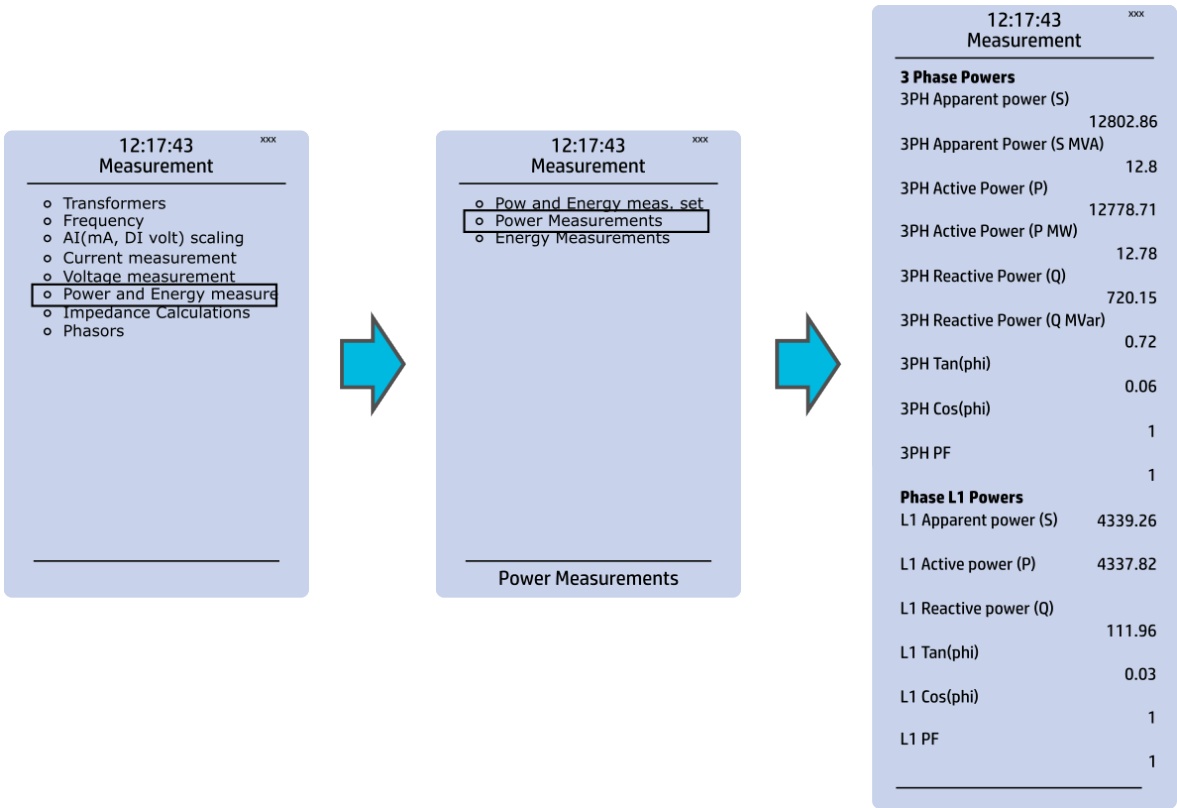
*Voltage measurement* submenu includes various individual measurements for each phase or phase-to-phase measurement.

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 zero sequence voltages.
- "System voltages" displays primary voltage magnitudes and primary voltage angles.
- "Harmonics" displays harmonics up to the 31<sup>st</sup> harmonic for all four voltages (U1, U2, U3, U4); each component can be displayed as absolute or percentage values, and as primary or secondary voltages or in per-unit values.

Power and energy measurement

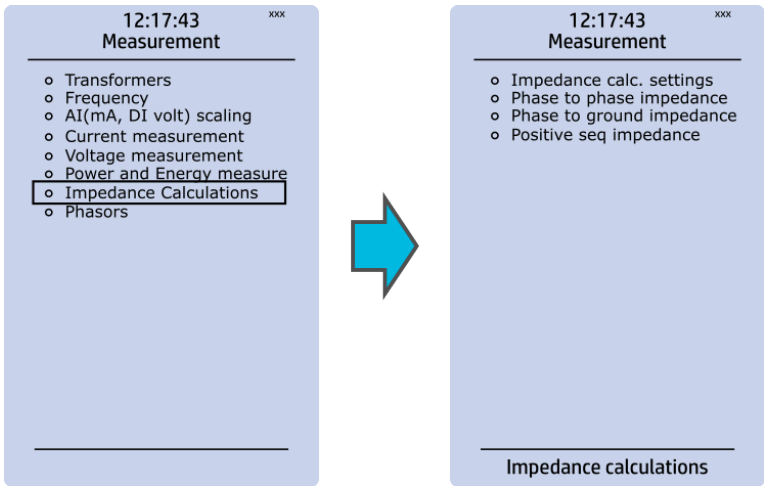
Figure. 3.6 - 40. Power and Energy measurement submenu.



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

Impedance calculations

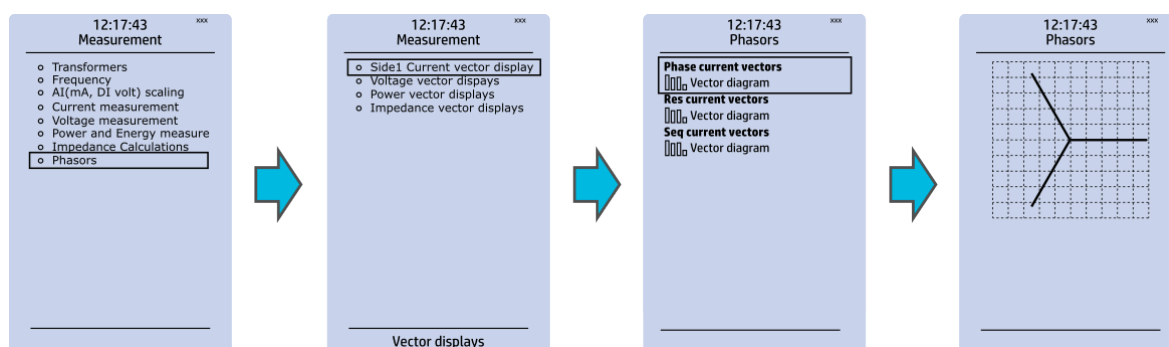
Figure. 3.6 - 41. Impedance calculations submenu.



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

## Phasors

Figure. 3.6 - 42. Phasors submenu.

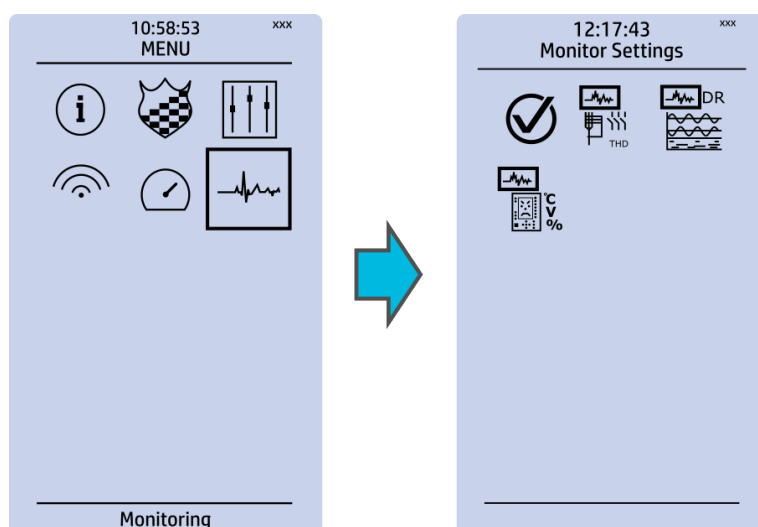


The *Phasors* submenu holds the vector displays for voltages and currents, as well as the various calculated components the device may have (e.g. power, impedance). Phasors are helpful when solving incorrect wiring issues.

## 3.7 Monitoring menu

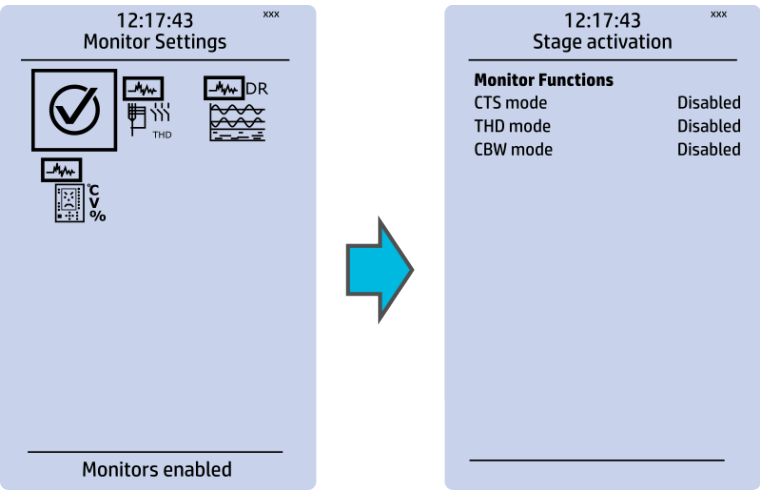
The *Monitoring* main menu includes submenus (see the image below) for enabling the various monitoring functions (*Monitors enabled*), setting the various monitoring functions (*Monitor functions*), controlling the disturbance recorder (*Disturbance REC*) and accessing the device diagnostics (*Device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

Figure. 3.7 - 43. Monitoring menu view.



Monitors enabled

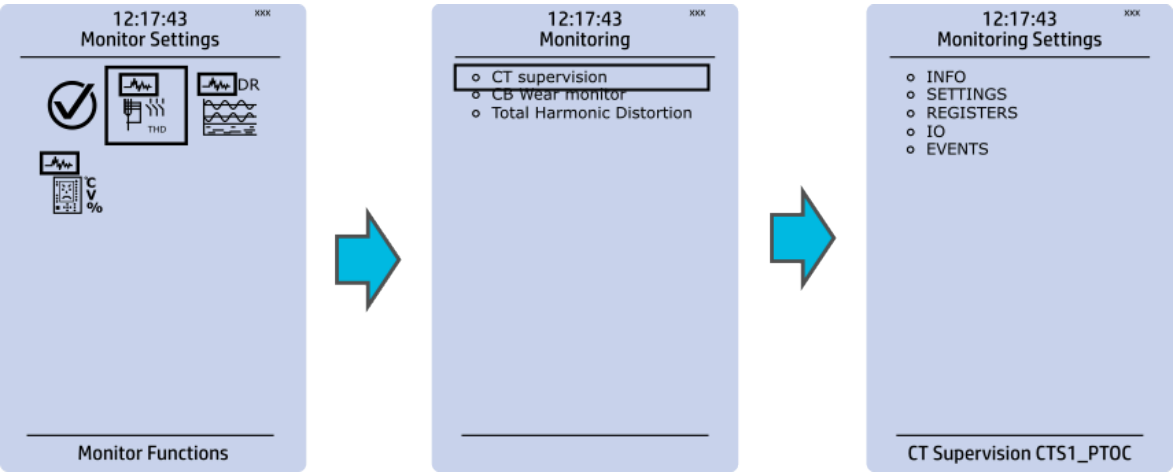
Figure. 3.7 - 44. Monitors enabled submenu.



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. 3.7 - 45. Monitor function view.

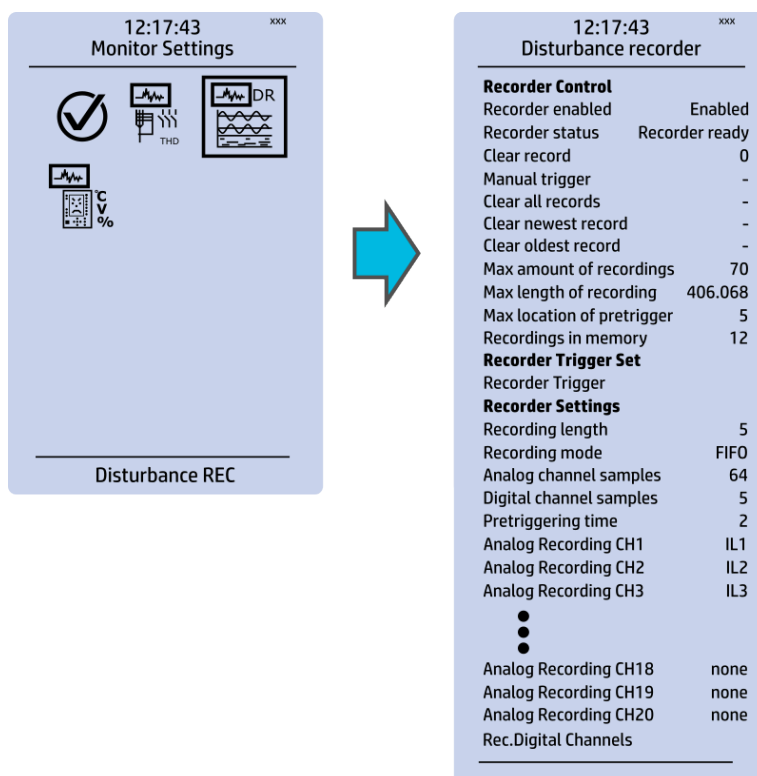


Configuring monitor functions is very similar to configuring protection and control stages. They, too, have the five sections that display information ("Info"), set the parameters ("Settings"), show the inputs and outputs ("I/O") and present the events and registers ("Events" and "Registers").



## Disturbance recorder

Figure. 3.7 - 46. Disturbance recorder settings.



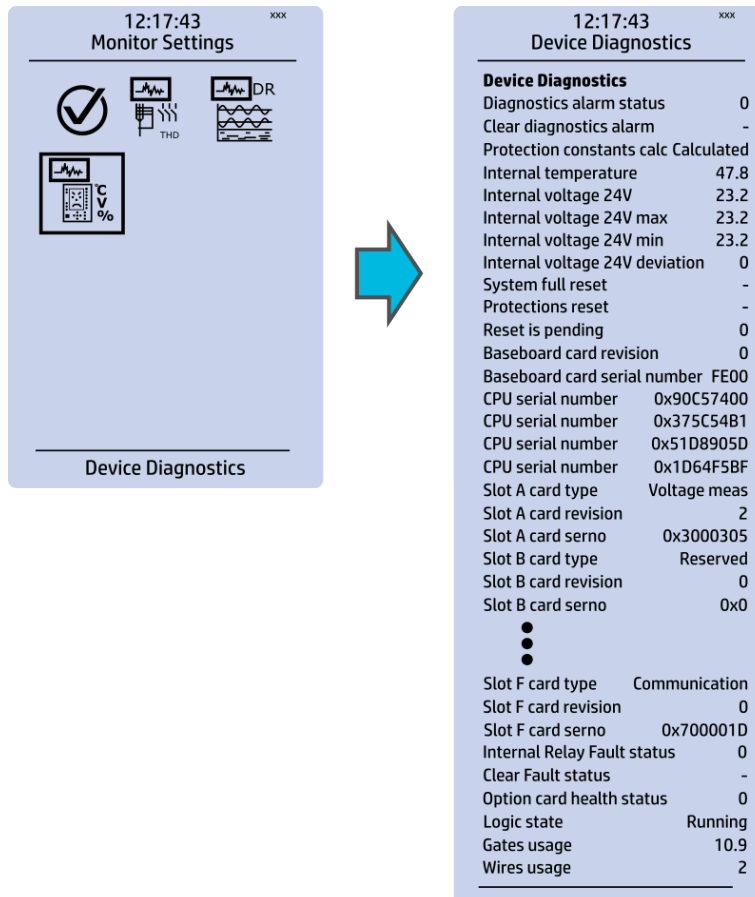
The *Disturbance recorder* submenu has the following settings:

- "Recorder enabled" enables or disables the recorder.
- "Recorder status" indicates the status of the recorder.
- "Clear record" records the chosen record in the memory.
- "Manual trigger" triggers the recorder when set to "Clear". Goes back to "-" when afterwards.
- "Clear all records", "Clear newest record" and "Clear oldest record" allows the clearing of all, the latest, or the oldest recording.
- "Max. amount of recordings" displays the maximum number of recordings; depends on the number of channels, the sample rate and the length of the file.
- "Max. length of recording" displays the maximum length of a single recording; depends on the number of chosen channels and the sample rate.
- "Recordings in memory" displays the number of recordings currently in the disturbance recorder's memory.
- "Recorder trigger" shows which signals or other states has been selected to trigger the recording (digital input, logical input or output, signals of a stage, object position, etc.); by default nothing triggers the recorder.
- "Recording length" displays the length of a single recording and can be set between 0.1...1,800.0 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 device 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 device'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. 3.7 - 47. 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.

## 3.8 Configuring user levels and their passwords

As a factory default, no user level is locked with a password in a device. 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.

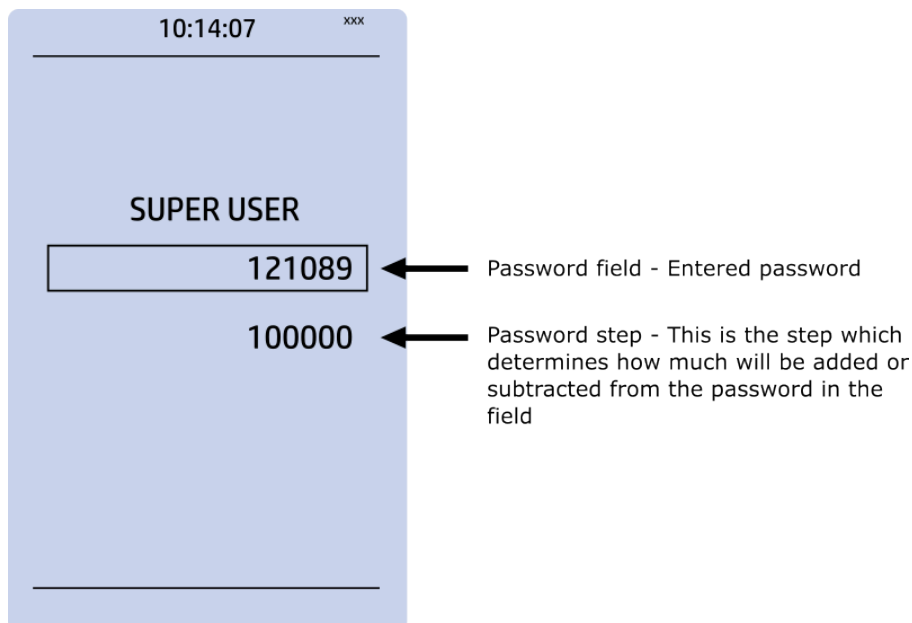
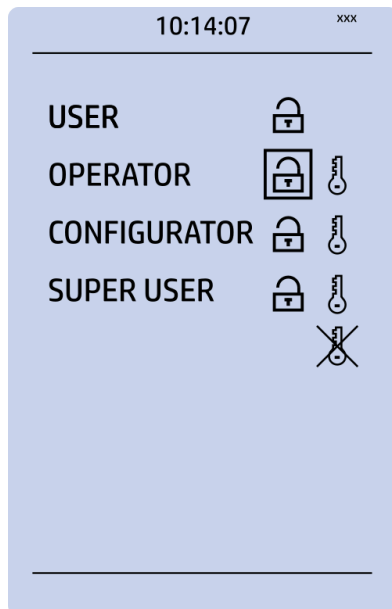


### NOTICE!

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. To remove the password, set the password to "0" (zero). 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.



**NOTICE!**

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

## 4 Functions

### 4.1 Functions included in AQ-P215

The AQ-P215 power monitoring device includes the following functions as well as the number of stages in those functions.

Table. 4.1 - 4. Measurement functions of AQ-P215.

Name	Description
ILx ILx TRMS ILx peak-to-peak	Phase currents
Phase angle ILx	Current phase angle
I01, I02	Residual currents
Phase angle I01, I02	Residual current angle
Sequence currents	Positive, negative and zero sequence currents
U1, U2, U3, U12, U23, U31 Ux TRMS	Phase-to-neutral voltages Phase-to-phase voltages Voltage TRMS values
U0	Residual voltage
Sequence voltages	Positive, negative and zero sequence voltages
f	Frequency
P, Q, S	Active, reactive and apparent power
S	Total three-phase and per-phase apparent power
P	Total three-phase and per-phase active power
Q	Total three-phase and per-phase reactive power
Tan (phi)	Three-phase and per-phase active power direction
Cos (phi)	Three-phase and per-phase reactive power direction
E+	Total and per-phase exported active energy
E-	Total and per-phase imported active energy
Eq+	Total and per-phase imported reactive capacitive energy
Eq-	Total and per-phase imported reactive inductive energy
E+/E-	Sum of imported and exported active energy

Name	Description
Eq+/Eq-	Sum of imported and exported reactive capacitive energy Sum of imported and exported reactive inductive energy
E+, E, Eq+, Eq-	Energy measurements
U <sub>1..31.harm.</sub> , I <sub>1..31.harm.</sub>	Voltage and current harmonics up to 31 <sup>st</sup>

Table. 4.1 - 5. Protection, control and monitoring functions of AQ-P215.

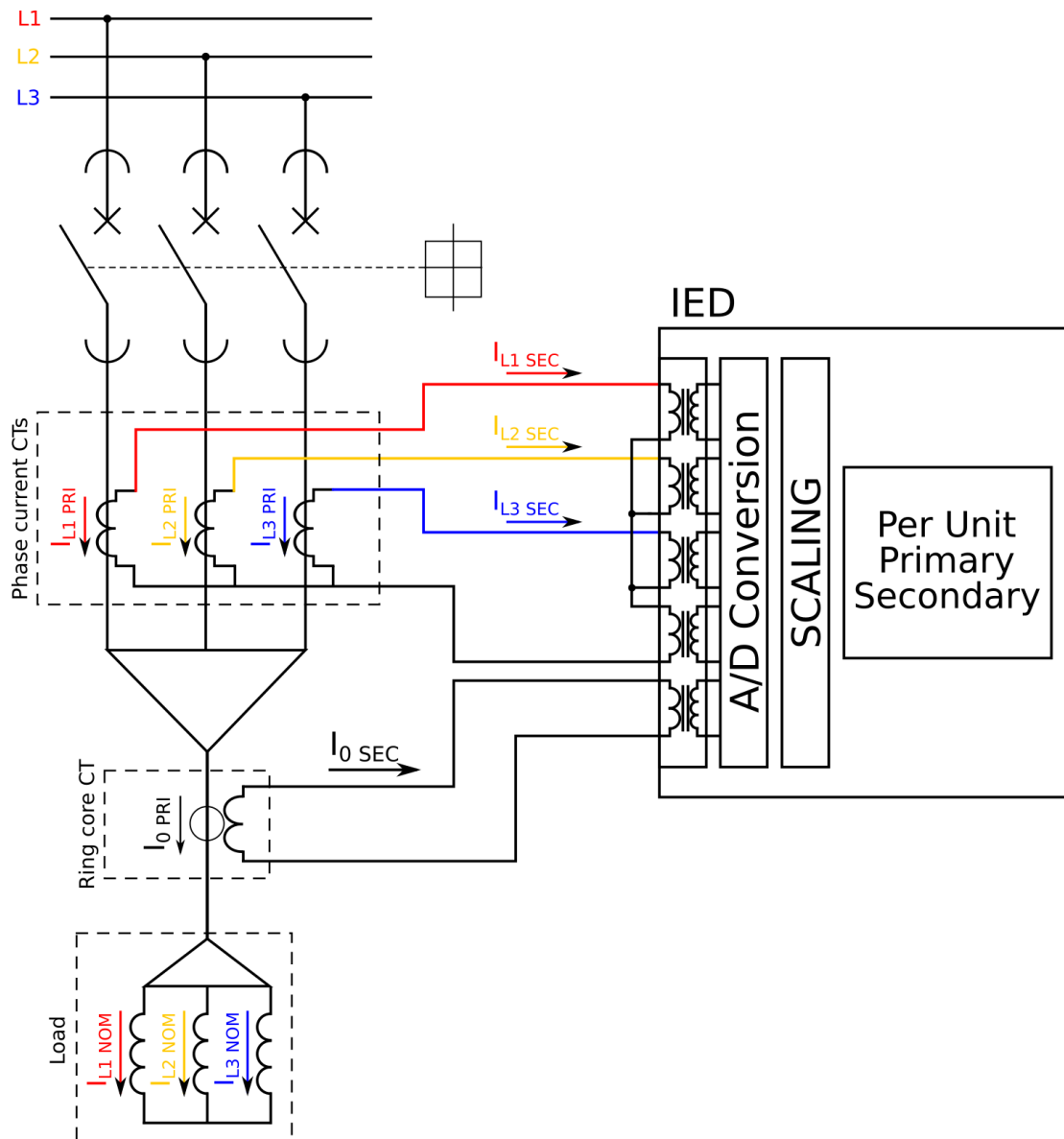
Name	IEC	ANSI	Description
RTD (1...16)	-	-	RTD alarms (Resistance temperature detector)
PGS (1...10)	PGx>/<	99	Programmable stage
SGS	-	-	Setting group selection
RHC	-	-	Running hour counter
PCS	-	-	Programmable control switch
mA output	-	-	Milliampere output control
DR	-	-	Disturbance recorder
MREC	-	-	Measurement recorder

## 4.2 Measurements

### 4.2.1 Current measurement and scaling

The current measurement module (CT module, or CTM) is used for measuring the currents from current transformers. The current measurements are updated every 5 milliseconds. The measured values are processed into the measurement database and they are used by measurement and protection functions. It is essential to understand the concept of current measurements to be able to get correct measurements.

Figure. 4.2.1 - 48. Current measurement terminology.



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

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

**NOM:** The nominal primary current of the protected object.

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

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

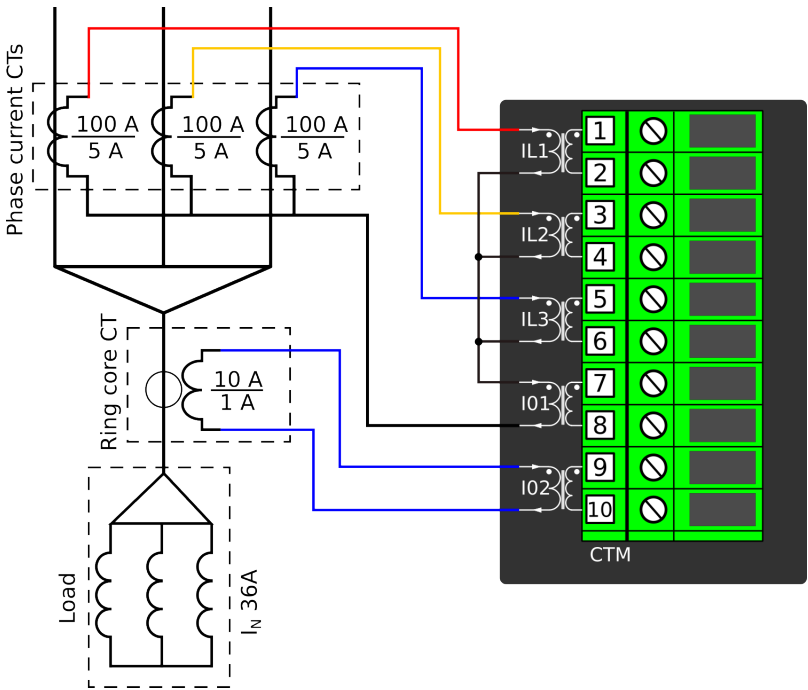
Normally, the primary current ratings for phase current transformers are 10 A, 12.5 A, 15 A, 20 A, 25 A, 30 A, 40 A, 50 A, 60 A and 75 A as well as their decimal multiples, while the secondary current ratings are 1 A and 5 A. Other, non-standard ratings can be directly connected as the scaling settings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

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

Example of CT scaling

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

Figure. 4.2.1 - 49. Connections.



The following table presents the initial data of the connection.



Table. 4.2.1 - 6. Initial data.

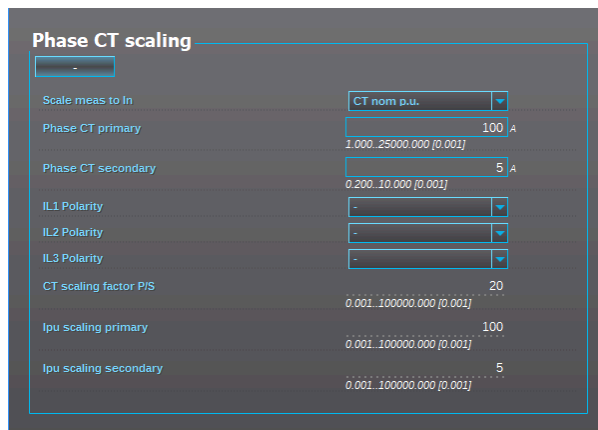
<b>Phase current CT:</b> <ul style="list-style-type: none"> <li>CT primary: 100 A</li> <li>CT secondary: 5 A</li> </ul>	<b>Ring core CT in Input I02:</b> <ul style="list-style-type: none"> <li>I0CT primary: 10 A</li> <li>I0CT secondary: 1 A</li> </ul>	<b>Load (nominal):</b> 36 A
<ul style="list-style-type: none"> <li>The phase currents are connected to the I01 residual via a Holmgren connection.</li> <li>The starpoint of the phase current CT's secondary current is towards the line.</li> </ul>		

Phase CT scaling

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

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

Figure. 4.2.1 - 50. Setting the phase current transformer scalings to CT nominal.



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

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

Figure. 4.2.1 - 51. Setting the phase current transformer scalings to the protected object's nominal current.

Parameter	Value
Scale meas to In	Object In p.u.
Phase CT primary	100 A
Phase CT secondary	5 A
Nominal current In	36 A
IL1 Polarity	-
IL2 Polarity	-
IL3 Polarity	-
CT scaling factor P/S	20
CT scaling factor NOM	2.778
Ipu scaling primary	36
Ipu scaling secondary	1.8

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

#### Residual IO CT scaling

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

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

Figure. 4.2.1 - 52. Residual I01 CT scaling (coarse).

Parameter	Value
I01 CT primary	100 A
I01 CT secondary	5 A
I01 Polarity	-
CT scaling factor P/S	20

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

Figure. 4.2.1 - 53. Residual I02 CT scaling (sensitive).

Residual I02 CT scaling

I02 CT primary

10 A

0.20000..25000.00000 [0.00001]

I02 CT secondary

1 A

0.00100..10.00000 [0.00001]

I02 Polarity

-

CT scaling factor P/S

100

0.001..100000.000 [0.001]

Displaying the scaling

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

Figure. 4.2.1 - 54. Scalings display (based on the CT nominal).

Analog Outputs

Set Mode

Direct

V L1-E	0,000 V	0,00 *	50,000 Hz
V L2-E	0,000 V	-120,00 *	50,000 Hz
V L3-E	0,000 V	120,00 *	50,000 Hz
I L1	5,000 A	0,00 *	50,000 Hz
I L2	5,000 A	-120,00 *	50,000 Hz
I L3	5,000 A	120,00 *	50,000 Hz

Primary Currents

Pri.Pha.curr.IL1

99.98 A

0.00..100000.00 [0.01]

Pri.Pha.curr.IL2

99.93 A

0.00..100000.00 [0.01]

Pri.Pha.curr.IL3

99.98 A

0.00..100000.00 [0.01]

Secondary Currents

Sec.Pha.curr.IL1

5 A

0.00..300.00 [0.01]

Sec.Pha.curr.IL2

5 A

0.00..300.00 [0.01]

Sec.Pha.curr.IL3

5 A

0.00..300.00 [0.01]

Per-Unit Currents

Pha.curr.IL1

1 xIn

0.000..1250.000 [0.001]

Pha.curr.IL2

0.999 xIn

0.000..1250.000 [0.001]

Pha.curr.IL3

1 xIn

0.000..1250.000 [0.001]

Figure. 4.2.1 - 55. Scalings display (based on the protected object's nominal current).

Analog Outputs

Set Mode

Direct

V L1-E	0,000 V	0,00 *	50,000 Hz
V L2-E	0,000 V	-120,00 *	50,000 Hz
V L3-E	0,000 V	120,00 *	50,000 Hz
I L1	1,800 A	0,00 *	50,000 Hz
I L2	1,800 A	-120,00 *	50,000 Hz
I L3	1,800 A	120,00 *	50,000 Hz

Primary Currents

Pri.Pha.curr.IL1

35.98 A

0.00..100000.00 [0.01]

Pri.Pha.curr.IL2

35.96 A

0.00..100000.00 [0.01]

Pri.Pha.curr.IL3

35.98 A

0.00..100000.00 [0.01]

Secondary Currents

Sec.Pha.curr.IL1

1.8 A

0.00..300.00 [0.01]

Sec.Pha.curr.IL2

1.8 A

0.00..300.00 [0.01]

Sec.Pha.curr.IL3

1.8 A

0.00..300.00 [0.01]

Per-Unit Currents

Pha.curr.IL1

0.999 xIn

0.000..1250.000 [0.001]

Pha.curr.IL2

0.999 xIn

0.000..1250.000 [0.001]

Pha.curr.IL3

1 xIn

0.000..1250.000 [0.001]

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

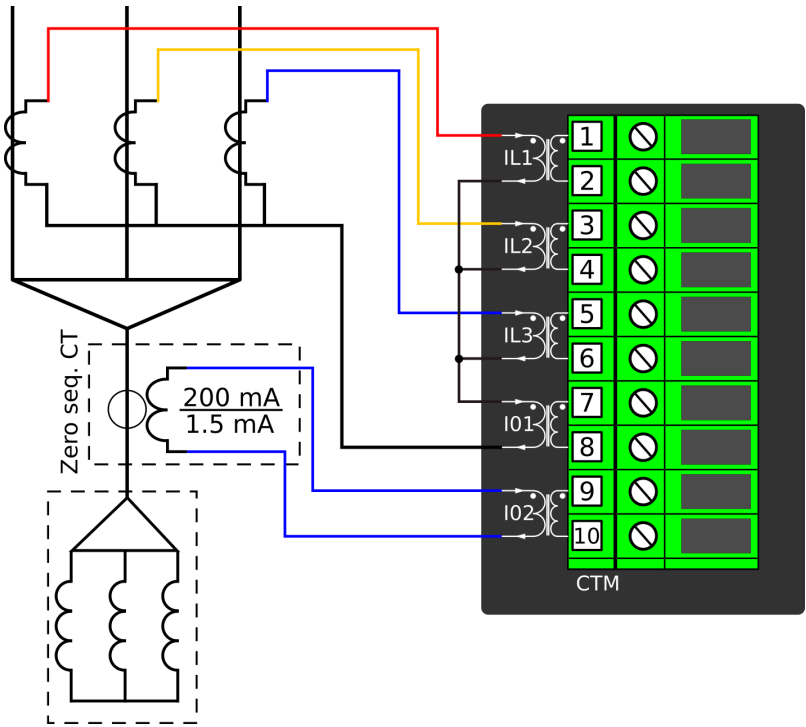
© Arcteq Relays Ltd  
IM00022

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Example of zero sequence CT scaling


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

Figure. 4.2.1 - 56. Connections of ZCT scaling.



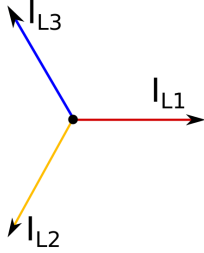
Troubleshooting

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



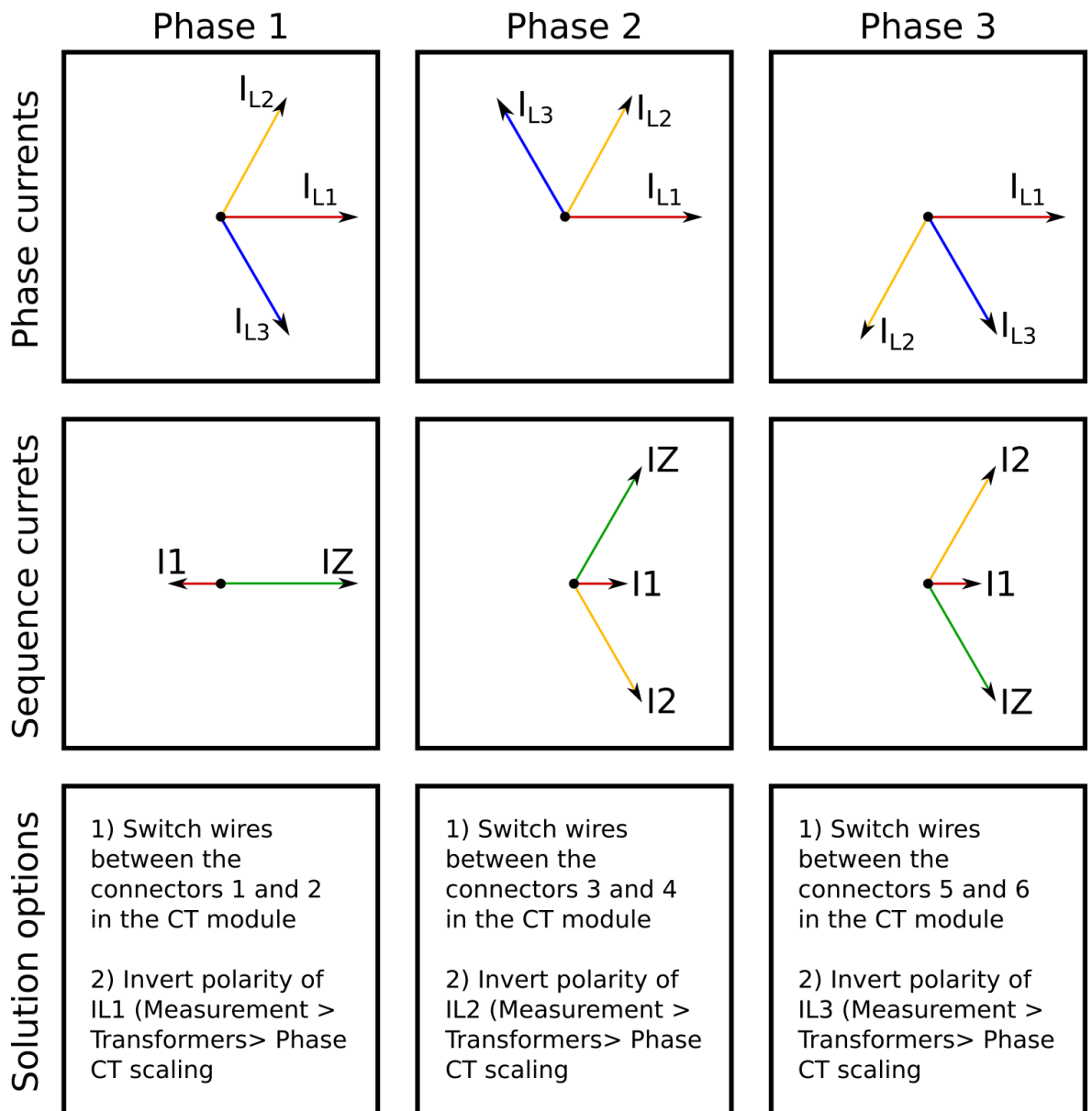
**WARNING!**  
If you work with energized CTs, extreme caution needs to be taken when checking the connections! An opened CT secondary circuit may generate dangerously high voltages. A "buzzing" sound from the connector can indicate an open circuit.

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

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

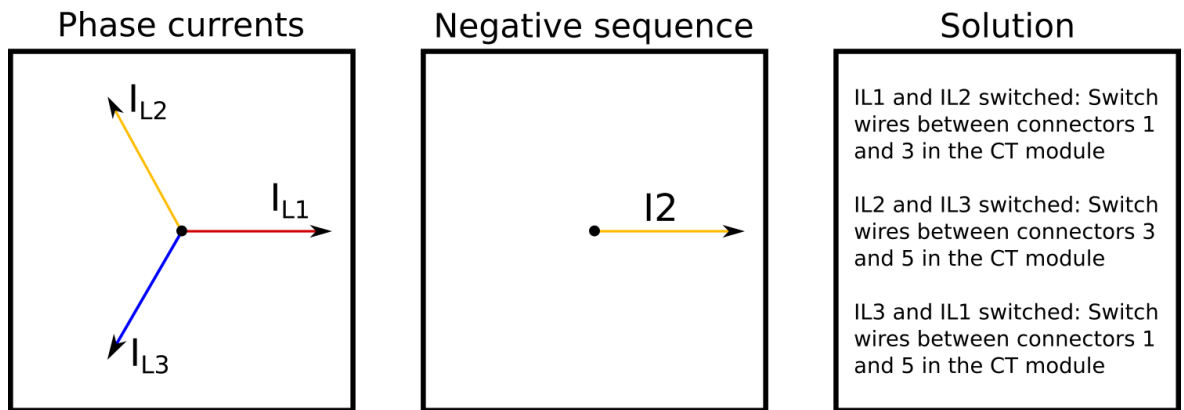
The following image presents the most common problems with phase polarity. Problems with phase polarity are easy to find because the vector diagram points towards the opposite polarity when a phase has been incorrectly connected.

Figure. 4.2.1 - 57. Common phase polarity problems.



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

Figure. 4.2.1 - 58. Common network rotation (mixed phases) problems.



## Settings

Table. 4.2.1 - 7. Settings of the Phase CT scaling.

Name	Range	Step	Default	Description
Scale measurement to In	<ul style="list-style-type: none"> <li>CT nom p.u.</li> <li>Object In p.u.</li> </ul>	-	<ul style="list-style-type: none"> <li>CT nom p.u.</li> </ul>	The selection of the reference used in the device's per-unit system scaling. Either the set phase current CT primary or the protected object's nominal current.
Phase CT primary	1.000...25 000.000A	0.001	100.000	The rated primary current of the current transformer.
Phase CT secondary	0.200...10.000A	0.001	5.000	The rated secondary current of the current transformer.
Nominal current In	1.000...25 000.000A	0.001	100.000	The nominal current of the protected object. This setting is only visible if the option "Object In p.u." has been selected in the "Scale measurement to In" setting.
IL1 Polarity	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	The selection of the first current measurement channel's (IL1) polarity (direction). The default setting is for the positive current to flow from connector 1 to connector 2, with the secondary currents' starpoint pointing towards the line.
IL2 Polarity	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	The selection of the second current measurement channel's (IL2) polarity (direction). The default setting is for the positive current to flow from connector 3 to connector 4, with the secondary currents' starpoint pointing towards the line.
IL3 Polarity	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	The selection of the third current measurement channel's (IL3) polarity (direction). The default setting is for the positive current to flow from connector 5 to connector 6, with the secondary currents' starpoint pointing towards the line.
CT scaling factor P/S	-	-	-	A feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current.

Name	Range	Step	Default	Description
CT scaling factor NOM	-	-	-	A feedback value; the calculated scaling factor that is the ratio between the set primary current and the set nominal current. This parameter is only visible if the option "Object In p.u." has been selected in the "Scale measurement to In" setting.
Ipu scaling primary	-	-	-	A feedback value; the scaling factor for the primary current's per-unit value.
Ipu scaling secondary	-	-	-	A feedback value; the scaling factor for the secondary current's per-unit value.

Table. 4.2.1 - 8. Settings of the Residual I01 CT scaling.

Name	Unit	Range	Step	Default	Description
I01 CT primary	A	0.200 00...25 000.000 00	0.000 01	100.000 00	The rated primary current of the current transformer.
I01 CT secondary	A	0.100 00...10.000 00	0.000 01	1.000 00	The rated secondary current of the current transformer.
I01 Polarity	-	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	The selection of the coarse residual measurement channel's (I01) polarity (direction). The default setting is for the positive current to flow from connector 7 to connector 8.
CT scaling factor P/S	-	-	-	-	A feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current.

Table. 4.2.1 - 9. Settings of the Residual I02 CT scaling.

Name	Unit	Range	Step	Default	Description
I02 CT primary	A	0.200 00...25 000.000 00	0.000 01	100.000 00	The rated primary current of the current transformer.
I02 CT secondary	A	0.001 00...10.000 00	0.000 01	0.200 00	The rated secondary current of the current transformer.
I02 Polarity	-	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	The selection of the sensitive residual measurement channel's (I02) polarity (direction). The default setting is for the positive current to flow from connector 9 to connector 10.
CT scaling factor P/S	-	-	-	-	A feedback value; the calculated scaling factor that is the ratio between the primary current and the secondary current.

## Measurements

The following measurements are available in the measured current channels.



Table. 4.2.1 - 10. Per-unit phase current measurements.

Name	Unit	Range	Step	Description
Phase current ILx ("Pha.curr.ILx")	× In	0.000...1 250.000	0.001	The current fundamental frequency component (in p.u.) from each of the phase current channels.
Phase current ILx TRMS ("Pha.curr.ILx TRMS")	× In	0.00...1 250.00	0.01	The TRMS current (inc. harmonics up to 31 <sup>st</sup> ) measurement (in p.u.) from each of the phase current channels.
Peak-to-peak current ILx ("P-P curr.ILx")	× In	0.00...500.00	0.01	The peak-to-peak current measurement (in p.u.) from each of the phase current channels.

Table. 4.2.1 - 11. Primary phase current measurements.

Name	Unit	Range	Step	Description
Primary phase current ILx ("Pri.Pha.curr.ILx")	A	0.00...1 000 000.00	0.01	The primary current measurement fundamental frequency component from each of the phase current channels.
Primary phase current ILx TRMS ("Pha.curr.ILx TRMS Pri")	A	0.00...1 000 000.00	0.01	The primary TRMS current (inc. harmonics up to 31 <sup>st</sup> ) measurement from each of the phase current channels.

Table. 4.2.1 - 12. Secondary phase current measurements.

Name	Unit	Range	Step	Description
Secondary phase current ILx ("Sec.Pha.curr.ILx")	A	0.00...300.00	0.01	The primary current measurement fundamental frequency component from each of the phase current channels.
Secondary phase current ILx TRMS ("Pha.curr.ILx TRMS Sec")	A	0.00...300.00	0.01	The primary TRMS current (inc. harmonics up to 31 <sup>st</sup> ) measurement from each of the phase current channels.

Table. 4.2.1 - 13. Phase angle measurements.

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

Table. 4.2.1 - 14. Per-unit residual current measurements.

Name	Unit	Range	Step	Description
Residual current I0x ("Res.curr.I0x")	× In	0.00...1 250.00	0.01	The current measurement fundamental frequency component (in p.u.) from the residual current channel I01 or I02.
Calculated I0	× In	0.00...1 250.00	0.01	The current measurement fundamental frequency component (in p.u.) from the calculated I0 current channel.
Phase current I0x TRMS ("Res.curr.I0x TRMS")	× In	0.00...1 250.00	0.01	The TRMS current (inc. harmonics up to 31 <sup>st</sup> ) measurement (in p.u.) from the residual current channel I01 or I02.
Peak-to-peak current I0x ("P-P curr.I0x")	× In	0.00...500.00	0.01	The peak-to-peak current measurement (in p.u.) from the residual current channel I01 or I02.

Table. 4.2.1 - 15. Primary residual current measurements.

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

Table. 4.2.1 - 16. Secondary residual current measurements.

Name	Unit	Range	Step	Description
Secondary residual current I0x ("Sec.Res.curr.I0x")	A	0.00...300.00	0.01	The secondary current measurement fundamental frequency component from the residual current channel I01 or I02.
Secondary calculated I0 ("Sec.calc.I0")	A	0.00...300.00	0.01	The secondary current measurement fundamental frequency component from the calculated current channel I0.
Secondary residual current I0x TRMS ("Res.curr.I0x TRMS Sec")	A	0.00...300.00	0.01	The secondary TRMS current (inc. harmonics up to 31 <sup>st</sup> ) measurement from the secondary residual current channel I01 or I02.

Table. 4.2.1 - 17. Residual phase angle measurements.

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

Table. 4.2.1 - 18. Per-unit sequence current measurements.

Name	Unit	Range	Step	Description
Positive sequence current	× In	0.00...1 250.00	0.01	The measurement (in p.u.) from the calculated positive sequence current.
Negative sequence current	× In	0.00...1 250.00	0.01	The measurement (in p.u.) from the calculated negative sequence current.
Zero sequence current	× In	0.00...1 250.00	0.01	The measurement (in p.u.) from the calculated zero sequence current.

Table. 4.2.1 - 19. Primary sequence current measurements.

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

Table. 4.2.1 - 20. Secondary sequence current measurements.

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

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

Table. 4.2.1 - 21. Sequence phase angle measurements.

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

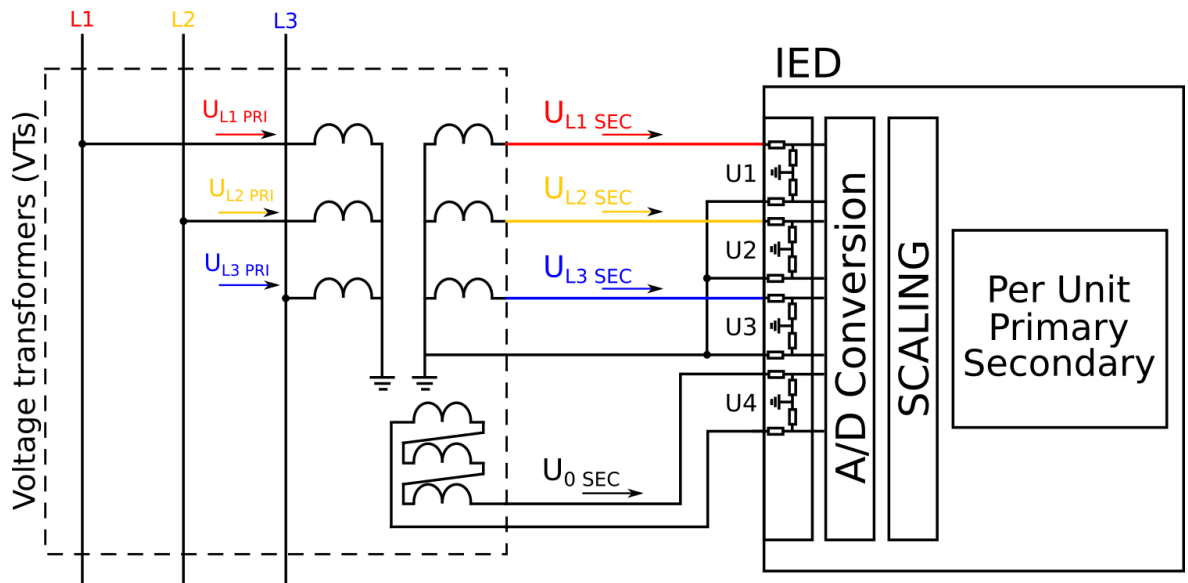
Table. 4.2.1 - 22. Harmonic current measurements.

Name		Range	Step	Description
Harmonics calculation values ("Harm Abs.or Perc.")	-	<ul style="list-style-type: none"> <li>Percent</li> <li>Absolute</li> </ul>	-	Defines whether the harmonics are calculated as percentage or absolute values.
Harmonics display	-	<ul style="list-style-type: none"> <li>Per unit</li> <li>Primary A</li> <li>Secondary A</li> </ul>	-	Defines how the harmonics are displayed: in p.u values, as primary current values, or as secondary current values.
Maximum harmonics value ("Ixx maximum harmonic")	A	0.00...100 000.00	0.01	Displays the maximum harmonics value of the selected current input ILx or IOx.
Fundamental frequency ("Ixx fundamental")	A	0.00...100 000.00	0.01	Displays the current value of the fundamental frequency component (RMS) from the selected current input ILx or IOx.
Ixx harmonics (2 <sup>nd</sup> ...31 <sup>st</sup> harmonic)	A	0.00...100 000.00	0.01	Displays the selected harmonic from the current input ILx or IOx.
Ixx Amplitude THD	%	0.000...100.000	0.001	Amplitude ratio THD voltage. Recognized by IEC.
Ixx Power THD	%	0.000...100.000	0.001	Power ratio THD voltage. Recognized by the IEEE.

## 4.2.2 Voltage measurement and scaling

The voltage measurement module (VT module, or VTM) is used for measuring the voltages from voltage transformers. The voltage measurements are updated every 5 milliseconds. The measured values are processed into the measurement database and they are used by measurement and protection functions. It is essential to understand the concept of voltage measurements to be able to get correct measurements.

Figure. 4.2.2 - 59. 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 device.

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 is correct, and that the scaling is set correctly.

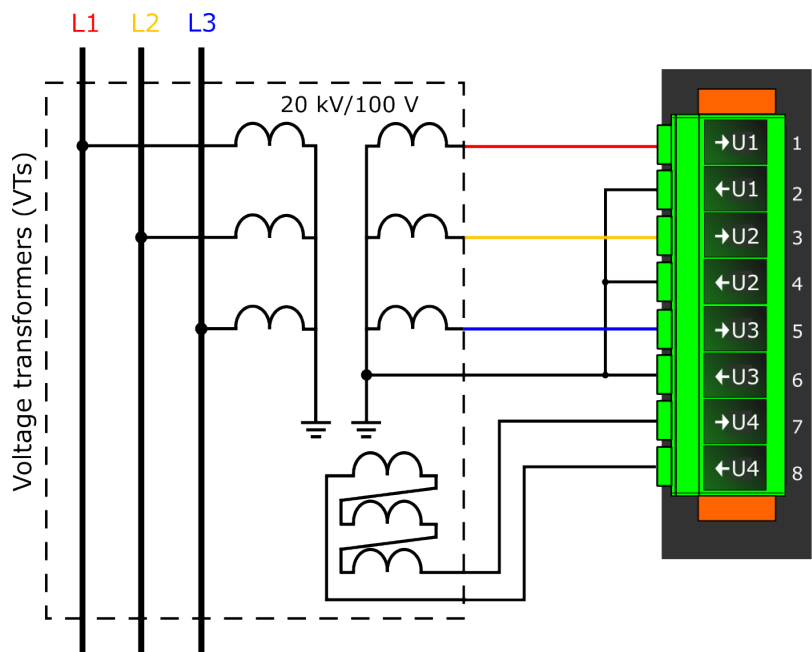
The device calculates the scaling factors based on the set VT primary, and secondary voltage values. The device measures secondary voltages, which are the voltage outputs from the VT installed into the application's primary circuit. The voltage can be measured directly from the system as well (up to 400 V nominal line to neutral voltage). When connecting voltage directly, measuring mode must be set to 3LN+U4 mode. The rated primary and secondary voltages of the VT need to be set for the device 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 device'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. 4.2.2 - 60. Connections.



The following table presents the initial data of the connection.

Table. 4.2.2 - 23. Initial data.

<b>Phase voltage VT</b> - VT primary: 20 000 V - VT secondary: 100 V	<b>Zero sequence voltage VT</b> - U4 VT primary: 20 000 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 device.	

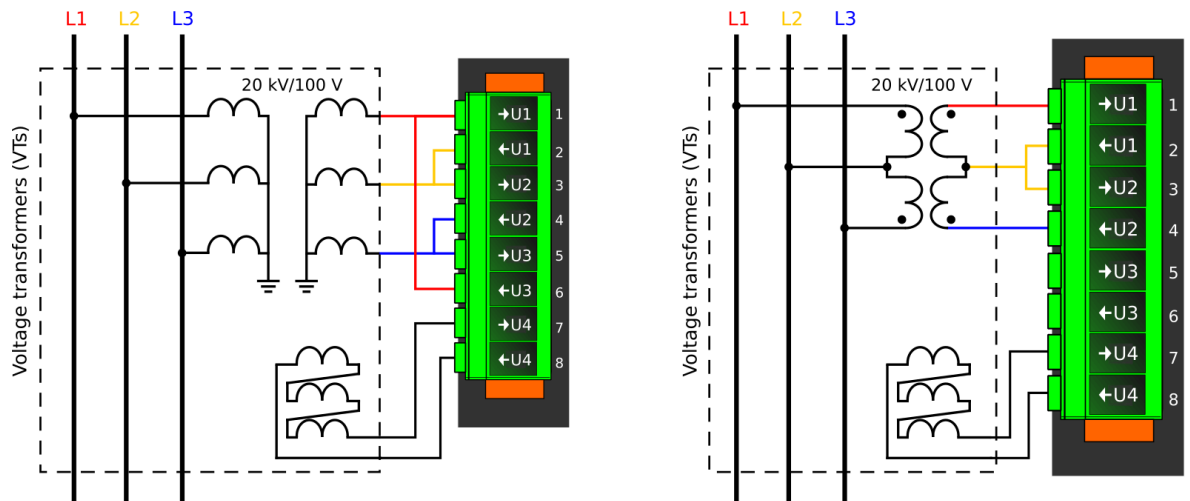
Once the settings have been sent to the device, device calculates the scaling factors and displays them for the user. The "VT scaling factor P/S" describes the ratio between the primary voltage and the secondary voltage. The per-unit scaling factors ("VT scaling factor p.u.") for both primary and secondary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

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).

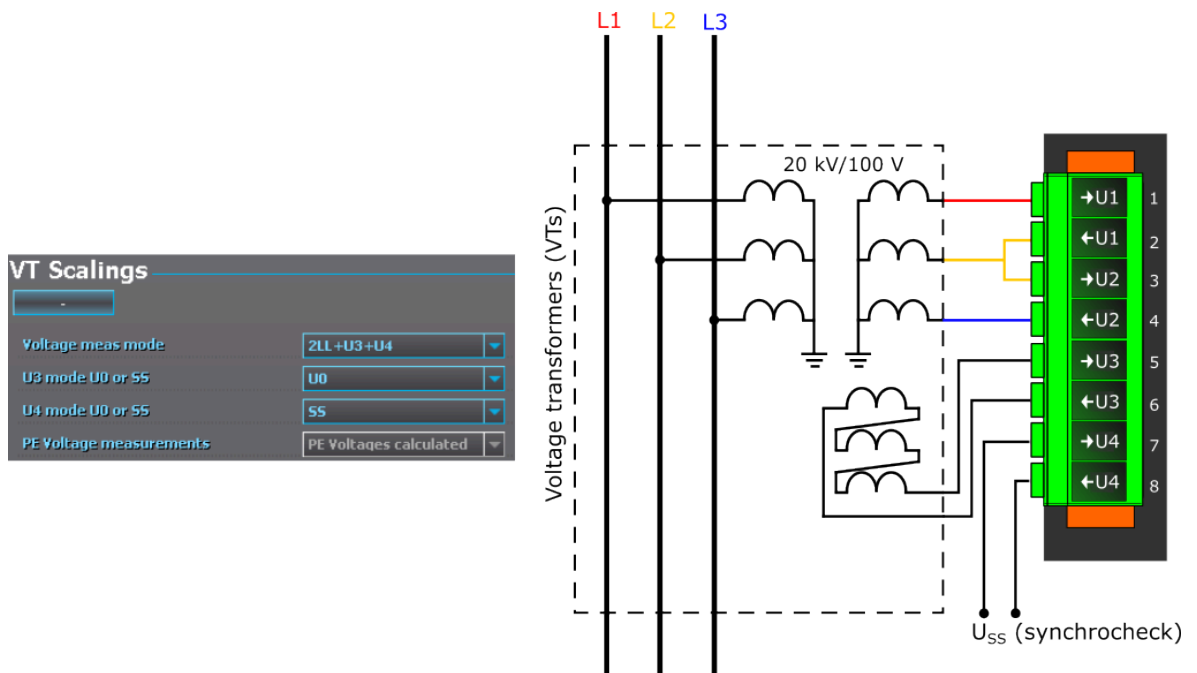
Figure. 4.2.2 - 61. Example connections for voltage line-to-line measurement.



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

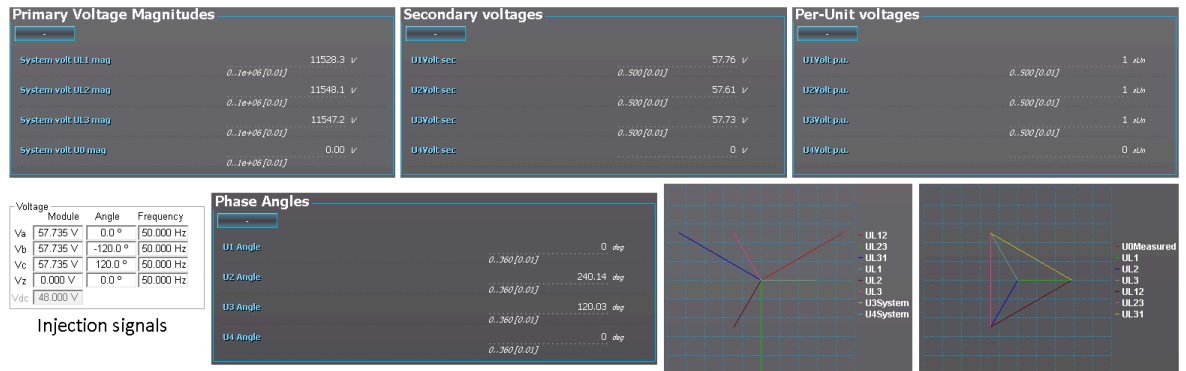
The voltage measurement channel  $U_4$  can be used to measure the zero sequence voltage ( $U_0$ ), the side 2 voltage of the circuit breaker (Synchrocheck), or for automatic voltage regulator function. If the  $2LL+U_3+U_4$  mode is selected, the third channel ( $U_3$ ) can be used for this purpose. Please note that  $U_0$  can only be measured by using a single channel.

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

Figure. 4.2.2 - 62.  $2LL+U_0+SS$  settings and connections.

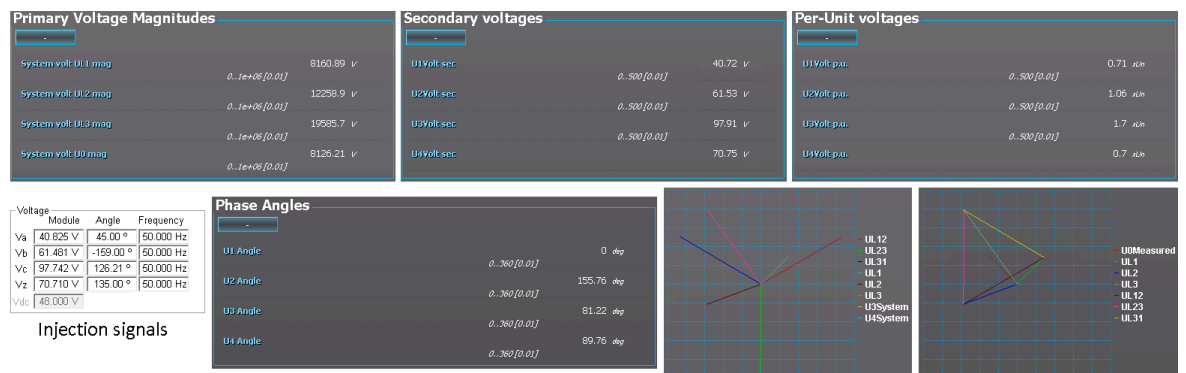
The image collection below presents the device's behavior when nominal voltage is injected into the device via secondary test equipment. The measurement mode is 3LN+U4 which means that the device is measuring line-to-neutral voltages. The VT scaling has been set to 20 000 : 100 V. The U4 channel measures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

Figure. 4.2.2 - 63. Measurement behavior when nominal voltage injected.



The image collection below presents the device's behavior when voltage is injected into the device via secondary test equipment during an earth fault. The measurement mode is 3LN+U4 which means that the device 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. 4.2.2 - 64. Device behavior when voltage injected during an earth fault.

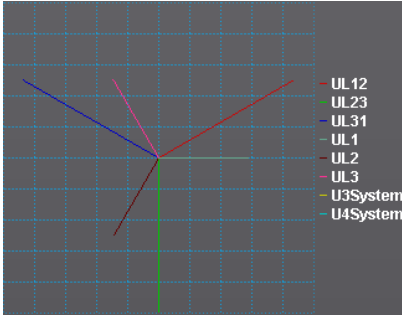


## Troubleshooting

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

Problem	Check / Resolution
The measured voltage amplitude in all phases does not match the injected voltage.	The scaling settings or the voltage measurement mode may be wrong, check that the settings match with the connected voltage transformer ( <i>Measurement</i> → <i>Transformers</i> → <i>VT Module</i> ).
The measured voltage amplitude does not match one of the measured phases./ The calculated U0 is measured even though it should not.	Check the wiring connections between the injection device or the VTs and the device.



Problem	Check / Resolution
<p>The measured voltage amplitudes are OK but the angles are strange./</p> <p>The voltage unbalance protection trips immediately after activation./</p> <p>The earth fault protection trips immediately after it is activated and voltage calculated.</p>	<p>The voltages are connected to the measurement module but the order or polarity of one or all phases is incorrect. In device settings, go to <i>Measurement</i> → <i>Phasors</i> and check the "System voltage vectors" diagram. When all connections are correct, the diagram (symmetric feeding) should look like this:</p> 

## Alternative

## Settings

Table. 4.2.2 - 24. Settings of the VT scaling.

Name	Range	Step	Default	Description
Voltage measurement mode	<ul style="list-style-type: none"> <li>3LN+U4</li> <li>3LL+U4</li> <li>2LL+U3+U4</li> </ul>	-	3LN+U4	The device's voltage wiring method. The voltages are scaled according the set voltage measurement mode.
U3 mode U0 or SS	<ul style="list-style-type: none"> <li>Not Used</li> <li>U0</li> <li>SS</li> </ul>	-	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.
U4 mode U0 or SS				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 (U3) Measured from	<ul style="list-style-type: none"> <li>Broken Delta</li> <li>Neutral point</li> <li>Open delta</li> </ul>	-	Broken delta	<p>Defines how the secondary voltage is scaled to the primary. "Broken Delta" is the most common mode. 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.</p> <p>Example with scaling 20000/100 for U<sub>0</sub> and injection 10V secondary:</p> <ul style="list-style-type: none"> <li>Broken delta: 1155V (10%)</li> <li>Neutral point: 2000 V (17.34%)</li> <li>Open delta: 667V (5.78%)</li> </ul>

Name	Range	Step	Default	Description
U0 (U4) Measured from				Defines how the secondary voltage is scaled to the primary. "Broken Delta" is the most common mode. 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. Example with scaling 20000/100 for U <sub>0</sub> and injection 10V secondary: <ul style="list-style-type: none"> <li>• Broken delta: 1155V (10%)</li> <li>• Neutral point: 2000 V (17.34%)</li> <li>• Open delta: 667V (5.78%)</li> </ul>
Set input voltage thresholds	<ul style="list-style-type: none"> <li>• No</li> <li>• Yes</li> </ul>	-	Yes	If this parameter is enabled, it is possible to set minimum voltage required for voltage measurement to start.
U1 input threshold	0.10...50.00 V <sub>sec</sub>	0.01 V <sub>sec</sub>	1.00 V <sub>sec</sub>	Sets the lowest voltage the channel is allowed to measure.
U2 input threshold				
U3 input threshold				
U4 input threshold				
Voltage memory	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Activated</li> </ul>	-	Disabled	Activates the voltage memory. The "Voltage memory" chapter describes the function in more detail.
P-E Voltage measurements	<ul style="list-style-type: none"> <li>• No P-E voltages available</li> <li>• P-E Voltages calculated</li> <li>• P-E Voltages measured</li> </ul>	-	-	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	1.0...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	1.0...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...400.0V	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	1.0...1 000 000.0V	0.1V	20 000.0V	The primary nominal voltage of the connected U0 or SS VT.
U4 Res/SS VT secondary	0.2...400.0V	0.1V	100.0V	The secondary nominal voltage of the connected U0 or SS VT.

Name	Range	Step	Default	Description
U1 Polarity	<ul style="list-style-type: none"> <li>-</li> <li>Invert</li> </ul>	-	-	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				The selection of the second voltage measurement channel's (U2) polarity (direction). The default setting is for the positive voltage to flow from connector 3 to connector 4, with the secondary voltage's starpoint pointing towards the line.
U3 Polarity				The selection of the third voltage measurement channel's (U3) polarity (direction). The default setting is for the positive voltage to flow from connector 5 to connector 6, with the secondary voltage's starpoint pointing towards the line.
U4 Polarity				The selection of the fourth voltage measurement channel's (U4) polarity (direction). The default setting is for the positive voltage to flow from connector 7 to connector 8, with the secondary voltage's starpoint pointing towards the line.

Table. 4.2.2 - 25. Read-only parameters of the VT scaling.

Name	Description
VT scaling factor P/S	A 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 feedback value; the scaling factor for the primary voltage's per-unit value.
VT scaling factor p.u. Sec	A feedback value; the scaling factor for the secondary voltage's per-unit value.
U3 VT scaling factor P/S U0/SS	A 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 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 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 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 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 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. 4.2.2 - 26. Per-unit voltage measurements.

Name	Range	Step	Description
Voltage Ux ("UxVolt p.u.")	0.00...500.00xU <sub>N</sub>	0.01xU <sub>N</sub>	The voltage measurement fundamental frequency component (in p.u.) from each of the voltage channels.
Voltage Ux TRMS ("UxVolt TRMS p.u.")	0.00...500.00xU <sub>N</sub>	0.01xU <sub>N</sub>	The TRMS voltage (inc. harmonics up to 31 <sup>st</sup> ) measurement (in p.u.) from each of the voltage channels.

Table. 4.2.2 - 27. Secondary voltage measurements.

Name	Range	Step	Description
Secondary voltage Ux ("Ux Volt sec")	0.00...500.00V	0.01V	The secondary voltage measurement fundamental frequency component from each of the voltage channels.
Secondary voltage Ux TRMS ("UxVolt TRMS sec")	0.00...500.00V	0.01V	The secondary TRMS voltage (inc. harmonics up to 31 <sup>st</sup> ) measurement from each of the voltage channels.

Table. 4.2.2 - 28. Voltage phase angle measurements.

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

Table. 4.2.2 - 29. Per-unit sequence voltage measurements.

Name	Range	Step	Description
Positive sequence voltage ("Pos.seq.Volt.p.u.")	0.00...500.00xU <sub>N</sub>	0.01xU <sub>N</sub>	The measurement (in p.u.) from the calculated positive sequence voltage.
Negative sequence voltage ("Neg.seq.Volt.p.u.")	0.00...500.00xU <sub>N</sub>	0.01xU <sub>N</sub>	The measurement (in p.u.) from the calculated negative sequence voltage.
Zero sequence voltage ("Zero.seq.Volt.p.u.")	0.00...500.00xU <sub>N</sub>	0.01xU <sub>N</sub>	The measurement (in p.u.) from the calculated zero sequence voltage.

Table. 4.2.2 - 30. Primary sequence voltage measurements.

Name	Range	Step	Description
Primary positive sequence voltage ("Pos.seq.Volt.pri")	0.00...1 000 000.00V	0.01V	The primary measurement from the calculated positive sequence voltage.
Primary negative sequence voltage ("Neg.seq.Volt.pri")	0.00...1 000 000.00V	0.01V	The primary measurement from the calculated negative sequence voltage.
Primary zero sequence voltage ("Zero.seq.Volt.pri")	0.00...1 000 000.00V	0.01V	The primary measurement from the calculated zero sequence voltage.

Table. 4.2.2 - 31. Secondary sequence voltage measurements.

Name	Range	Step	Description
Secondary positive sequence voltage ("Pos.seq.Volt.sec")	0.00...4 800.00V	0.01V	The secondary measurement from the calculated positive sequence voltage.
Secondary negative sequence voltage ("Neg.seq.Volt.sec")	0.00...4 800.00V	0.01V	The secondary measurement from the calculated negative sequence voltage.
Secondary zero sequence voltage ("Zero.seq.Volt.sec")	0.00...4 800.00V	0.01V	The secondary measurement from the calculated zero sequence voltage.

Table. 4.2.2 - 32. Sequence voltage angle measurements.

Name	Range	Step	Description
Positive sequence voltage angle ("Pos.seq.Volt.Angle")	0.00...360.00°	0.01°	The calculated positive sequence voltage angle.
Negative sequence voltage angle ("Neg.seq.Volt.Angle")	0.00...360.00°	0.01°	The calculated negative sequence voltage angle.
Zero sequence voltage angle ("Zero.seq.Volt.Angle")	0.00...360.00°	0.01°	The calculated zero sequence voltage angle.

Table. 4.2.2 - 33. System primary voltage measurements.

Name	Range	Step	Description
System voltage magnitude UL12 ("System volt UL12 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-line UL12 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.

Name	Range	Step	Description
System voltage magnitude UL23 ("System volt UL23 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-line UL23 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.
System voltage magnitude UL31 ("System volt UL31 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-line UL31 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.
System voltage magnitude UL1 ("System volt UL1 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-neutral UL1 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.
System voltage magnitude UL2 ("System volt UL2 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-neutral UL2 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.
System voltage magnitude UL3 ("System volt UL3 mag")	0.00...1 000 000.00V	0.01V	The primary line-to-neutral UL3 voltage fundamental frequency component (measured or calculated). You can also select the row where the unit for this is kV.
System voltage magnitude U0 ("System volt U0 mag")	0.00...1 000 000.00V	0.01V	The primary zero sequence U0 voltage fundamental frequency component (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")	0.00...1 000 000.00V	0.01V	The primary measured Synchrocheck voltage fundamental frequency component (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	Range	Step	Description
System voltage magnitude U4 ("System volt U4 mag")	0.00...1000 000.00V	0.01V	The primary measured Synchrocheck voltage fundamental frequency component (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. 4.2.2 - 34. Primary system voltage angles.

Name	Range	Step	Description
System voltage angle UL12 ("System volt UL12 ang")	0.00...360.00°	0.01°	The primary line-to-line angle UL12 (measured or calculated).
System voltage angle UL23 ("System volt UL23 ang")	0.00...360.00°	0.01°	The primary line-to-line angle UL23 (measured or calculated).
System voltage angle UL31 ("System volt UL31 ang")	0.00...360.00°	0.01°	The primary line-to-line angle UL23 (measured or calculated).
System voltage angle UL1 ("System volt UL1 ang")	0.00...360.00°	0.01°	The primary line-to-neutral angle UL1 (measured or calculated).
System voltage angle UL2 ("System volt UL2 ang")	0.00...360.00°	0.01°	The primary line-to-neutral angle UL2 (measured or calculated).
System voltage angle UL3 ("System volt UL3 ang")	0.00...360.00°	0.01°	The primary line-to-neutral angle UL3 (measured or calculated).
System voltage angle U0 ("System volt U0 ang")	0.00...360.00°	0.01°	The primary zero sequence angle U0 (measured or calculated).

Name	Range	Step	Description
System voltage angle U3 ("System volt U3 ang")	0.00...360.00°	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")	0.00...360.00°	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. 4.2.2 - 35. Harmonic voltage measurements.

Name	Range	Step	Description
Harmonics calculation values ("Harm Abs.or Perc.")	<ul style="list-style-type: none"> <li>Percent</li> <li>Absolute</li> </ul>	-	Defines whether the harmonics are calculated as percentages or absolute values.
Harmonics display	<ul style="list-style-type: none"> <li>Per unit</li> <li>Primary V</li> <li>Secondary V</li> </ul>	-	Defines how the harmonics are displayed: in p.u. values, as primary voltage values, or as secondary voltage values.
Maximum harmonics value ("UxMaxH")	0.00...100 000.00V	0.01V	Displays the maximum harmonics value of the selected voltage input Ux.
Fundamental frequency ("Ux Fund")	0.00...100 000.00V	0.01V	Displays the voltage value of the fundamental frequency component of the selected voltage input Ux.
Ux harmonics (2 <sup>nd</sup> ...31 <sup>st</sup> harmonic)	0.00...100 000.00V	0.01V	Displays the selected harmonic from the voltage input Ux.
Ux Amplitude THD	0.000...100.000V	0.001V	Amplitude ratio THD voltage. Recognized by IEC.
Ux Power THD	0.000...100.000V	0.001V	Power ratio THD voltage. Recognized by the IEEE.

## Voltage memory

Certain protection functions (such as impedance or directional overcurrent) use the device's measured current and voltage to determine whether the electrical network fault appears to be inside the protected area. The determination is made by comparing the angle between the operating quantity (zone/tripping area) and the actual measured quantity. The function then produces an output when the required terms are met.



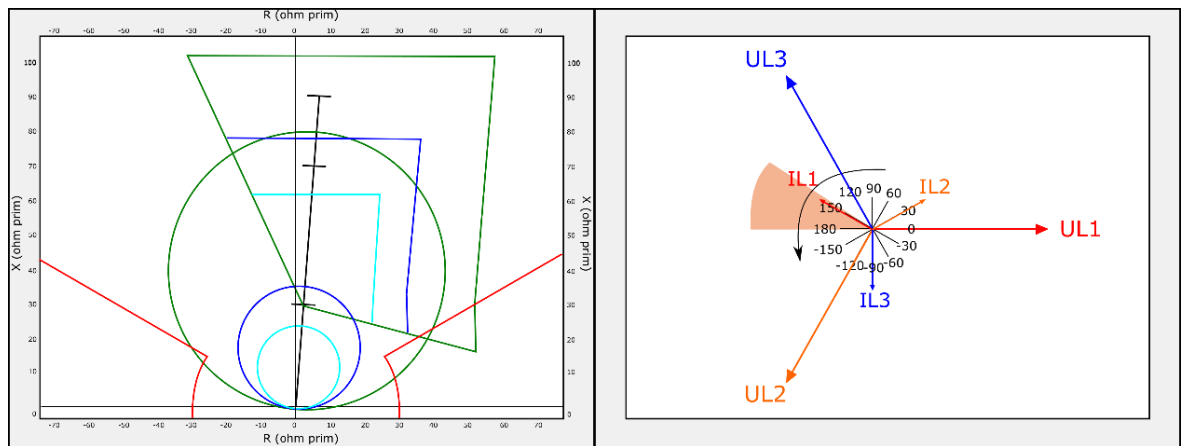
In close-in faults the system voltage on the secondary side may fall down to a few volts or close to nothing. In such cases, when the measured voltage is absent, the fault direction cannot be solved. As backup, non-directional protection can be used for tripping, but in such cases the selectivity of the network will reduce. However, an angle memory for voltage can be used to prevent this from happening. An adjustable voltage level with pre-fault voltage angles can be used as a reference for fault direction and/or distance. The reference can be set manually for duration. Thanks to the configurable voltage memory even time-delayed backup tripping can be initiated.

The user can activate voltage memory (and find all related settings) by following this path in device settings: *Measurement* → *Transformers* → *VT Module (3U/4U) 1* → *Voltage memory* ("Activated"/"Disabled").

The activation of voltage memory depends of following criteria:

1. All used line-to-line or line-to-neutral voltages need to be below the set value for the "VMEM activation voltage" parameter.
2. At least one phase current must be above the set value for the "Measured current condition 3I>" parameter. This setting limit is optional.

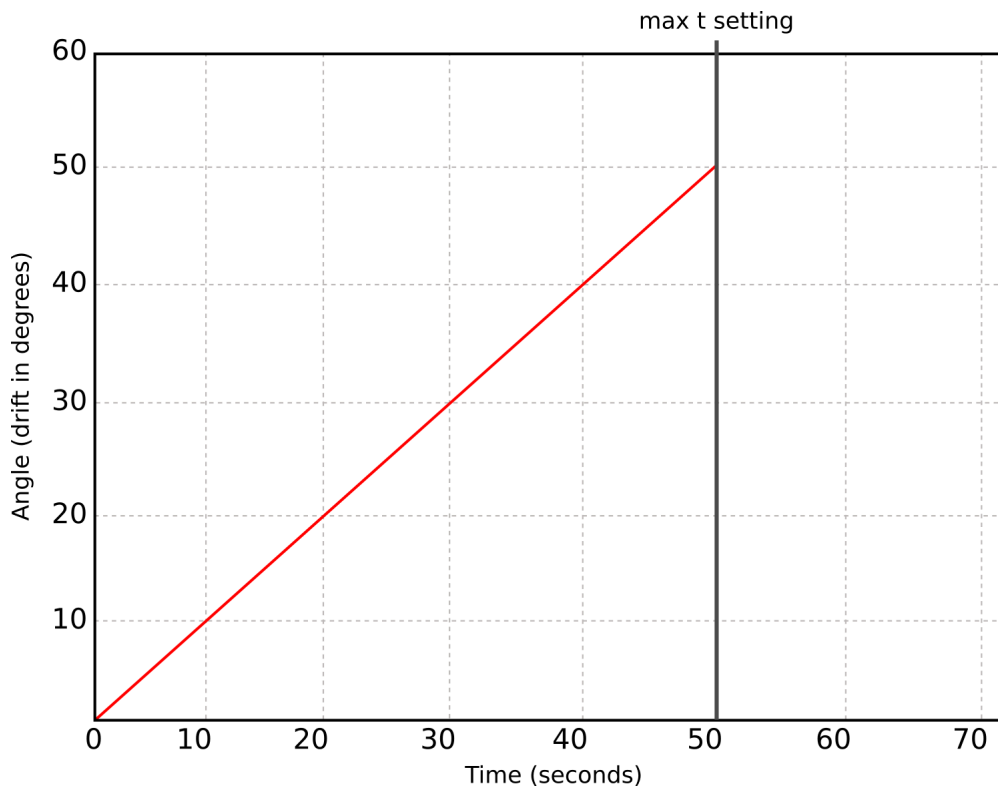
Figure. 4.2.2 - 65. Distance protection characteristics and directional overcurrent.



Voltage memory activates when the above-mentioned criteria are met. Voltage memory uses the "VMEM activation voltage" parameter as voltage amplitude even when the actual measured voltage has decreased below it or close to zero. The angle used by this function is the one captured the moment before the fault occurred and voltage memory was activated. When voltage memory is activated, the output "Voltage memory on" signal is activated. This signal can be found in the device's I/O matrix.

While voltage memory is active, voltages are absent and therefore angle measurement is not possible. Healthy state angles (before a fault) are used during a fault. This is why a drift between the assumed voltage angle and the actual measured phase current angle takes place. While voltage memory is used, the angle of phase currents drifts approximately one degree for each passing second (see the graph below).

Figure. 4.2.2 - 66. Voltage angle drift.



The blocking signal for voltage memory can be found among other stage-related settings in the tab *VT Module (3U/4U) 1*. The blocking signal is checked in the beginning of each program cycle.

#### VMEM activation voltage and Measured current condition 3I>

When the voltage memory function is enabled, it activates when all line voltages drop below the "VMEM activation voltage" threshold limit. This limit can be set to be anything between 2...50 V AC. When "Measured current condition 3I>" is used, activation cannot be based on just the voltage. Therefore, at least one of the three-phase currents must also rise above the set current pick-up setting.

#### VMEM max active time

Voltage memory can be active for a specific period of time, set in "VMAX active time". It can be anything between 0.02...50.00 seconds. The function supports the definite time (DT) delay type. It depends on the application for how long the memory should be used. During massive bolted faults, the fault should be cleared and the breaker opened as soon as possible; therefore, a short operating time for voltage memory is usually applied. A typical delay for voltage memory is between 0.5...1.0 s. When the operating time passes and voltage memory is no longer used, directional overcurrent and/or distance protection goes to the unidirectional mode to secure a safe tripping. The memory uses longer operating times when a backup protection is applied (e.g. in distance-protection zones are farther away).

#### Forced CT f tracking on VMEM

While fixed frequency tracking is used, all protection stage-based sampling (apart from frequency protection) is based on a set fixed frequency such as 50 Hz or 60 Hz. When the frequency drops massively during a fault while angle memory is in use, it is also possible that the frequency of the system starts to fluctuate. In such cases, if current sampling of used protection stages is based on 50/60 Hz, there could be an error in current magnitude and in angle measurement. To minimize these errors, it is recommended that the frequency is measured and protection-based sampling from the current is performed while voltages are gone.

When the "Forced CT f tracking" parameter is activated and voltages are gone, the frequency from the selected current-based reference channel 3 (the current from IL3) is used for current sampling. This eliminates any possible measurement errors in the fixed frequency mode.

For example, let us say a 500 A current is measured on the primary side while the fixed frequency is set to 50 Hz. This results in the frequency dropping to 46 Hz, while the actual current measurement would be 460 A. Therefore, the system would have an error of 40 A.

Table. 4.2.2 - 36. Voltage memory event messages.

Event block name	Event names
M1VT1	Voltage memory enabled
M1VT1	Voltage memory disabled
M1VT1	Voltage low detected ON
M1VT1	Voltage low detected OFF
M1VT1	Current high detected ON
M1VT1	Current high detected OFF
M1VT1	Frequency tracked from CT ON
M1VT1	Frequency tracked from CT OFF
M1VT1	Using Voltage memory ON
M1VT1	Using Voltage memory OFF
M1VT1	Voltage memory blocked ON
M1VT1	Voltage memory blocked OFF

### 4.2.3 Power and energy calculation

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

If a unit has more than one CT measurement module, the user can choose which module's current measurement is used by the power calculation. The power and energy measurements are updated every 5 milliseconds.

#### Line-to-neutral voltages available

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

Figure. 4.2.3 - 67. Three-phase power (S) calculation.

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

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

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

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

Figure. 4.2.3 - 68. Three-phase active power (P) calculation.

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

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

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

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

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

Figure. 4.2.3 - 69. Three-phase reactive power (Q) calculation.

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

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

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

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

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

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

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

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

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

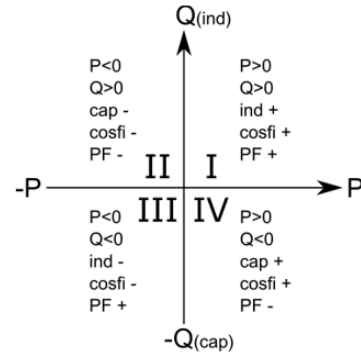
The direction of reactive power is divided into four quadrants. Reactive power may be inductive or capacitive on both forward and reverse directions. Reactive power quadrant can be indicated with  $\tan(\varphi)$  (tangent phi), which is calculated according the following formula:

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

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

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

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



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

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

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

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

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

#### Only line-to-line voltages available

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

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

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

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

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

### Troubleshooting

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

### Settings

Table. 4.2.3 - 37. Power and energy measurement settings

Name	Range	Step	Default	Description
3ph active energy measurement	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables/disables the active energy measurement.


Name	Range	Step	Default	Description
3ph reactive energy measurement	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables/disables the reactive and apparent energy measurement.
3ph energy megas or kilos	<ul style="list-style-type: none"> <li>Mega</li> <li>Kilo</li> </ul>	-	Mega	Defines whether energy is measured with the prefix 'kilo' ( $10^3$ ) or 'mega' ( $10^6$ ).
Edit energy values	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	<p>When this parameter is enabled it is possible to manually edit exported and imported active energy values.</p> <div>  <p><b>NOTICE!</b> "E 3ph M or k" parameter has to be set to "kilo" for this feature to function.</p> </div>
Invert imp/exp energy directions	<ul style="list-style-type: none"> <li>Not inverted</li> <li>Inverted</li> </ul>	-	Not inverted	Inverts the direction of imported and exported energy without affecting the direction of power calculation.
Nominal power kVA	0.10...500000.00kVA	0.01kVA	100kVA	Defines the nominal power of the protected object.
PQ Quadrant	<ul style="list-style-type: none"> <li>Undefined</li> <li>Q1 Fwd Ind</li> <li>Q2 Rev Cap</li> <li>Q3 Rev Ind</li> <li>Q4 Fwd Cap</li> </ul>	-	Undefined	Indicates what the power PQ quadrant is at that moment.
VA Quadrant	<ul style="list-style-type: none"> <li>Undefined</li> <li>Q1 Fwd Cap AV</li> <li>Q2 Rev Ind AV</li> <li>Q3 Rev Cap VA</li> <li>Q4 Fwd Ind VA</li> </ul>	-	Undefined	Indicates what the power VA quadrant is at that moment.
Reset energy calculators ("Reset 3ph Energies")	<ul style="list-style-type: none"> <li>-</li> <li>Reset</li> </ul>	-	-	Resets the memory of the three-phase energy calculators. Goes automatically back to the "-" state after the reset is finished.
Phase active energy measurement	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables/disables the active energy per phase measurement.
Phase reactive energy measurement	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables/disables the reactive energy per phase measurement.
Phase energies megas or kilos	<ul style="list-style-type: none"> <li>Mega</li> <li>Kilo</li> </ul>	-	Mega	Defines whether energy (per phase) is measured with the prefix 'kilo' ( $10^3$ ) or 'mega' ( $10^6$ ).
Reset energy calculators (per phase) ("Reset E per phase")	<ul style="list-style-type: none"> <li>-</li> <li>Reset</li> </ul>	-	-	Resets the memory of the individual phase energy calculator. Goes automatically back to the "-" state after the reset is finished.

Table. 4.2.3 - 38. Energy Dose Counter 1 settings

Name	Range	Step	Default	Description
Energy dose counter mode	<ul style="list-style-type: none"> <li>Disabled</li> <li>Activated</li> </ul>	-	Disabled	Enables/disables energy dose counters generally.
Clear pulse counter	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	-	-	Resets the "DC 1...4 Pulses sent" counters back to zero.
DC 1...4 enable	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables/disables the energy dose counter 1...4 individually.
DC 1...4 Input signal select	<ul style="list-style-type: none"> <li>3PH.Fwd.Act.EP</li> <li>3PH.Rev.Avt.EP</li> <li>3PH.Fwd.React.EQ.CAP</li> <li>3PH.Fwd.React.EQ.IND</li> <li>3PH.Rev.React.EQ.CAP</li> <li>3PH.Rev.React.EQ.IND</li> </ul>	-	3PH.Fwd.Act.EP	Selects whether the energy is active or reactive, whether the direction of the energy is forward or reverse, and whether reactive energy is inductive or capacitive.
DC 1...4 Input signal	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	-	The total amount of energy consumed.
DC 1...4 Pulse magnitude	0...1800kW/var	0.005kW/var	1kW/Var	The set pulse size. An energy pulse is given every time the set magnitude is exceeded.
DC 1...4 Pulse length	0...1800s	0.005s	1s	The total length of a control pulse.
DC1...4 Pulses sent	0...4 294 967 295	1	-	Indicates the total number of pulses sent.

Table. 4.2.3 - 39. DC 1...4 Pulse out settings

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

## Power measurements

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

Table. 4.2.3 - 40. Three-phase power calculations.

Name	Range	Step	Description
3PH Apparent power (S)	$-1 \times 10^6 \dots 1 \times 10^6$ kVA	0.01kVA	The total three-phase apparent power in kilo-volt-ampere
3PH Active power (P)	$-1 \times 10^6 \dots 1 \times 10^6$ kW	0.01kW	The total three-phase active power in kilowatts
3PH Reactive power (Q)	$-1 \times 10^6 \dots 1 \times 10^6$ kVar	0.01kVar	The total three-phase reactive power in kilovars

Name	Range	Step	Description
3PH Apparent power (S MVA)	$-1 \times 10^5 \dots 1 \times 10^5 \text{MVA}$	0.01MVA	The total three-phase apparent power in megawatts
3PH Active power (P MW)	$-1 \times 10^5 \dots 1 \times 10^5 \text{MW}$	0.01MW	The total three-phase active power in mewatts
3PH Reactive power (Q MVar)	$-1 \times 10^5 \dots 1 \times 10^5 \text{MVar}$	0.01MVar	The total three-phase active power in megavars
3PH Tan(phi)	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The direction of three-phase active power
3PH Cos(phi)	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The direction of three-phase reactive power
3PH Power factor	$-1 \times 10^6 \dots 1 \times 10^6$	0.0001	The three-phase power factor

Table. 4.2.3 - 41. Single-phase power calculations (L1...L3).

Name	Unit	Range	Step	Description
Lx Apparent power (S)	kVA	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The apparent power of Phase Lx in kilo-volt-amperes
Lx Active power (P)	kW	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The active power of Phase Lx in kilowatts
Lx Reactive power (Q)	kVar	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The reactive power of Phase Lx kilovars
Lx Tan(phi)	-	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The direction of Phase Lx's active power
Lx Cos(phi)	-	$-1 \times 10^6 \dots 1 \times 10^6$	0.01	The direction of Phase Lx's reactive power
Lx Power factor	-	$-1 \times 10^6 \dots 1 \times 10^6$	0.0001	The power factor of Phase Lx

## Energy measurements

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

Table. 4.2.3 - 42. Three-phase energy calculations.

Name	Range	Step	Description
Exported Active Energy (P) (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of exported active energy.
Imported Active Energy (P) (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of imported active energy.
Active Energy (P) Export/Import balance (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of imported and exported active energy.
Exported (Q) while Export (P) (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of exported reactive energy while active power is exported.
Imported (Q) while Export (P). (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total amount of imported reactive energy while active energy is exported.



Name	Range	Step	Description
Reactive energy (Q) balance while export (P) (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of imported and exported reactive capacitive energy while active power is exported.
Exported (Q) while Import (P) (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of exported reactive energy while active energy is imported.
Imported (Q) while Import (P) (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of imported reactive energy while active energy is imported.
Reactive energy (Q) balance while Import (P) (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of imported and exported reactive energy while active energy is imported.
Apparent Energy (S) while Export (P) (kVAh or MVAh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of exported apparent energy while active energy is exported.
Apparent Energy (S) while Import (P) (kVAh or MVAh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The total amount of exported apparent energy while active energy is imported.
Apparent Energy (S) Net	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total amount of apparent energy.
Real Energy (P) Net	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of active energy supply and demand.
Reactive Energy (Q) Net	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of reactive energy supply and demand.
Real Energy (P) Supply	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total amount of active energy supplied. Default supply direction towards busbar.
Reactive Energy (Q) Supply	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total reactive energy supplied. Default supply direction towards busbar.
Real Energy (P) Demand	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total amount of active energy demand. Default demand direction from busbar.
Reactive Energy (Q) Demand	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	Total amount of reactive energy demand. Default demand direction from busbar.

Table. 4.2.3 - 43. Single-phase energy calculations (L1...L3).

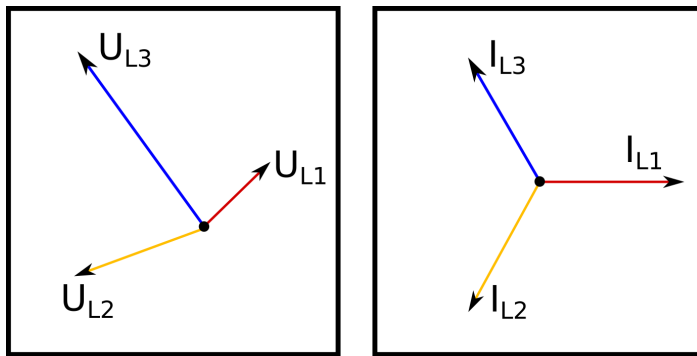
Name	Range	Step	Description
Export Active Energy Lx (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The exported active energy of the phase.
Import Active Energy (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The imported active energy of the phase.
Active Energy (P) Export/Import balance (kWh or MWh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of the phase's imported and exported active energy.
Exported (Q) while Export (P) Lx (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The exported reactive energy of the phase while active energy is exported.
Imported (Q) while Export (P) Lx (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The imported reactive energy of the phase while active energy is exported.
Reactive Energy (Q) balance while Export (P) Lx (kVarh or MVarh)	$-1 \times 10^9 \dots 1 \times 10^9$	0.01	The sum of the phase's imported and exported reactive energy while active energy is exported.

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

### Calculation examples

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

Voltages (line-to-neutral):	Currents:
U <sub>L1</sub> = 40.825 V, 45.00°	I <sub>L1</sub> = 2.5 A, 0.00°
U <sub>L2</sub> = 61.481 V, -159.90°	I <sub>L2</sub> = 2.5 A, -120.00°
U <sub>L3</sub> = 97.742 V, 126.21°	I <sub>L3</sub> = 2.5 A, 120.00°



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

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

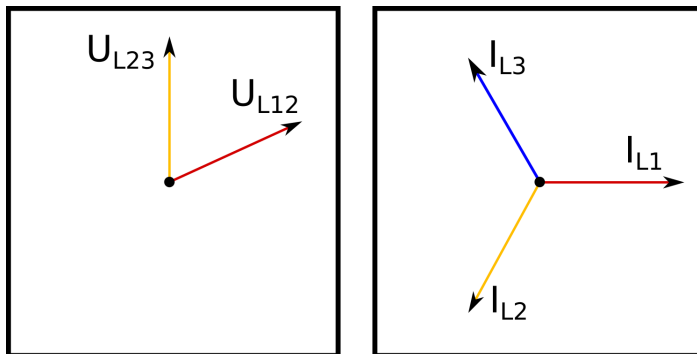
$$Q_{L1} = U_{L1} \times I_{L1} \sin \varphi = 40.825 \text{ V} \times 2.5 \text{ A} \sin(45^\circ - 0^\circ) = 72.2 \text{ var (secondary)} \quad \mathbf{2.89 \text{ MVar (primary)}}$$

$$L1 \tan(\phi) = Q_{L1}/P_{L1} = 2.89/2.89 = \mathbf{1.00} \qquad L1 \cos(\phi) = P_{L1}/S_{L1} = 2.89/4.08 = \mathbf{0.71}$$

Name	Value	Name	Value	Name	Value	Name	Value
L1 (S)	4.08 MVA	L2 (S)	6.15 MVA	L3 (S)	9.77 MVA	3PH (S)	20.00 MVA
L1 (P)	2.89 MW	L2 (P)	4.72 MW	L3 (P)	9.71 MW	3PH (P)	17.32 MW

Name	Value	Name	Value	Name	Value	Name	Value
L1 (Q)	2.89 Mvar	L2 (Q)	-3.94 Mvar	L3 (Q)	1.06 Mvar	3PH (Q)	0.01 Mvar
L1 Tan	1.00	L2 Tan	-0.83	L3 Tan	0.11	3PH Tan	0.00
L1 Cos	0.71	L2 Cos	0.77	L3 Cos	0.99	3PH Cos	0.87

Voltages (line-to-line):	Currents:
$U_{L12} = 100.00 \text{ V}, 30.00^\circ$	$I_{L1} = 2.5 \text{ A}, 0.00^\circ$
$U_{L23} = 100.00 \text{ V}, -90.00^\circ$	$I_{L2} = 2.5 \text{ A}, -120.00^\circ$
	$I_{L3} = 2.5 \text{ A}, 120.00^\circ$



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

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

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

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

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

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

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

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

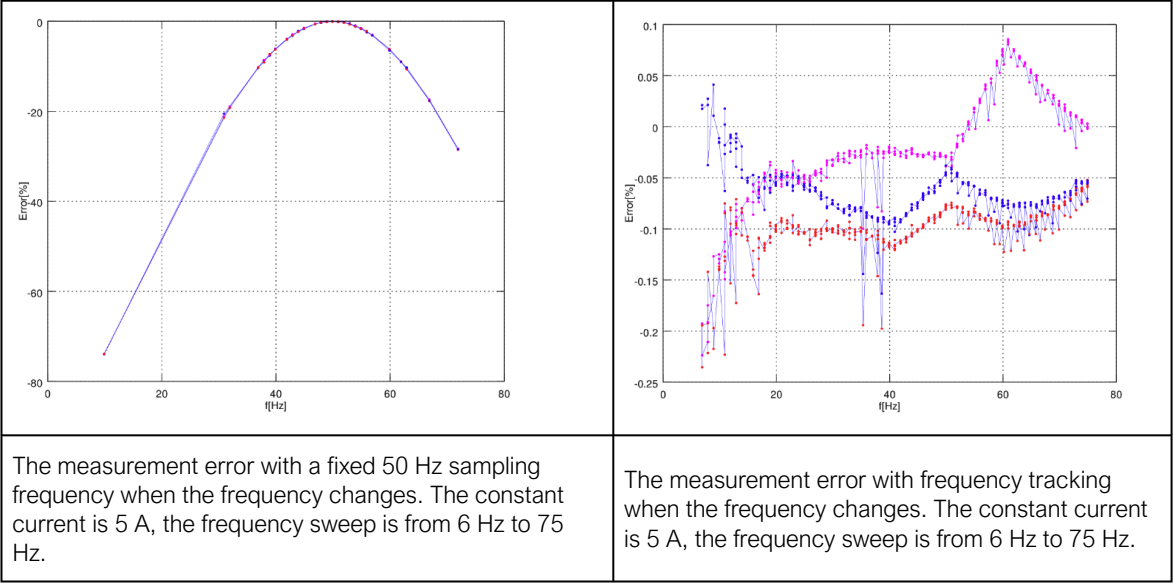
Name	Values
3PH (S)	20.00 MVA
3PH (P)	17.32 MW
3PH (Q)	0.00 Mvar
3PH Tan	0.00
3PH Cos	0.87

4.2.4 Frequency tracking and scaling

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

Frequency independent current and voltage measurement accuracy is achieved with algorithms specified in patent US 10,809,287.

Table. 4.2.4 - 44. Frequency tracking effect (FF changes from 6 Hz to 75 Hz).



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

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

Troubleshooting

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

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

## Settings

Table. 4.2.4 - 45. Settings of the frequency tracking.

Name	Range	Step	Default	Description
Sampling mode	<ul style="list-style-type: none"> <li>Fixed</li> <li>Tracking</li> </ul>	-	Fixed	Defines which measurement sampling mode is in use: the fixed user-defined frequency, or the tracked system frequency.
Max. tracking frequency allowed (+Nom freq.)	0.001...75.000 Hz	0.001 Hz	0.001 Hz	Defines the upper limit for the deviation from the system nominal frequency to be tracked. If the frequency increases more than allowed from the nominal value, the tracking is discarded and the value of the nominal frequency will be used.
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".
Min. tracking frequency allowed (-Nom freq.)	0.001...75.000 Hz	0.001 Hz	0.001 Hz	Defines the lower limit for the deviation from the system nominal frequency to be tracked. If the frequency decreases more than allowed from the nominal value, the tracking is discarded and the value of the nominal frequency will be used.
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	<ul style="list-style-type: none"> <li>None</li> <li>CT1IL1</li> <li>CT2IL1</li> <li>VT1U1</li> <li>VT2U1</li> </ul>	-	CT1IL1	The first reference source for frequency tracking.
Frequency reference 2	<ul style="list-style-type: none"> <li>None</li> <li>CT1IL2</li> <li>CT2IL2</li> <li>VT1U2</li> <li>VT2U2</li> </ul>	-	CT1IL2	The second reference source for frequency tracking.

Name	Range	Step	Default	Description
Frequency reference 3	<ul style="list-style-type: none"> <li>None</li> <li>CT1IL3</li> <li>CT2IL3</li> <li>VT1U3</li> <li>VT2U3</li> </ul>	-	CT1IL3	The third reference source for frequency tracking.
Frequency tracking quality	<ul style="list-style-type: none"> <li>No trackable channels</li> <li>Reference 1 trackable</li> <li>Reference 2 trackable</li> <li>References 1 &amp; 2 trackable</li> <li>Reference 3 trackable</li> <li>Reference 1 &amp; 3 trackable</li> <li>References 2 &amp; 3 trackable</li> <li>All references trackable</li> </ul>	-	-	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	<ul style="list-style-type: none"> <li>No track ch</li> <li>Ref1</li> <li>Ref2</li> <li>Ref3</li> </ul>	-	-	Indicates which reference is used at the moment for frequency tracking.
Start behavior	<ul style="list-style-type: none"> <li>Start tracking immediately</li> <li>First nominal or tracked</li> </ul>	-	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	<ul style="list-style-type: none"> <li>Use track frequency</li> <li>Use nom frequency</li> </ul>	-	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.
System measured frequency	<ul style="list-style-type: none"> <li>One f measured</li> <li>Two f measured</li> <li>Three f measured</li> </ul>	-	-	Displays the amount of frequencies that are measured.

Name	Range	Step	Default	Description
f.atm. Protections	0.000...75.000Hz	0.001Hz	-	Frequency measurement value used by protection functions. When frequency is not measurable this value returns to value set to "System nominal frequency" parameter.
f.atm. Display	0.000...75.000Hz	0.001Hz	-	Frequency measurement value used in display. When frequency is not measurable this value is "0 Hz".
f measurement from	<ul style="list-style-type: none"> <li>• Not measurable</li> <li>• Avg Ref 1</li> <li>• Avg Ref 2</li> <li>• Avg Ref 3</li> <li>• Track Ref 1</li> <li>• Track Ref 2</li> <li>• Track Ref 3</li> <li>• Fast Ref 1</li> <li>• Fast Ref 2</li> <li>• Fast Ref 3</li> </ul>	-	-	Displays which reference is used for frequency measurement.
SS1.meas.frqs	0.000...75.000Hz	0.001Hz	-	Displays frequency used by "system set" channel 1 and 2.
SS2.meas.frqs				
SS1f meas.from	<ul style="list-style-type: none"> <li>• Not measurable</li> <li>• Fast Ref U3</li> <li>• Fast Ref U4</li> </ul>	-	-	Displays which voltage channel frequency reference is used by "system set" voltage channel.
SS2f meas.from	<ul style="list-style-type: none"> <li>• Not measurable</li> <li>• Fast Ref U4</li> </ul>	-	-	Displays if U4 channel frequency reference is measurable or not when the channel has been set to "system set" mode.

### 4.3 General menu

The *General* menu consists of basic settings and indications of the device. Additionally, the all activated functions and their status are displayed in the *Protection*, *Control* and *Monitor* profiles.

Table. 4.3 - 46. The *General* menu read-only parameters

Name	Description
Serial number	The unique serial number identification of the unit.
Firmware version	The firmware software version of the unit.
Hardware configuration	The order code identification of the unit.
System phase rotating order at the moment	The selected system phase rotating order. Can be changed with parameter "System phase rotating order".
UTC time	The UTC time value which the device's clock uses.

Table. 4.3 - 47. Parameters and indications in the *General* menu.

Name	Range	Default	Description
Device name	-	Unitname	The file name uses these fields when loading the .aq3 configuration file from the AQ-200 unit.
Device location	-	Unitlocation	
Time synchronization source	<ul style="list-style-type: none"> <li>Internal</li> <li>External NTP</li> <li>External Serial</li> <li>IRIG-B</li> </ul>	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	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Disabled	When this parameter is enabled it is possible for the user to force the protection, control and monitoring functions to different statuses like START and TRIP. This is done in the function's <i>Info</i> page with the <i>Force status to</i> parameter.
System phase rotating order	<ul style="list-style-type: none"> <li>A-B-C</li> <li>A-C-B</li> </ul>	A-B-C	Allows the user to switch the expected order in which the phase measurements are wired to the unit.
Language	<ul style="list-style-type: none"> <li>User defined</li> <li>English</li> <li>Finnish</li> <li>Chinese</li> <li>Spanish</li> <li>French</li> <li>German</li> <li>Russian</li> <li>Ukrainian</li> <li>Kazakh</li> </ul>	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.
AQtivate ethernet port	<ul style="list-style-type: none"> <li>All</li> <li>COM A</li> <li>Double Ethernet card</li> </ul>	All	If the device has a double Ethernet option card it is possible to choose which ports are available for connecting with AQtivate software.
Clear events	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	-	Clears the event history recorded in the AQ-200 device.
LCD Contrast	0...255	120	Changes the contrast of the LCD display.
Return to default view	0...3600s	0s	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	<ul style="list-style-type: none"> <li>-</li> <li>Activated</li> </ul>	-	When activated, all LEDs are lit up. LEDs with multiple possible colors blink each color.
Reset latches	<ul style="list-style-type: none"> <li>-</li> <li>Reset</li> </ul>	-	Resets the latched signals in the logic and the matrix. When a reset command is given, the parameter automatically returns back to "-".
Measurement recorder	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Disabled	Enables the measurement recorder tool, further configured in <i>Tools</i> → <i>Misc</i> → <i>Measurement recorder</i> .



Name	Range	Default	Description
I/O default object selection	<ul style="list-style-type: none"> <li>• OBJ1</li> <li>• OBJ2</li> <li>• OBJ3</li> <li>• OBJ4</li> <li>• OBJ5</li> <li>• OBJ6</li> <li>• OBJ7</li> <li>• OBJ8</li> <li>• OBJ9</li> <li>• OBJ10</li> </ul>	OBJ1	"I" and "O" push buttons on the front panel of the device have an indication LED. This parameter defines which objects' status push buttons follow when lighting up the LEDs.
Reconfigure mimic	<ul style="list-style-type: none"> <li>• -</li> <li>• Reconfigure</li> </ul>	-	Reloads the mimic to the unit.

Table. 4.3 - 48. General menu logical inputs.

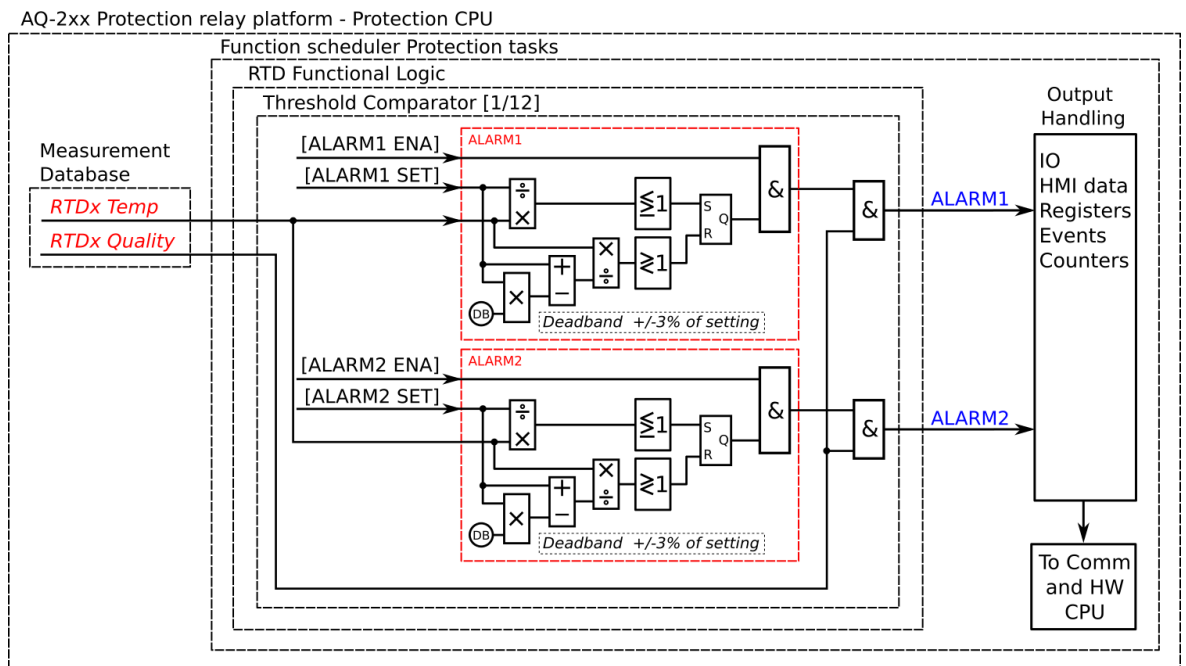
Name	Description
Reset last fault registers	Signal set to this point can be used for resetting latest recorded fault register.

## 4.4 Protection functions

### 4.4.1 Resistance temperature detectors (RTD)

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.

Figure. 4.4.1 - 70. Simplified function block diagram of the resistance temperature detection function.



## Settings

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.

Table. 4.4.1 - 49. Function settings for Channel x (Sx).

Name	Range	Step	Default	Description
S1...S16 enable	No Yes	-	No	Enables/disables the selection of sensor measurements and alarms.
S1...S16 module	<ul style="list-style-type: none"> <li>InternalRTD1</li> <li>InternalRTD2</li> <li>ExtModuleA</li> <li>ExtModuleB</li> <li>ExtModuleC</li> </ul>	-	InternalRTD1	Selects the measurement module. Internal RTD modules are option cards installed to the device. External modules are Modbus based external devices.
S1...S16 channel	<ul style="list-style-type: none"> <li>Channel 0</li> <li>Channel 1</li> <li>Channel 2</li> <li>Channel 3</li> <li>Channel 4</li> <li>Channel 5</li> <li>Channel 6</li> <li>Channel 7</li> </ul>	-	Channel 0	Selects the measurement channel in the selected module.

Name	Range	Step	Default	Description
S1...S16 Deg C/Dec F	<ul style="list-style-type: none"> <li>Deg C</li> <li>Deg F</li> </ul>	-	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	<ul style="list-style-type: none"> <li>Ok</li> <li>Invalid</li> </ul>	-	-	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	<ul style="list-style-type: none"> <li>Disable</li> <li>Enable</li> </ul>	-	Disable	Enables/disables the selection of Alarm 1 for the measurement channel x.
S1...S16 Alarm1 >/<	<ul style="list-style-type: none"> <li>&gt;</li> <li>&lt;</li> </ul>	-	>	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	<ul style="list-style-type: none"> <li>Ok</li> <li>Invalid</li> </ul>	-	-	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	<ul style="list-style-type: none"> <li>Disable</li> <li>Enable</li> </ul>	-	Disable	Enables/disables the selection of Alarm 2 for the measurement channel x.
S1...S16 Alarm2 >/<	<ul style="list-style-type: none"> <li>&gt;</li> <li>&lt;</li> </ul>	-	>	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 >/<").

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.

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 the events listed below. 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.

The function's outputs can be used for direct I/O controlling and user logic programming. The function also provides a resettable cumulative counter for the ALARM events.

The function offers sixteen (16) independent stages; the events are segregated for each stage operation.

Table. 4.4.1 - 50. Event messages.

Event block name	Event names
RTD1	S1...S16 Alarm1 ON
RTD1	S1...S16 Alarm1 OFF
RTD1	S1...S16 Alarm2 ON
RTD1	S1...S16 Alarm2 OFF
RTD1	S1...S16 Meas Ok
RTD1	S1...S16 Meas Invalid

### 4.4.2 Programmable stage (PSx>/< 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 device 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 group selection controls the operating characteristics of the function, i.e. the user or user-defined logic can change function parameters while the function is running.

## Analog values

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

Table. 4.4.2 - 51. Phase and residual current measurements (IL1, IL2, IL3, Io1 and Io2)

Name	Description
ILx ff (p.u.)	Fundamental frequency RMS value (in p.u.)
ILx 2 <sup>nd</sup> h.	ILx 2 <sup>nd</sup> harmonic value (in p.u.)
ILx 3 <sup>rd</sup> h.	ILx 3 <sup>rd</sup> harmonic value (in p.u.)
ILx 4 <sup>th</sup> h.	ILx 4 <sup>th</sup> harmonic value (in p.u.)
ILx 5 <sup>th</sup> h.	ILx 5 <sup>th</sup> harmonic value (in p.u.)
ILx 7 <sup>th</sup> h.	ILx 7 <sup>th</sup> harmonic value (in p.u.)
ILx 9 <sup>th</sup> h.	ILx 9 <sup>th</sup> harmonic value (in p.u.)
ILx 11 <sup>th</sup> h.	ILx 11 <sup>th</sup> harmonic value (in p.u.)
ILx 13 <sup>th</sup> h.	ILx 13 <sup>th</sup> harmonic value (in p.u.)
ILx 15 <sup>th</sup> h.	ILx 15 <sup>th</sup> harmonic value (in p.u.)
ILx 17 <sup>th</sup> h.	ILx 17 <sup>th</sup> harmonic value (in p.u.)
ILx 19 <sup>th</sup> h.	ILx 19 <sup>th</sup> harmonic value (in p.u.)
ILx TRMS	ILx TRMS value (in p.u.)
ILx Ang	ILx Angle (degrees)

Table. 4.4.2 - 52. Other current measurements

Name	Description
IOZ Mag	Zero sequence current value (in p.u.)
IOCALC Mag	Calculated IO value (in p.u.)
I1 Mag	Positive sequence current value (in p.u.)
I2 Mag	Negative sequence current value (in p.u.)
IOCALC Ang	Angle of calculated residual current (degrees)
I1 Ang	Angle of positive sequence current (degrees)
I2 Ang	Angle of negative sequence current (degrees)
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

Name	Description
I02ResP	I02 primary current of a current-resistive component
I02CapP	I02 primary current of a current-capacitive component
I02ResS	I02 secondary current of a current-resistive component
I02CapS	I02 secondary current of a current-capacitive component

Table. 4.4.2 - 53. Voltage measurements

Name	Description
UL12Mag	UL12 Primary voltage V
UL23Mag	UL23 Primary voltage V
UL31Mag	UL31 Primary voltage V
UL1Mag	UL1 Primary voltage V
UL2Mag	UL2 Primary voltage V
UL3Mag	UL3 Primary voltage V
UL12Ang	UL12 angle (degrees)
UL23Ang	UL23 angle (degrees)
UL31Ang	UL31 angle (degrees)
UL1Ang	UL1 angle (degrees)
UL2Ang	UL2 angle (degrees)
UL3Ang	UL3 angle (degrees)
U0Ang	UL0 angle (degrees)
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 (degrees)
U1 pos.seq.V Ang	Positive sequence voltage angle (degrees)
U2 neg.seq.V Ang	Negative sequence voltage angle (degrees)

Table. 4.4.2 - 54. Power measurements

Name	Description
S3PH	Three-phase apparent power S (kVA)
P3PH	Three-phase active power P (kW)

Name	Description
Q3PH	Three-phase reactive power Q (kvar)
tanfi3PH	Three-phase active power direction
cosfi3PH	Three-phase reactive power direction
SLx	Phase apparent power L1 / L2 / L3 S (kVA)
PLx	Phase active power L1 / L2 / L3 P (kW)
QLx	Phase reactive power L1 / L2 / L3 Q (kVar)
tanfiLx	Phase active power direction L1 / L2 / L3
cosfiLx	Phase reactive power direction L1 / L2 / L3

Table. 4.4.2 - 55. Phase-to-phase and phase-to-neutral impedances, resistances and reactances

Name	Description
RLxPri	Resistance R L12, L23, L31, L1, L2, L3 primary ( $\Omega$ )
XLxPri	Reactance X L12, L23, L31, L1, L2, L3 primary ( $\Omega$ )
ZLxPri	Impedance Z L12, L23, L31, L1, L2, L3 primary ( $\Omega$ )
RLxSec	Resistance R L12, L23, L31, L1, L2, L3 secondary ( $\Omega$ )
XLxSec	Reactance X L12, L23, L31, L1, L2, L3 secondary ( $\Omega$ )
ZLxSec	Impedance Z L12, L23, L31, L1, L2, L3 secondary ( $\Omega$ )
ZLxAngle	Impedance Z L12, L23, L31, L1, L2, L3 angle

Table. 4.4.2 - 56. Other impedances, resistances and reactances

Name	Description
RSeqPri	Positive Resistance R primary ( $\Omega$ )
XSeqPri	Positive Reactance X primary ( $\Omega$ )
RSeqSec	Positive Resistance R secondary ( $\Omega$ )
XSeqSec	Positive Reactance X secondary ( $\Omega$ )
ZSeqPri	Positive Impedance Z primary ( $\Omega$ )
ZSeqSec	Positive Impedance Z secondary ( $\Omega$ )
ZSeqAngle	Positive Impedance Z angle

Table. 4.4.2 - 57. Conductances, susceptances and admittances (L1, L2, L3)

Name	Description
GLxPri	Conductance G L1, L2, L3 primary (mS)
BLxPri	Susceptance B L1, L2, L3 primary (mS)
YLxPriMag	Admittance Y L1, L2, L3 primary (mS)
GLxSec	Conductance G L1, L2, L3 secondary (mS)
BLxSec	Susceptance B L1, L2, L3 secondary (mS)
YLxSecMag	Admittance Y L1, L2, L3 secondary (mS)
YLxAngle	Admittance Y L1, L2, L3 angle (degrees)

Table. 4.4.2 - 58. Other conductances, susceptances and admittances

Name	Description
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

Table. 4.4.2 - 59. Other measurements

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



## Magnitude multiplier

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 zero sequence 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:

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

When this multiplier is in use, the full earth fault zero sequence voltage is 11 547 V primary which is then multiplied with the above-calculated scaling factor, inverting 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. Similarly, any chosen measurement value can be scaled to the desired form.

## Read-only parameters

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

Table. 4.4.2 - 60. Information displayed by the function.

Name	Range	Description
Condition	<ul style="list-style-type: none"> <li>• Normal</li> <li>• Start</li> <li>• Trip</li> <li>• Blocked</li> </ul>	Displays status of the function.
Expected operating time	-1800.000...1800.000s	Displays the expected operating time when a fault occurs.
Time remaining to trip	0.000...1800.000s	When the function has detected a fault and counts down time towards a trip, this displays how much time is left before tripping occurs.
PSx Scaled magnitude X	-5 000 000...5 000 000	Displays measurement value after multiplying it the value set to <i>PSx Magnitude multiplier</i> .
PSx >/< MeasMag1/ MagSet1 at the moment	-5 000 000...5 000 000	The ratio between measured magnitude and the pick-up setting.
PSx >/< MeasMag2/ MagSet2 at the moment	-5 000 000...5 000 000	The ratio between measured magnitude and the pick-up setting.
PSx >/< MeasMag3/ MagSet3 at the moment	-5 000 000...5 000 000	The ratio between measured magnitude and the pick-up setting.

Name	Range	Description
PSx >/< CalcMeasMag/ MagSet at the moment	-5 000 000...5 000 000	The ratio between calculated magnitude and the pick-up setting.

## Pick-up settings

The *Pick-up setting Mag* setting parameter controls the pick-up of the PSx>/< 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. 4.4.2 - 61. Pick-up settings.

Name	Range	Step	Default	Description
PS# Pick-up term Mag#	<ul style="list-style-type: none"> <li>• Over &gt;</li> <li>• Over (abs) &gt;</li> <li>• Under &lt;</li> <li>• Under (abs) &lt;</li> <li>• Delta set (%) +/- &gt;</li> <li>• Delta abs (%) &gt;</li> <li>• Delta +/- measval</li> <li>• Delta abs measval</li> </ul>	-	Over	Comparator mode for the magnitude. See "Comparator modes" section below for more information.
PS# Pick-up setting Mag#/calc >/<	-5 000 000.0000...5 000 000.0000	0.0001	0.01	Pick-up magnitude
PS# Setting hysteresis Mag#	0.0000...50.0000%	0.0001%	3%	Setting hysteresis
Definite operating time delay	0.000...1800.000s	0.005s	0.04s	Delay setting
Release time delays	0.000...1800.000s	0.005s	0.06s	Pick-up release delay

## Comparator modes

When setting the comparators, the user must first choose a comparator mode.

Table. 4.4.2 - 62. Comparator modes

Mode	Description
Over >	<b>Greater than.</b> If the measured signal is greater than the set pick-up level, the comparison condition is fulfilled.
Over (abs) >	<b>Greater than (absolute).</b> If the absolute value of the measured signal is greater than the set pick-up level, the comparison condition is fulfilled.

Mode	Description
Under <	<b>Less than.</b> 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.
Under (abs) <	<b>Less than (absolute).</b> 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.
Delta set (%) +/- >	<b>Relative change over time.</b> 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.
Delta abs (%) >	<b>Relative change over time (absolute).</b> 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.
Delta +/- measval	<b>Change over time.</b> 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.
Delta abs measval	<b>Change over time (absolute).</b> 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.

### 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 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 "PSx" in event block names) generates events and registers from the status changes in the events listed below. 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.

The function's outputs can be used for direct I/O controlling and user logic programming. The function also provides a resettable cumulative counter for the START, TRIP and BLOCKED events.

Table. 4.4.2 - 63. Event messages.

Event block name	Event names
PSx	PS1...10 >/< Start ON
PSx	PS1...10 >/< Start OFF
PSx	PS1...10 >/< Trip ON
PSx	PS1...10 >/< Trip OFF
PSx	PS1...10 >/< Block ON
PSx	PS1...10 >/< 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. 4.4.2 - 64. Register content.

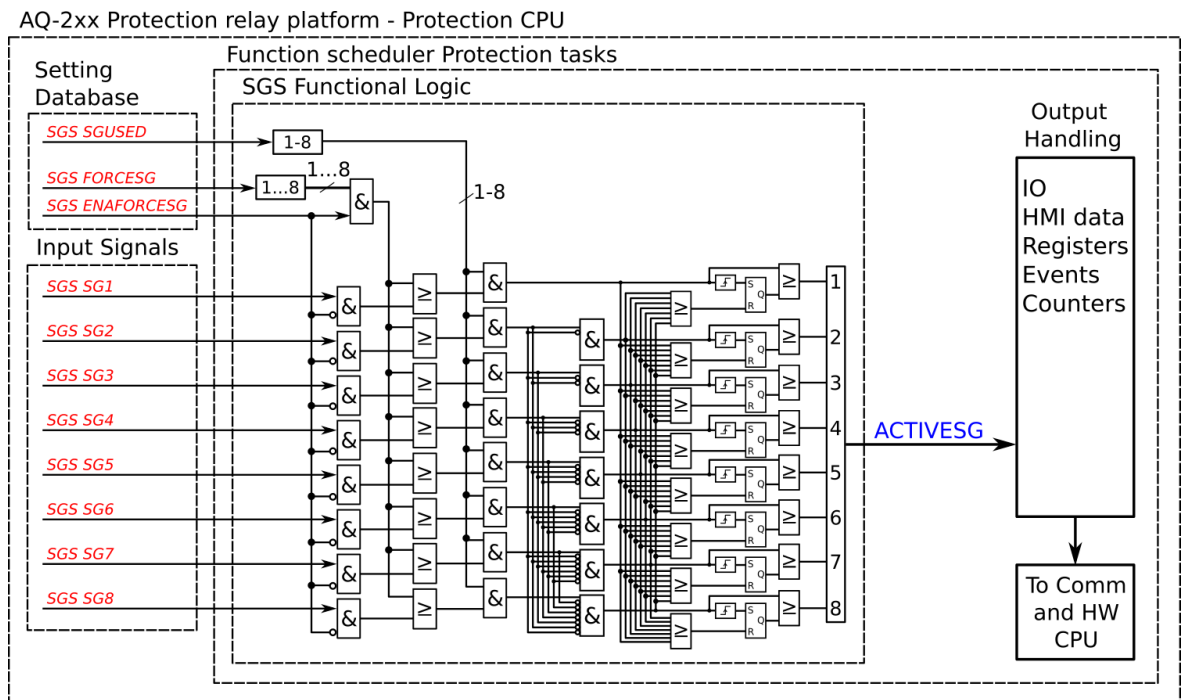
Register	Description
Date and time	dd.mm.yyyy hh:mm:ss.mss
Event	Event name
>/< Mag#	The numerical value of the magnitude
Mag#/Set#	Ratio between the measured magnitude and the pick-up setting
Trip time remaining	0 ms...1800s
Setting group in use	Setting group 1...8 active

## 4.5 Control functions

### 4.5.1 Setting group selection

All device 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.

Figure. 4.5.1 - 71. Simplified function block diagram of the setting group selection function.

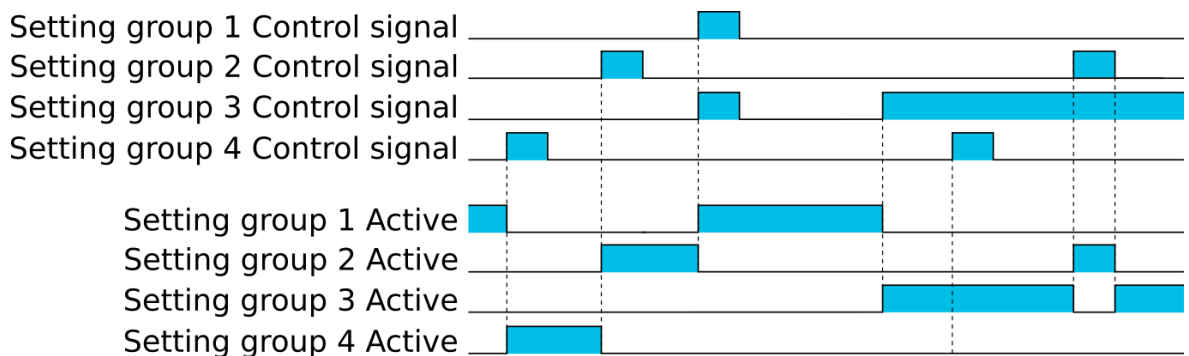


Setting group selection can be applied to each of the setting groups individually by activating one of the various internal logic inputs and connected digital inputs. The user can also force any of the setting groups on when the "Force SG change" setting is enabled by giving the wanted quantity of setting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

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

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

Figure. 4.5.1 - 72. 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. 4.5.1 - 65. Settings of the setting group selection function.

Name	Range	Default	Description
Active setting group	<ul style="list-style-type: none"> <li>• SG1</li> <li>• SG2</li> <li>• SG3</li> <li>• SG4</li> <li>• SG5</li> <li>• SG6</li> <li>• SG7</li> <li>• SG8</li> </ul>	SG1	Displays which setting group is active.
Force setting group	<ul style="list-style-type: none"> <li>• None</li> <li>• SG1</li> <li>• SG2</li> <li>• SG3</li> <li>• SG4</li> <li>• SG5</li> <li>• SG6</li> <li>• SG7</li> <li>• SG8</li> </ul>	None	The selection of the overriding setting group. After "Force SG change" is enabled, any of the configured setting groups in the device can be overridden. This control is always based on the pulse operating mode. It also requires that the selected setting group is specifically controlled to ON after "Force SG" is disabled. If there are no other controls, the last set setting group remains active.
Force setting group change	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Enabled</li> </ul>	Disabled	The selection of whether the setting group forcing is enabled or disabled. This setting has to be active before the setting group can be changed remotely or from a local HMI. This parameter overrides the local control of the setting groups and it remains on until the user disables it.
Used setting groups	<ul style="list-style-type: none"> <li>• SG1</li> <li>• SG1...2</li> <li>• SG1...3</li> <li>• SG1...4</li> <li>• SG1...5</li> <li>• SG1...6</li> <li>• SG1...7</li> <li>• SG1...8</li> </ul>	SG1	The selection of the activated setting groups in the application. Newly-enabled setting groups use default parameter values.
Remote setting group change	<ul style="list-style-type: none"> <li>• None</li> <li>• SG1</li> <li>• SG2</li> <li>• SG3</li> <li>• SG4</li> <li>• SG5</li> <li>• SG6</li> <li>• SG7</li> <li>• SG8</li> </ul>	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. 4.5.1 - 66. Signals of the setting group selection function.

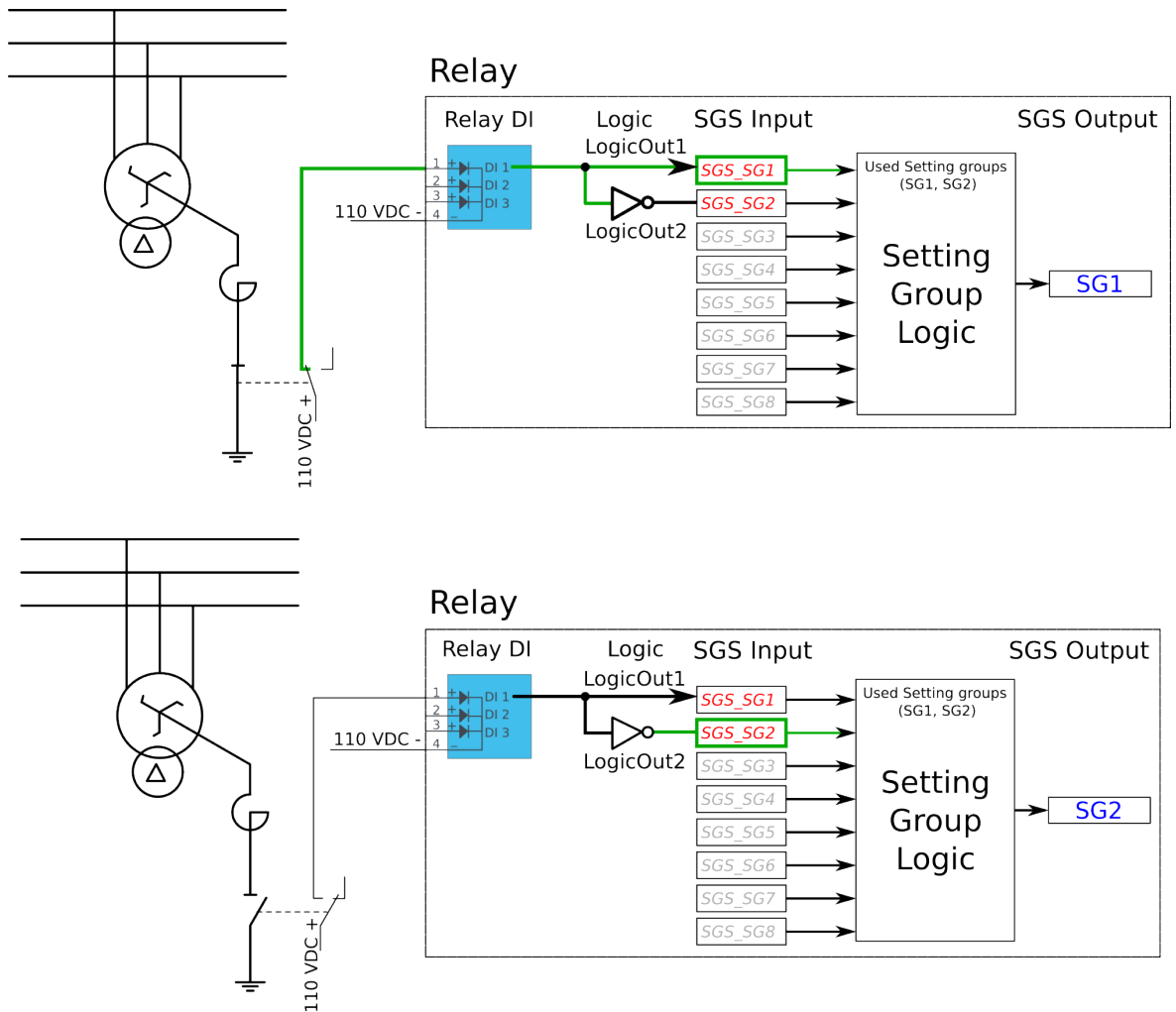
Name	Description
Setting group 1	The selection of Setting group 1 ("SG1"). Has the highest priority input in setting group control. Can be controlled with pulses or static signals. If static signal control is applied, no other SG requests will be processed.
Setting group 2	The selection of Setting group 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	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	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	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	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	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	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. 4.5.1 - 73. 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. 4.5.1 - 74. Setting group control – two-wire connection from Petersen coil status.

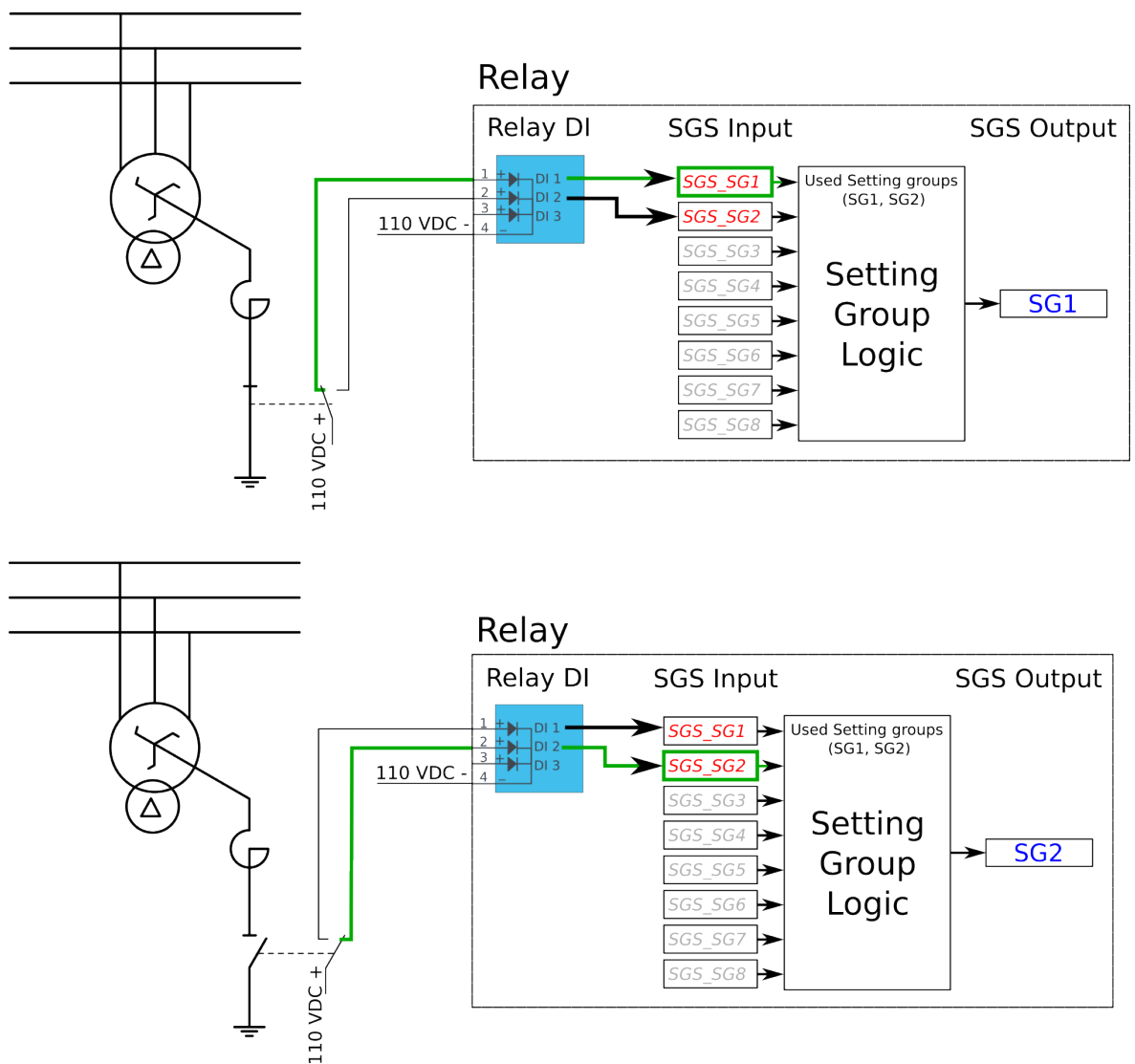
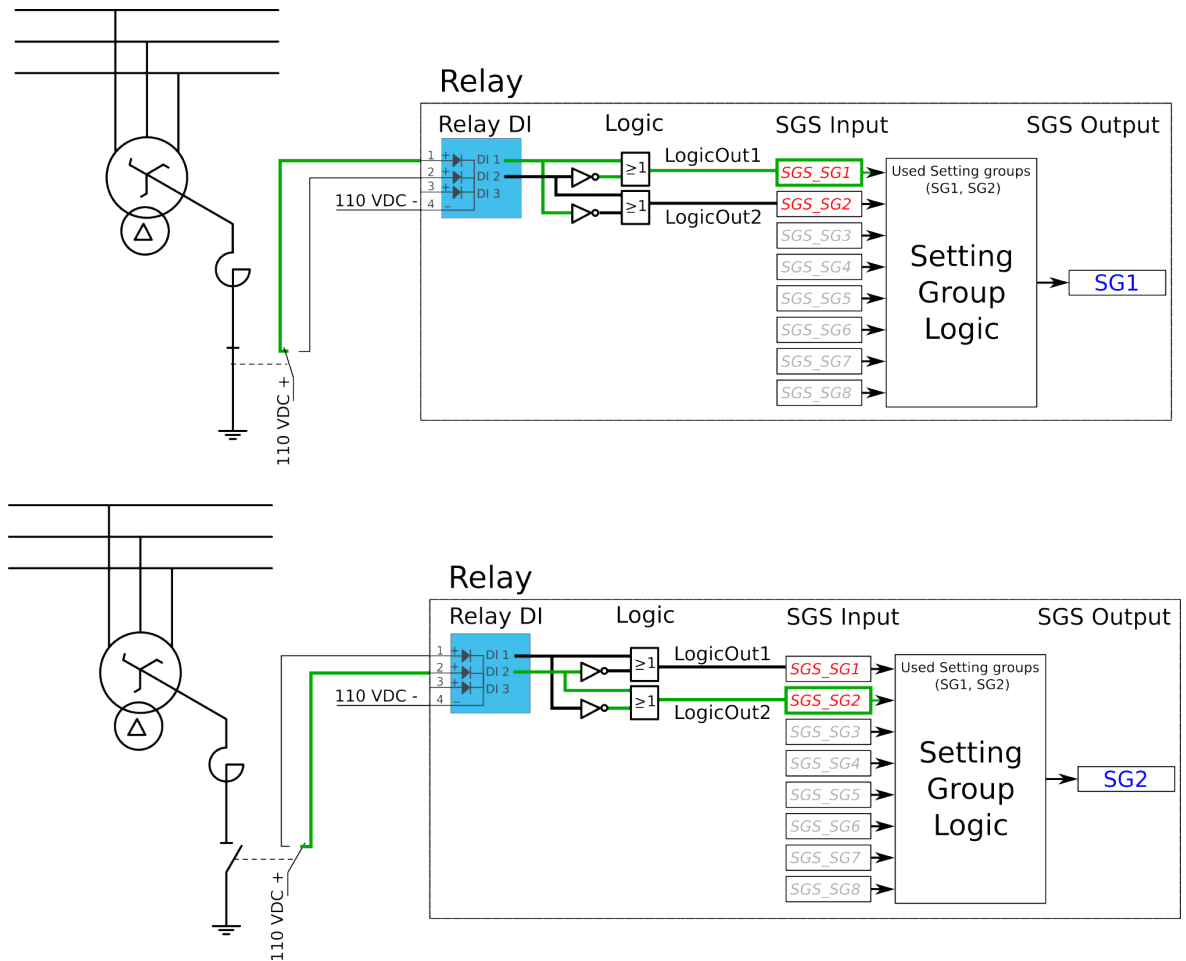


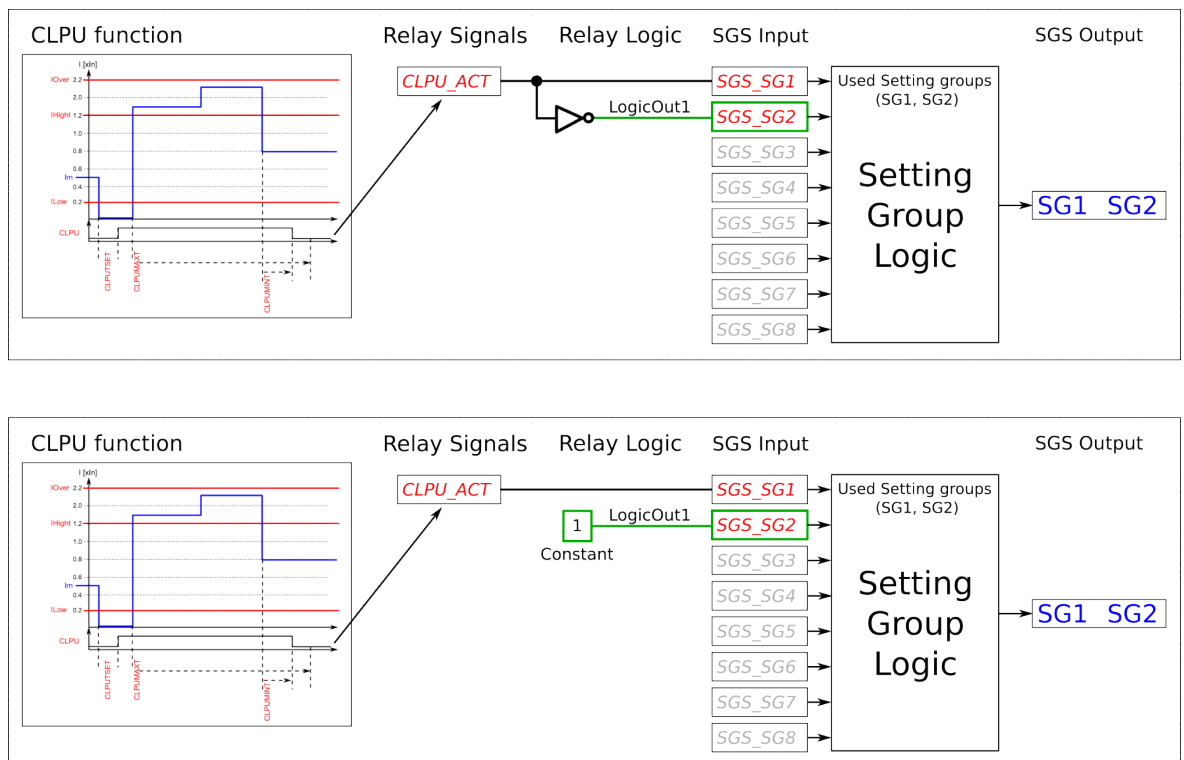
Figure. 4.5.1 - 75. Setting group control – two-wire connection from Petersen coil status with additional logic.



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 device's internal logics. For example, the setting group change can be based on the cold load pick-up function (see the image below).

Figure. 4.5.1 - 76. 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 device'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 the status changes in the events listed below. 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.

Table. 4.5.1 - 67. Event messages.

Event block name	Event names
SGS	SG2...8 Enabled
SGS	SG2...8 Disabled
SGS	SG1...8 Request ON
SGS	SG1...8 Request OFF
SGS	Remote Change SG Request ON

Event block name	Event names
SGS	Remote Change SG Request OFF
SGS	Local Change SG Request ON
SGS	Local Change SG Request OFF
SGS	Force Change SG ON
SGS	Force Change SG OFF
SGS	SG Request Fail Not configured SG ON
SGS	SG Request Fail Not configured SG OFF
SGS	Force Request Fail Force ON
SGS	Force Request Fail Force OFF
SGS	SG Req. Fail Lower priority Request ON
SGS	SG Req. Fail Lower priority Request OFF
SGS	SG1...8 Active ON
SGS	SG1...8 Active OFF

## 4.5.2 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.

Table. 4.5.2 - 68. Main settings (output channels).

Name	Range	Default	Description
mA option card 1	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Enabled</li> </ul>	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	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Disabled	Enables and disables the outputs of the mA output card 2.
	Enable mA output channels 7 and 8			

Table. 4.5.2 - 69. Settings for mA output channels.

Name	Range	Step	Default	Description
Enable mA output channel	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	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	<ul style="list-style-type: none"> <li>Currents</li> <li>Voltages</li> <li>Powers</li> <li>Impedance and admittance</li> <li>Other</li> </ul>	-	Currents	Defines the measurement category that is used for mA output control.
Magnitude of mA output channel	(dependent on the measurement category selection)	-	(dependent on the measurement category selection)	Defines the measurement magnitude used for mA output control. The available measurements depend on the selection of the "Magnitude selection for mA output channel" parameter.
Input value 1	$-10^7 \dots 10^7$	0.001	0	The first input point in the mA output control curve.
Scaled mA output value 1	0.0000...24.0000mA	0.0001mA	0mA	The mA output value when the measured value is equal to or less than Input value 1.
Input value 2	$-10^7 \dots 10^7$	0.001	1	The second input point in the mA output control curve.
Scaled mA output value 2	0.0000...24.0000mA	0.0001mA	0mA	The mA output value when the measured value is equal to or greater than Input value 2.

Figure. 4.5.2 - 77. Example of the effects of mA output channel settings.

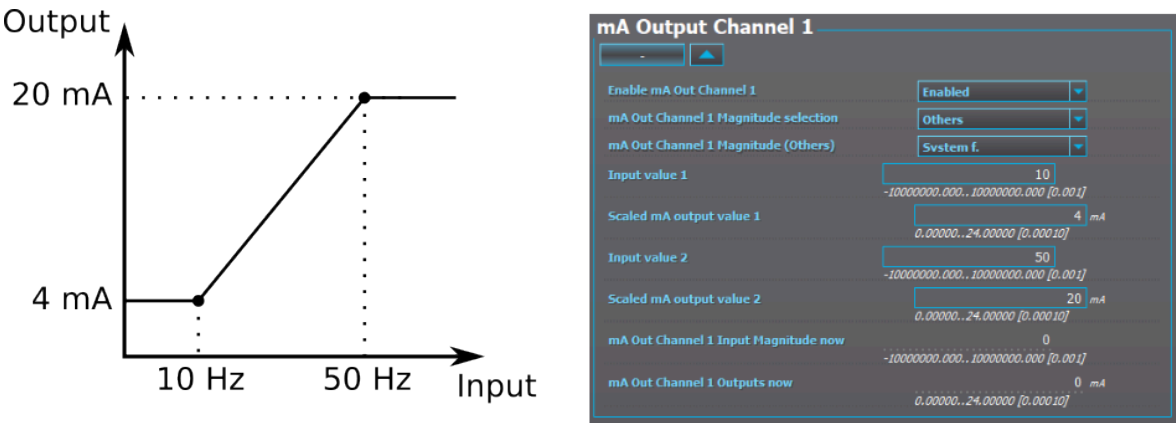


Table. 4.5.2 - 70. Hardware indications.

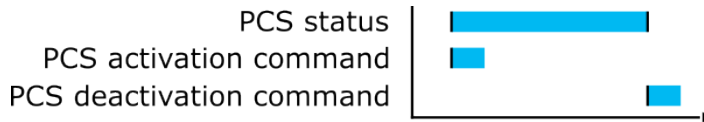
Name	Range	Description
Hardware in mA output channels 1...4	<ul style="list-style-type: none"><li>• None</li><li>• Slot A</li><li>• Slot B</li><li>• Slot C</li><li>• Slot D</li><li>• Slot E</li><li>• Slot F</li></ul>	Indicates the option card slot where the mA output card is located.
Hardware in mA output channels 5...8		

Table. 4.5.2 - 71. Measurement values reported by mA output cards.

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

### 4.5.3 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 device'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. 4.5.3 - 72. 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	<ul style="list-style-type: none"> <li>User</li> <li>Operator</li> <li>Configurator</li> <li>Super user</li> </ul>	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 the status changes in the events listed below. 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. The function offers five (5) independent switches. The function's output signals can be used for direct I/O controlling and user logic programming.

Table. 4.5.3 - 73. Event messages.

Event block name	Event names
PCS	Switch 1 ON
PCS	Switch 1 OFF
PCS	Switch 2 ON
PCS	Switch 2 OFF
PCS	Switch 3 ON
PCS	Switch 3 OFF
PCS	Switch 4 ON

Event block name	Event names
PCS	Switch 4 OFF
PCS	Switch 5 ON
PCS	Switch 5 OFF

#### 4.5.4 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 "4x mA output & 1x mA input" option cards
- mA input in "4x mA input & 1x mA output" option cards
- Digital input voltages

Table. 4.5.4 - 74. Main settings (input channel).

Name	Range	Step	Default	Description
Analog input scaling	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Activated</li> </ul>	-	Disabled	Enables and disables the input.
Scaling curve 1...10	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Activated</li> </ul>	-	Disabled	Enables and disables the scaling curve and the input measurement.



Name	Range	Step	Default	Description
Curve 1...10 input signal select	<ul style="list-style-type: none"> <li>• S7 mA Input</li> <li>• S8 mA Input</li> <li>• S15 mA Input</li> <li>• S16 mA Input</li> <li>• DI1...DI20 Voltage</li> <li>• RTD S1...S16 Resistance</li> <li>• mA In 1 (I card 1)</li> <li>• mA In 2 (I card 2)</li> <li>• mA In 1 (T card 1)</li> <li>• mA In 2 (T card 1)</li> <li>• mA In 3 (T card 1)</li> <li>• mA In 4 (T card 1)</li> <li>• mA In 1 (T card 2)</li> <li>• mA In 2 (T card 2)</li> <li>• mA In 3 (T card 2)</li> <li>• mA In 4 (T card 2)</li> </ul>	-	S7 mA Input	Defines the measurement used by scaling curve.
Curve 1...10 input signal filtering	<ul style="list-style-type: none"> <li>• No</li> <li>• Yes</li> </ul>	-	No	Enables calculation of the average of received signal.
Curve 1...10 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...10 input signal out of range set	<ul style="list-style-type: none"> <li>• No</li> <li>• Yes</li> </ul>	-	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...10 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...10 input	-1 000 000.00...1 000 000.00	0.00001	-	Displays the input measurement received by the curve.
Curve1...10 input maximum	-1 000 000.00...1 000 000.00	0.00001	0	Defines the maximum input of the curve. If input is above the set limit, "ASC1...4 input out of range" is activated.
Curve1...10 output	-1 000 000.00...1 000 000.00	0.00001	-	Displays the output of the curve.

The input signal filtering parameter 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...10 input out of range" signal, which can be used inside logic or with other functions of the device. 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.

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.

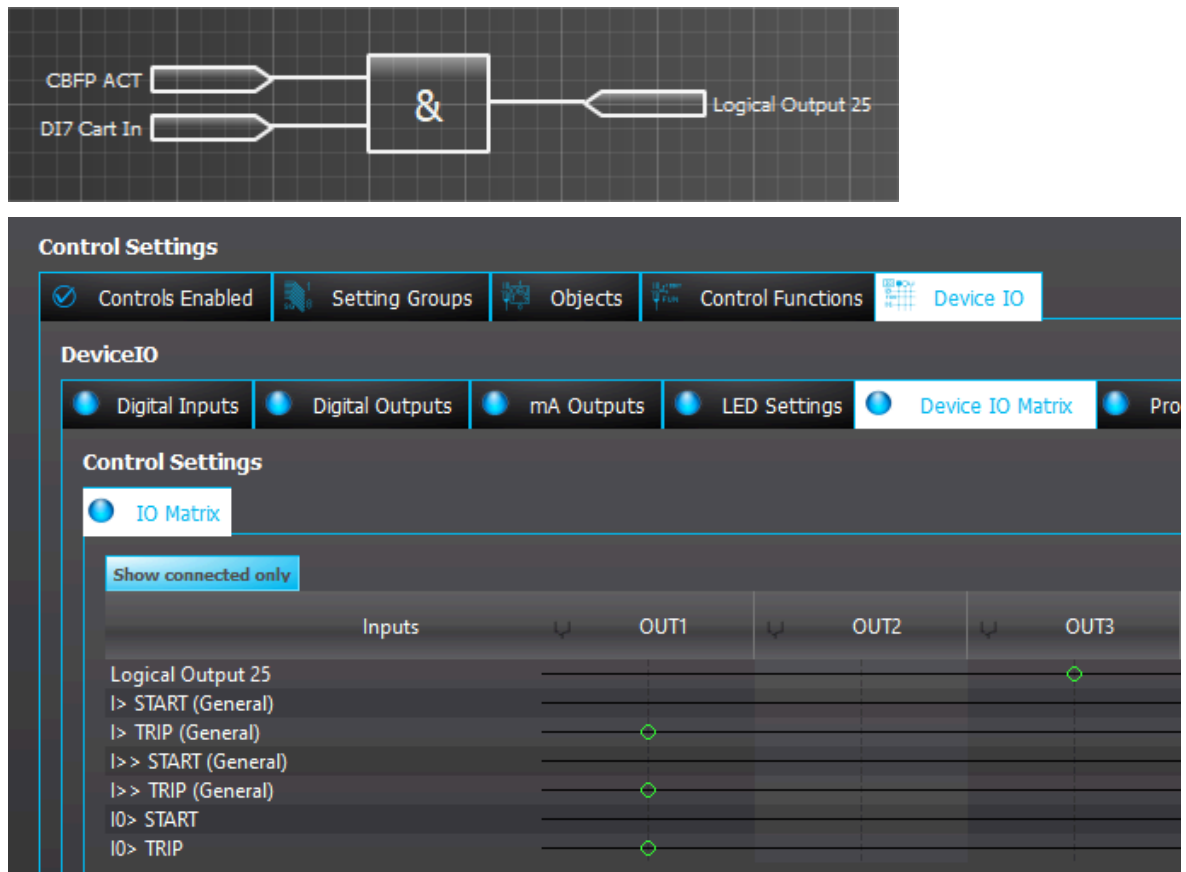
Table. 4.5.4 - 75. Output settings and indications.

Name	Range	Step	Default	Description
Curve 1...10 update cycle	5...10 000ms	5ms	150ms	Defines the length of the input measurement update cycle. If the user wants a fast operation, this setting should be fairly low.
Scaled value handling	<ul style="list-style-type: none"> <li>Floating point</li> <li>Integer out (Floor)</li> <li>Integer (Ceiling)</li> <li>Integer (Nearest)</li> </ul>	-	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	$-10^7 \dots 10^7$	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	$-10^7 \dots 10^7$	0.000 01	0	Scales the measured milliampere signal at Point 2.
Add curvepoint 3...20	<ul style="list-style-type: none"> <li>Not used</li> <li>Used</li> </ul>	-	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.

### 4.5.5 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. 32 logical outputs are available. The figure below presents a logic output example where a signal from the circuit breaker failure protection function controls the digital output relay number 3 ("OUT3") when the circuit breaker's cart status is "In".

Figure. 4.5.5 - 78. Logic output example. Logical output is connected to an output relay in matrix.



### Logical output descriptions

Logical outputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix
- block settings
- 
- 
- etc.

Table. 4.5.5 - 76. Logical output user description.

Name	Range	Default	Description
User editable description LO1...32	1...31 characters	Logical output 1...32	Description of the logical output. This description is used in several menu types for easier identification.

## Events

The logical outputs (abbreviated "LOGIC" in event block names) generates events from the status changes in the events listed below. 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. The function's output signals can be used for direct I/O controlling and user logic programming.

Table. 4.5.5 - 77. Event messages.

Event block name	Event names
LOGIC1	Logical out 1...32 ON
LOGIC1	Logical out 1...32 OFF

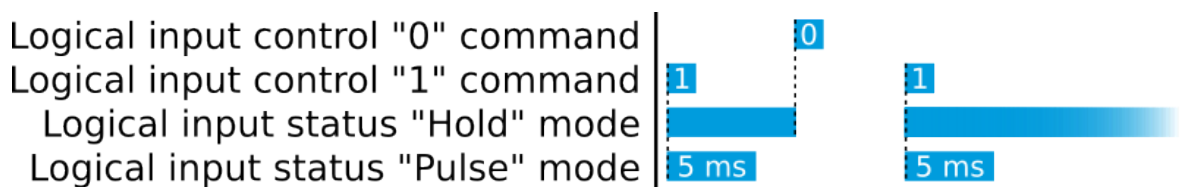
## 4.5.6 Logical inputs

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. Logical inputs are volatile signals: their status will always return to "0" when the AQ-200 device is rebooted. 32 logical inputs are available.

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.

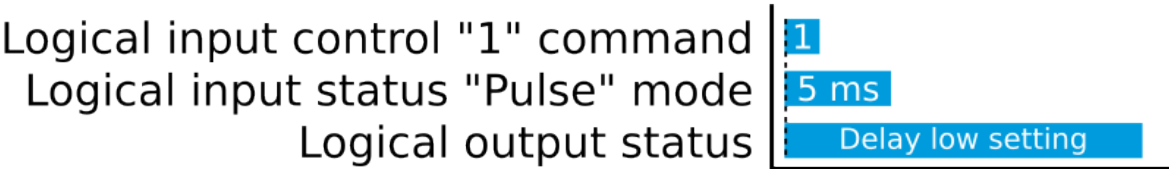
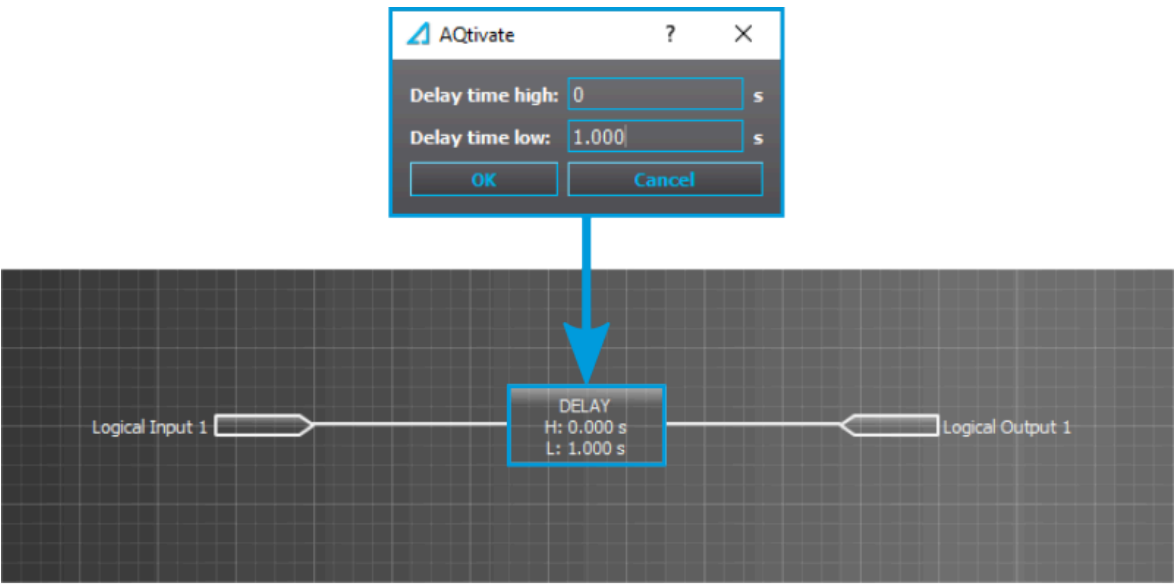
The figure below presents the operation of a logical input in Hold mode and in Pulse mode.

Figure. 4.5.6 - 79. 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. 4.5.6 - 80. Extending a logical input pulse.



Logical input descriptions

Logical inputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix
- block settings
- 
- 
- etc.

Table. 4.5.6 - 78. Logical input user description.

Name	Range	Default	Description
User editable description LI1...32	1...31 characters	Logical input 1...32	Description of the logical input. This description is used in several menu types for easier identification.

Events

The logical outputs (abbreviated "LOGIC" in event block names) generates events from the status changes in the events listed below. 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. The function's output signals can be used for direct I/O controlling and user logic programming.

Table. 4.5.6 - 79. Event messages.

Event block name	Event names
LOGIC2	Logical in 1...32 ON
LOGIC2	Logical in 1...32 OFF

## 4.6 Monitoring functions

### 4.6.1 Disturbance recorder (DR)

The disturbance recorder is a high-capacity (64 MB permanent flash memory) 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. Maximum capacity of recordings is 100.

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.

Table. 4.6.1 - 80. Analog recording channels.

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

Signal	Description
I02"f	Residual current I <sub>02</sub> fine* (CT card 2)
U1(2)VT1	Line-to-neutral U <sub>L1</sub> or line-to-line voltage U <sub>L12</sub> (VT card 1)
U2(3)VT1	Line-to-neutral U <sub>L2</sub> or line-to-line voltage U <sub>L23</sub> (VT card 1)
U3(1)VT1	Line-to-neutral U <sub>L3</sub> or line-to-line voltage U <sub>L31</sub> (VT card 1)
U0(ss)VT1	Zero sequence voltage U <sub>0</sub> or synchrocheck voltage U <sub>SS</sub> (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 1)
IL1""	Phase current I <sub>L1</sub> (CT card 3)
IL2""	Phase current I <sub>L2</sub> (CT card 3)
IL3""	Phase current I <sub>L3</sub> (CT card 3)
I01""c	Residual current I <sub>01</sub> coarse* (CT card 3)
I01""f	Residual current I <sub>01</sub> fine* (CT card 3)
I02""c	Residual current I <sub>02</sub> coarse* (CT card 3)
I02""f	Residual current I <sub>02</sub> fine* (CT card 3)
ISup_3	Current measurement module voltage supply supervision (CT card 3)
UL1(2)VT2	Line-to-neutral U <sub>L1</sub> or line-to-line voltage U <sub>L12</sub> (VT card 2)
UL2(3)VT2	Line-to-neutral U <sub>L2</sub> or line-to-line voltage U <sub>L23</sub> (VT card 2)
UL3(1)VT2	Line-to-neutral U <sub>L3</sub> or line-to-line voltage U <sub>L31</sub> (VT card 2)
U0(SS)VT2	Zero sequence voltage U <sub>0</sub> or synchrocheck voltage U <sub>SS</sub> (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. 4.6.1 - 81. 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. 4.6.1 - 82. Digital recording channels – Measurements.

Signal	Description	Signal	Description
<b>Currents</b>			
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)
<b>Voltages</b>			



Signal	Description	Signal	Description
Ux Volt p.u.	Ux voltage in per-unit values (U1, U2, U3, U4)	System volt ULxx mag	Magnitude of the system voltage ULxx (UL12, UL23, UL31)
Ux Volt pri	Primary Ux voltage (U1, U2, U3, U4)	System volt ULxx mag(kV)	Magnitude of the system voltage ULxx in kilovolts (UL12, UL23, UL31)
Ux Volt sec	Secondary Ux voltage (U1, U2, U3, U4)	System volt ULxx ang	Angle of the system voltage ULxx (UL12, UL23, UL31)
Ux Volt TRMS p.u.	Ux voltage TRMS in per-unit values (U1, U2, U3, U4)	System volt ULx mag	Magnitude of the system voltage ULx (U1, U2, U3, U4)
Ux Volt TRMS pri	Primary Ux voltage TRMS (U1, U2, U3, U4)	System volt ULx mag(kV)	Magnitude of the system voltage ULx in kilovolts (U1, U2, U3, U4)
Ux Volt TRMS sec	Secondary Ux voltage TRMS (U1, U2, U3, U4)	System volt ULx ang	Angle of the system voltage ULx (U1, U2, U3, U4)
Pos./Neg./Zero seq.Volt.p.u.	Positive/Negative/Zero sequence voltage in per-unit values	System volt U0 mag	Magnitude of the system voltage U0
Pos./Neg./Zero seq.Volt.pri	Primary positive/negative/zero sequence voltage	System volt U0 mag(kV)	Magnitude of the system voltage U0 in kilovolts
Pos./Neg./Zero seq.Volt.sec	Secondary positive/negative/zero sequence voltage	System volt U0 mag(%)	Magnitude of the system voltage U0 in percentages
Ux Angle	Ux angle (U1, U2, U3, U4)	System volt U0 ang	Angle of the system voltage U0
Pos./Neg./Zero Seq volt.Angle	Positive/Negative/Zero sequence voltage angle	Ux Angle difference	Ux angle difference (U1, U2, U3)
<b>Resistive and reactive currents</b>			
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)

Signal	Description	Signal	Description
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	Enablebasedfunctions(VT1)	Enable frequency-based functions
POW1 3PH Active power (P)	Three-phase active power	Track.sys.f.	Tracked system frequency
POW1 3PH Active power (P MW)	Three-phase active power in megawatts	Sampl.f. used	Used sample frequency
POW1 3PH Reactive power (Q)	Three-phase reactive power	Tr f CH x	Tracked frequency (channels A, B, C)
POW1 3PH Reactive power (Q MVar)	Three-phase reactive power in megavars	Alg f Fast	Fast frequency algorithm
POW1 3PH Tan(phi)	Three-phase tangent phi	Alg f avg	Average frequency algorithm
POW1 3PH Cos(phi)	Three-phase cosine phi	Frequency based protections blocked	When true ("1"), all frequency-based protections are blocked.
3PH PF	Three-phase power factor	f atm. Protections (when not measurable returns to nominal)	Frequency at the moment. If the system nominal is set to 50 Hz, this will show "50 Hz".
Neutral conductance G (Pri)	Primary neutral conductance	f atm. Display (when not measurable is 0 Hz)	Frequency at the moment. If the frequency is not measurable, this will show "0 Hz".
Neutral susceptance B (Pri)	Primary neutral susceptance	f meas qlty	Quality of tracked frequency

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

Table. 4.6.1 - 83. Digital recording channels – Binary signals.

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

**NOTICE!**

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. 4.6.1 - 84. Recorder control settings.

Name	Range	Description
Recorder enabled	<ul style="list-style-type: none"> <li>Enabled</li> <li>Disabled</li> </ul>	Enables and disables the disturbance recorder function.
Recorder status	<ul style="list-style-type: none"> <li>Recorder ready</li> <li>Recording triggered</li> <li>Recording and storing</li> <li>Storing recording</li> <li>Recorder full</li> <li>Wrong config</li> </ul>	Indicates the status of recorder.
Clear record+	0...2 <sup>32</sup> -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	<ul style="list-style-type: none"> <li>-</li> <li>Trig</li> </ul>	Triggers disturbance recording manually. This parameter will return back to "-" automatically.
Clear all records	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	Clears all disturbance recordings.
Clear newest record	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	Clears the newest stored disturbance recording.
Clear oldest record	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	Clears the oldest stored disturbance recording.
Max. number of recordings	0...100	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	Displays the maximum length of a single recording.
Max. location of the pre-trigger	0.000...1800.000s	Displays the highest pre-triggering time that can be set with the settings currently in use.
Recordings in memory	0...100	Displays how many recordings are stored in the memory.

Table. 4.6.1 - 85. 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. 4.6.1 - 86. Recorder settings.

Name	Range	Default	Description
Recording length	0.100...1800.000s	1s	Sets the length of a recording.
Recording mode	<ul style="list-style-type: none"> <li>FIFO</li> <li>Keep olds</li> </ul>	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	<ul style="list-style-type: none"> <li>64s/c</li> <li>32s/c</li> <li>16s/c</li> <li>8s/c</li> </ul>	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	0.2s	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	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Disabled	<p>Enables and disables the automatic transfer of recordings. The recordings are taken from the device's protection CPU and transferred to the device's FTP directory in the communication CPU; the FTP client then automatically loads the recordings from the device and transfers them further to the SCADA system.</p> <p>Please note that when this setting is enabled, all new disturbance recordings will be pushed to the FTP server of the device. 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 device, it is no longer accessible through setting tools <i>Disturbance recorder</i> → <i>Get DR files</i> command.</p>
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".

**NOTICE!**

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 device, the device automatically calculates and displays the total length of recordings. However, if the user wishes to confirm this calculation, they can do so with the following formula. Please note that the formula assumes there are no other files in the FTP that share the 64 MB space.

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

Where:

- total sample reserve = the number of samples available in the FTP when no other files are saved; calculated by dividing the total number of available bytes by 4 bytes (=the size of one sample); e.g. 64 306 588 bytes/4 bytes = 16 076 647 samples.
- $f_n$  = the nominal frequency (Hz).
- $Ch_{an}$  = the number of analog channels recorded; "+ 1" stands for the time stamp for each recorded sample.
- $SR$  = the selected sample rate (s/c).
- 200 Hz = the rate at which digital channels are always recorded, i.e. 5 ms.
- $Ch_{dig}$  = the number of digital channels recorded.

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

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

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

## Application example

This chapter presents an application example of how to set the disturbance recorder and analyze its output. The recorder is configured by using the setting tool software or device 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/](http://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  $\mu$ s)
- the analog channels 1...8 are used
- digital channels are tracked every 5 ms
- the first activation of the overcurrent stage trip ( $I > \text{TRIP}$ ) triggers the recorder
- the pre-triggering time is 5 (ie. how long is recorded before the  $I > \text{TRIP}$  signal) and the post-triggering time is 1 s

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

Figure. 4.6.1 - 81. Disturbance recorder settings.

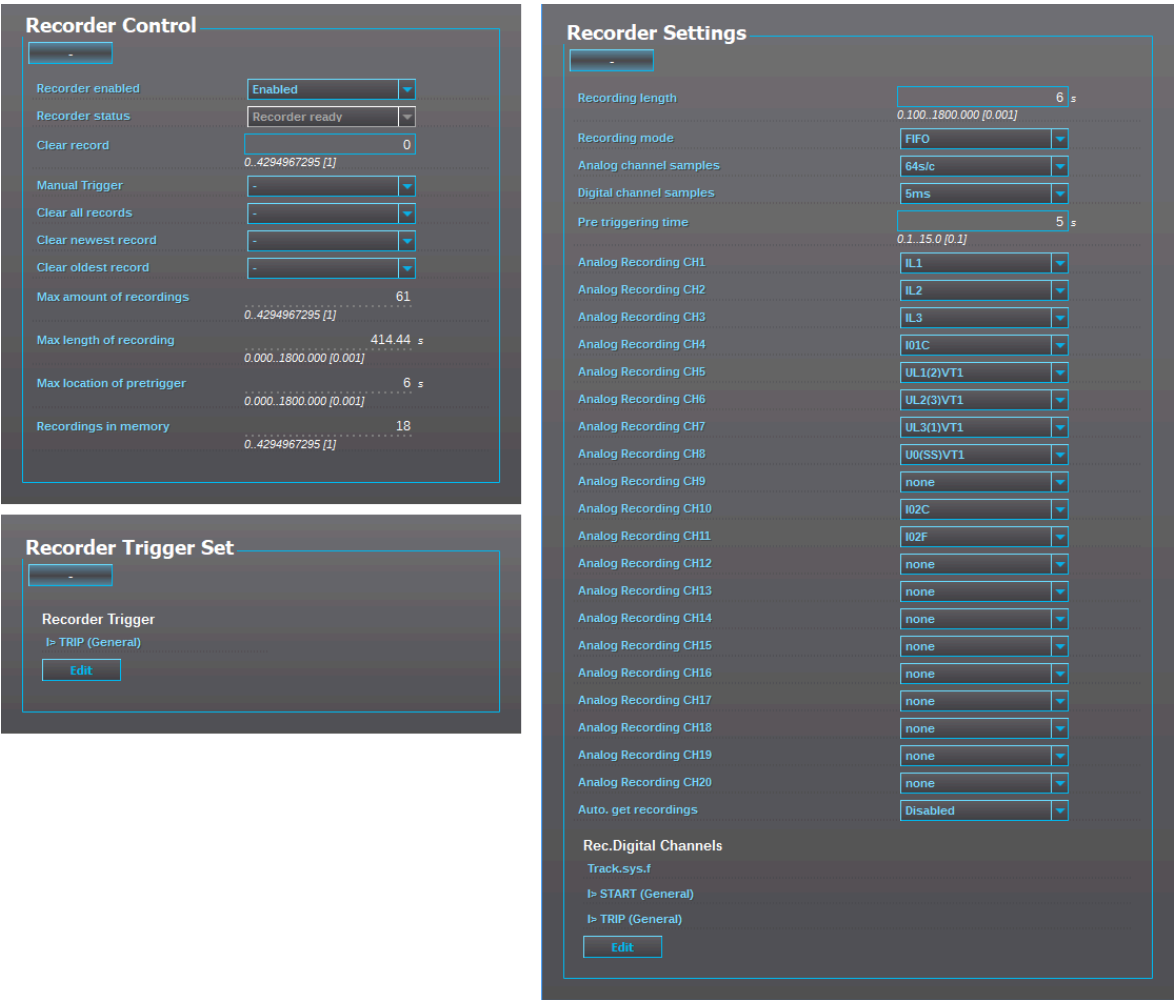
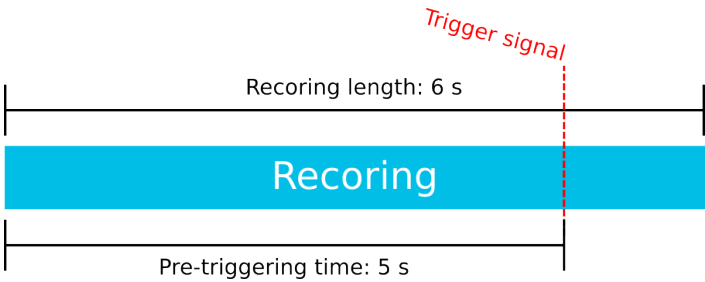
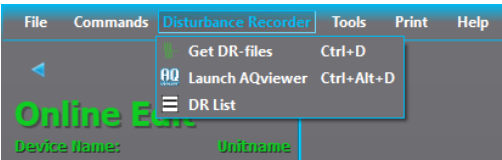


Figure. 4.6.1 - 82. Effects of recording length and pre-triggering time signals. This example is based on the settings shown above.



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 software instructions can be found in AQtivate 200 Instruction manual ([arcteq.fi/downloads/](http://arcteq.fi/downloads/)).

## Events

The disturbance recorder function (abbreviated "DR" in event block names) generates events and registers from the status changes in the events listed below. Events cannot be masked off. The events triggered by the function are recorded with a time stamp.

Table. 4.6.1 - 87. Event messages.

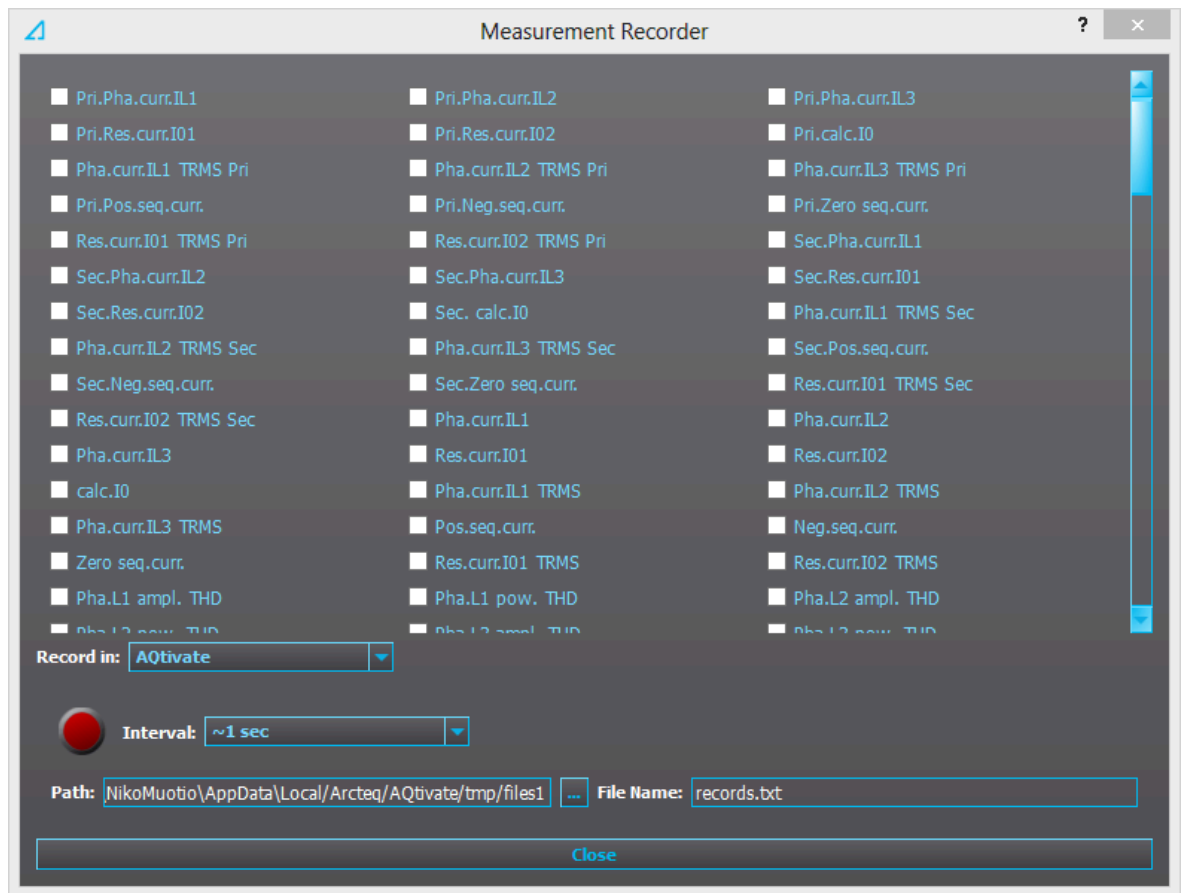
Event block name	Event names
DR1	Recorder triggered ON
DR1	Recorder triggered OFF
DR1	Recorder memory cleared
DR1	Oldest record cleared
DR1	Recorder memory full ON
DR1	Recorder memory full OFF
DR1	Recording ON
DR1	Recording OFF
DR1	Storing recording ON
DR1	Storing recording OFF
DR1	Newest record cleared

### 4.6.2 Event logger

Event logger records status changes of protection functions, digital inputs, logical signals etc. Events are recorded with a timestamp. The time stamp resolution is 1 ms. Up to 15 000 events can be stored at once. When 15 000 events have been recorded, the event history will begin to remove the oldest events to make room for new events. You can find more information about event masks in the selected function's "Events" tab. Event masks determine what is recorded into the event history; they are configured in each function's individual settings in the *Protection, Control and Monitoring* menu. Event history is accessible with PC setting tool (*Tools → Events and Logs → Event history*) and from the device HMI if "Events" view has been configured with Carousel designer in PC setting tool.



### 4.6.3 Measurement recorder



Measurements can be recorded to a file with the measurement recorder. The chosen measurements are recorded at selected intervals. In the "Measurement recorder" window, the measurements the user wants to be recorded can be selected by checking their respective check boxes. In order for the measurement recorder to activate, a connection to a device 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 device.

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 device, 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. 4.6.3 - 83. Measurement recorder values viewed with AQtivate PRO.

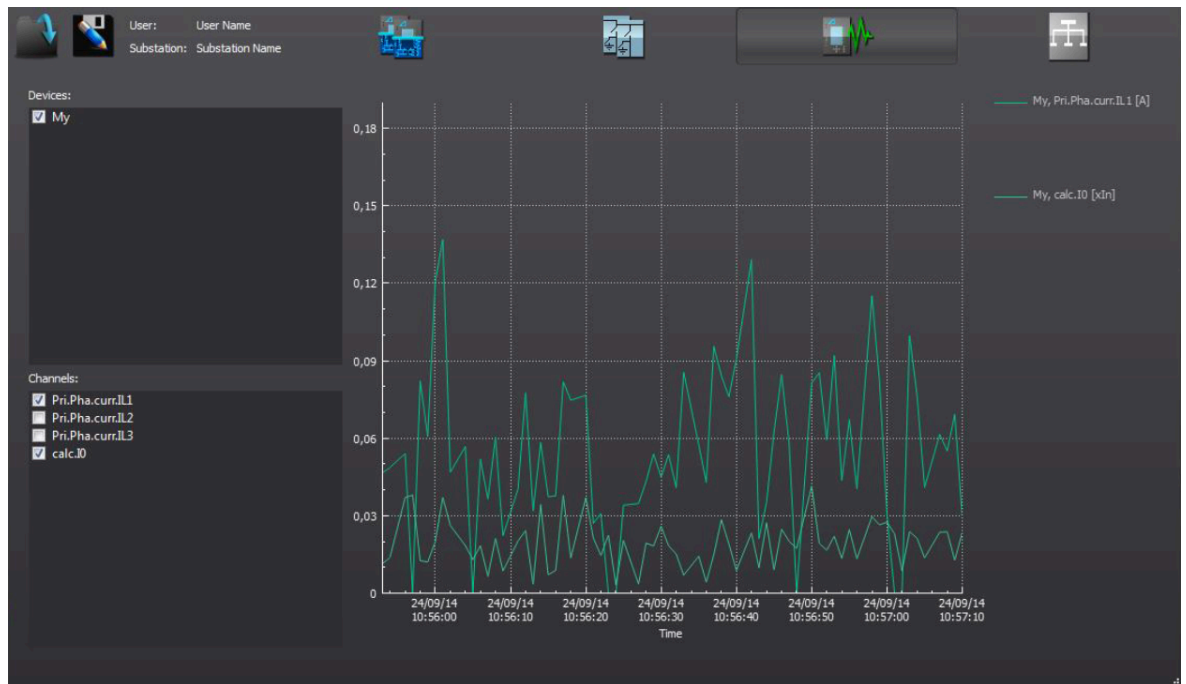


Table. 4.6.3 - 88. Available analog signals.

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.	<b>Voltage measurements</b>	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)	<b>Other measurements</b>
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	<b>Power measurements</b>	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	<b>Energy measurements</b>	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	

## 4.6.4 Running hour counter

The running hour counter (abbreviated "RHC" in event block names) is capable of counting the running time of a motor, a generator, or a similar application.

The counter value can be added to the mimic view and read to SCADA.

Table. 4.6.4 - 89. Parameter descriptions

Name	Range	Description
Activate counter input	Any binary input	Counter runs whenever input set here is active.
Running hours	hh:mm:ss	Indicates running hours counted so far. This value can be edited by the user. The user input must be set in seconds, which is then converted by the device to hours, minutes and seconds (hh:mm:ss).
Start count	0...4294967295 Starts	Start counter.
Clear hours	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	Clears "Running hours" and "Start count".

The function (abbreviated "RHC" in event block names) generates events from the status changes in the events listed below. 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.

Table. 4.6.4 - 90. Event messages.

Event block name	Event name
RHC1	Running hour counter ON
RHC1	Running hour counter OFF
RHC1	Running hour counter cleared ON

Event block name	Event name
RHC1	Running hour counter cleared OFF

## 5 Communication

### 5.1 Connections menu

"Connections" menu is found under "Communication" menu. It contains all basic settings of ethernet port and RS-485 serial port included with every AQ-200 device as well as settings of communication option cards.

Table. 5.1 - 91. Ethernet settings.

Name	Range	Description
IP address	0.0.0.0...255.255.255.255	Set IP address of the ethernet port in the back of the AQ-200 series device.
Netmask	0.0.0.0...255.255.255.255	Set netmask of the ethernet port in the back of the AQ-200 series device.
Gateway	0.0.0.0...255.255.255.255	Set gateway of the ethernet port in the back of the AQ-200 series device.
MAC-Address	00-00-00-00-00-00...FF-FF-FF-FF-FF-FF	Indication of MAC address of the AQ-200 series device.
Storm Protection	<ul style="list-style-type: none"> <li>Disable</li> <li>Enable</li> </ul>	When enabled, the Storm protection functionality of the internal switch in the device is enabled. This functionality aims to protect the device from excess ethernet traffic caused by storm situation. When enabled, the packet rate allowed to pass through on the ingress port towards the device, is limited to 150 packets per second. Multicast packets are also included in the packet limit.
Double Ethernet card mode	<ul style="list-style-type: none"> <li>Switch</li> <li>HSR</li> <li>PRP</li> </ul>	If the device has a double ethernet option card it is possible to choose its mode.
COM A and Ethernet option card connection	<ul style="list-style-type: none"> <li>Block all</li> <li>Allow both directions</li> <li>Allow COM A to option card</li> <li>Allow option card to COM A</li> </ul>	If the device has ethernet option card it is possible to determine the allowed direction of data.
Double Ethernet link events	<ul style="list-style-type: none"> <li>Disable</li> <li>Enable</li> </ul>	Disables or enables "Double Ethernet Link A down" and "Double Ethernet Link B down" logic signals and events.
Double Ethernet PRP ports	<ul style="list-style-type: none"> <li>AB</li> <li>BA</li> </ul>	LanA and LanB port assignment for communication cards that support PRP.

Virtual Ethernet enables the device to be connected to multiple different networks simultaneously via one physical Ethernet connection. Virtual Ethernet has its own separate IP address and network configurations. All Ethernet-based protocol servers listen for client connections on the IP addresses of both the physical Ethernet and the Virtual Ethernet.



Table. 5.1 - 92. Virtual Ethernet settings.

Name	Description
Enable virtual adapter (No / Yes)	Enable virtual adapter. Off by default.
IP address	Set IP address of the virtual adapter.
Netmask	Set netmask of the virtual adapter.
Gateway	Set gateway of the virtual adapter.

AQ-200 series devices are always equipped with an RS-485 serial port. In the software it is identified as "Serial COM1" port.

Table. 5.1 - 93. Serial COM1 settings.

Name	Range	Description
Bitrate	<ul style="list-style-type: none"> <li>9600bps</li> <li>19200bps</li> <li>38400bps</li> </ul>	Bitrate used by RS-485 port.
Databits	7...8	Databits used by RS-485 port.
Parity	<ul style="list-style-type: none"> <li>None</li> <li>Even</li> <li>Odd</li> </ul>	Paritybits used by RS-485 port.
Stopbits	1...2	Stopbits used by RS-485 port.
Protocol	<ul style="list-style-type: none"> <li>None</li> <li>ModbusRTU</li> <li>ModbusIO</li> <li>IEC103</li> <li>SPA</li> <li>DNP3</li> <li>IEC101</li> </ul>	Communication protocol used by RS-485 port.

AQ-200 series supports communication option card type that has serial fiber ports (Serial COM2) and RS-232 port (Serial COM3).

Table. 5.1 - 94. Serial COM2 settings.

Name	Range	Description
Bitrate	<ul style="list-style-type: none"> <li>9600bps</li> <li>19200bps</li> <li>38400bps</li> </ul>	Bitrate used by serial fiber channels.
Databits	7...8	Databits used by serial fiber channels.
Parity	<ul style="list-style-type: none"> <li>None</li> <li>Even</li> <li>Odd</li> </ul>	Paritybits used by serial fiber channels.
Stopbits	1...2	Stopbits used by serial fiber channels.

Name	Range	Description
Protocol	<ul style="list-style-type: none"> <li>None</li> <li>ModbusRTU</li> <li>ModbusIO</li> <li>IEC103</li> <li>SPA</li> <li>DNP3</li> <li>IEC101</li> </ul>	Communication protocol used by serial fiber channels.
Echo	<ul style="list-style-type: none"> <li>Off</li> <li>On</li> </ul>	Enable or disable echo.
Idle Light	<ul style="list-style-type: none"> <li>Off</li> <li>On</li> </ul>	Idle light behaviour.

Table. 5.1 - 95. Serial COM3 settings.

Name	Range	Description
Bitrate	<ul style="list-style-type: none"> <li>9600bps</li> <li>19200bps</li> <li>38400bps</li> </ul>	Bitrate used by RS-232 port.
Databits	7...8	Databits used by RS-232 port.
Parity	<ul style="list-style-type: none"> <li>None</li> <li>Even</li> <li>Odd</li> </ul>	Paritybits used by RS-232 port.
Stopbits	1...2	Stopbits used by RS-232 port.
Protocol	<ul style="list-style-type: none"> <li>None</li> <li>ModbusRTU</li> <li>ModbusIO</li> <li>IEC103</li> <li>SPA</li> <li>DNP3</li> <li>IEC101</li> </ul>	Communication protocol used by RS-232 port.

## 5.2 Time synchronization

Time synchronization source can be selected with "Time synchronization" parameter in the "General" menu.

Table. 5.2 - 96. General time synchronization source settings.

Name	Range	Description
Time synchronization source	<ul style="list-style-type: none"> <li>Internal</li> <li>External NTP</li> <li>External serial</li> <li>IRIG-B</li> <li></li> </ul>	Selection of time synchronization source.

## 5.2.1 Internal

If no external time synchronization source is available the mode should be set to "internal". This means that the AQ-200 device clock runs completely on its own. Time can be set to the device with AQtivate setting tool with *Commands* → *Sync Time* command or in the clock view from the HMI. When using *Sync time* command AQtivate sets the time to device the connected computer is currently using. Please note that the clock doesn't run when the device is powered off.

## 5.2.2 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. 5.2.2 - 97. 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. 5.2.2 - 98. Client settings.

Name	Range	Description
IP address	0.0.0.0...255.255.255.255	Defines the address of the NTP client. <b>NOTE:</b> This address must be different than the general IP address of the device.
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	00-00-00-00-00-00...FF-FF-FF-FF-FF-FF	Displays the MAC address of the client.
Network status	<ul style="list-style-type: none"> <li>Running</li> <li>IP error</li> <li>NM error</li> <li>GW error</li> </ul>	Displays the status or possible errors of the NTP (client) settings.

Table. 5.2.2 - 99. Status.

Name	Range	Description
NTP quality for events	<ul style="list-style-type: none"> <li>No sync</li> <li>Synchronized</li> </ul>	Displays the status of the NTP time synchronization at the moment. <b>NOTE:</b> This indication is not valid if another time synchronization method is used (external serial).

Name	Range	Description
NTP-processed message count	0...4294967295	Displays the number of messages processed by the NTP protocol.



**NOTICE!**

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

Additionally, the time zone of the device can be set by connecting to the device and the selecting the time zone at *Commands* → *Set time zone* in AQtivate setting tool.

## 5.3 Communication protocols

### 5.3.1 Fast Modbus/TCP

The fast Modbus/TCP is available as a part of the PMU functionality in the AQ-P215 model. The fast Modbus/TCP is designed to respond quickly to measured data, supporting only 64 configurable holding registers. All measurements are updated every 5 ms on Fast Modbus. Only Function code 3 ("Read holding registers") is supported. Other restrictions are described below.

#### Setting up the fast Modbus/TCP protocol

The fast Modbus/TCP protocol is set up at *PMU Functions* → *Fast Modbus/TCP*. The unit's fast Modbus/TCP application is run on a different CPU (the protection CPU) than the ordinary Modbus/TCP application (the communication CPU); therefore the user needs to configure another unique IP address and other network settings for this processor. The same physical Ethernet port is still used.

Table. 5.3.1 - 100. Settings.

Name	Range	Default	Description
Fast Modbus/TCP Enable	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Disabled	Enabled and disables the fast Modbus/TCP protocol.
IP port	0...65 535	502	Defines the TCP/IP port used by the server.
Fast Modbus/TCP Reconfigure	<ul style="list-style-type: none"> <li>-</li> <li>Reconfigure</li> </ul>	-	Reconfigures the fast Modbus/TCP protocol after the Modbus map has been changed.

Table. 5.3.1 - 101. CPU settings.

Name	Range	Default	Description
IP address	-	10.0.0.1	Defines the IP address of the fast Modbus/TCP interface.
Netmask	-	255.255.255.0	Defines the netmask of fast Modbus/TCP interface.
Gateway	-	10.0.0.254	Defines the gateway of fast Modbus/TCP interface.
MAC address	-	00-01-02-03-04-05	Displays the MAC address of fast Modbus/TCP interface.

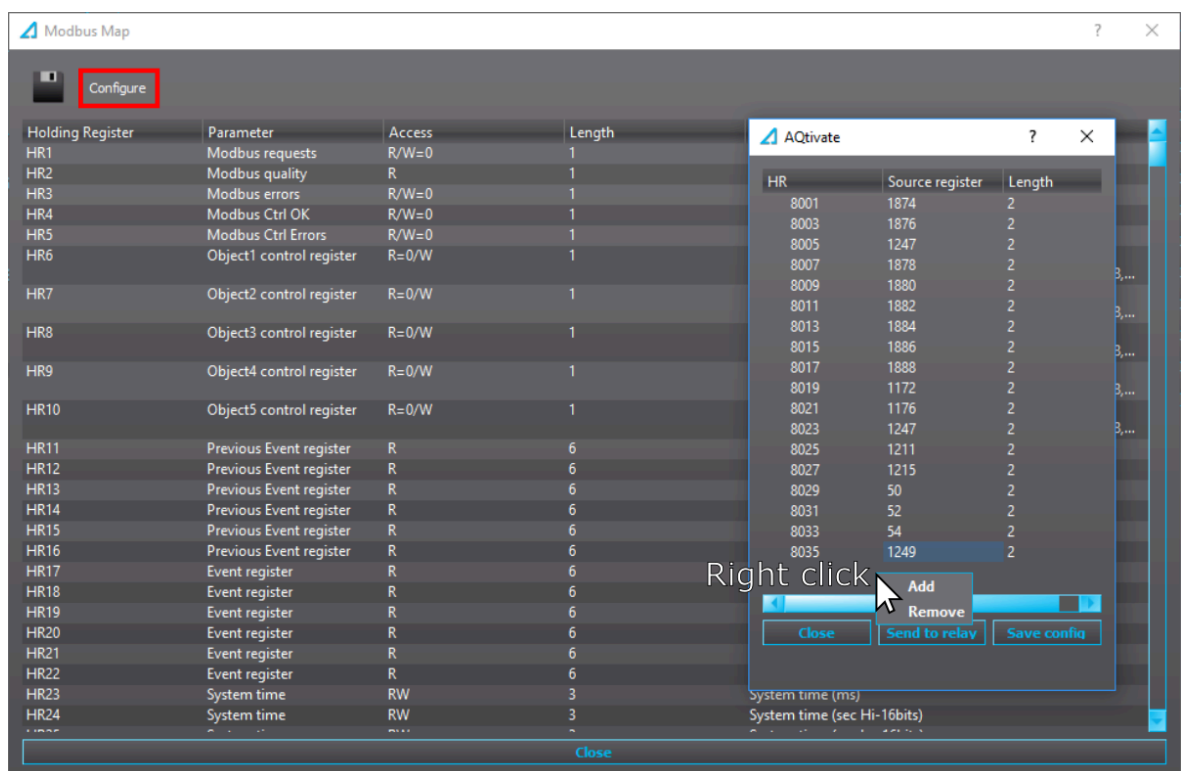
Name	Range	Default	Description
Network status	<ul style="list-style-type: none"> <li>Running</li> <li>IP error</li> <li>NM error</li> <li>GW error</li> </ul>	-	Indicates the status of the interface.

Please note that changing the Network settings for this interface requires a full system reset to be performed after the change. This can be done at *Monitoring* → *Device Diagnostics* → "System full reset".

### Resctrictions of the fast Modbus/TCP protocol

- Only 64 holding registers (starting from HR8001) can be configured.
- Only Function code 3 ("Read holding registers") is supported. If other functions are required, a normal Modbus/TCP application can be used.
- Only one client connection for the fast Modbus/TCP is allowed.
- Holding registers <HR26 of the static map cannot be mirrored to the fast Modbus/TCP registers.
- Every item mapped to the fast Modbus/TCP registers uses 32 bits (= 2 holding registers/item).

### Configuration of the fast Modbus/TCP protocol



The fast Modbus/TCP application uses the same configuration dialog as the regular Modbus/TCP application. Holding registers (starting from HR8001) can be configured to the mirror registers of the static Modbus map. To add configurable holding registers, right-click on the window and click "Add".

### 5.3.2 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 IEC 61850. The following services are supported by IEC 61850 in Arcteq devices:

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

The device's current IEC 61850 setup can be viewed and edited with the IEC61850 tool (*Tools* → *Communication* → *IEC 61850*).

## 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. 5.3.2 - 102. General settings.

Name	Range	Step	Default	Description
Enable IEC 61850	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Enabled</li> </ul>	-	Disabled	Enables and disables the IEC 61850 communication protocol.
Reconfigure IEC 61850	<ul style="list-style-type: none"> <li>• -</li> <li>• Reconfigure</li> </ul>	-	-	Reconfigures IEC 61850 settings.
IP port	0...65 535	1	102	Defines the IP port used by the IEC 61850 protocol. The standard (and default) port is 102.
Control Authority switch	<ul style="list-style-type: none"> <li>• Remote Control</li> <li>• Station Level Control</li> </ul>	-	Remote Control	The device can be set to allow object control via IEC 61850 only from clients that are of category Station level control. This would mean that other Remote control clients would not be allowed to control. In Remote control mode all IEC 61850 clients of both remote and station level category are allowed to control objects.
Ethernet port	<ul style="list-style-type: none"> <li>• All</li> <li>• COM A</li> <li>• Double ethernet card</li> </ul>	-	All	Determines which ports use IEC61850. Parameter is visible if double ethernet option card is found in the device.
General deadband	0.1...10.0 %	0.1 %	2 %	Determines the general data reporting deadband settings.
Active energy deadband	0.1...1000.0 kWh	0.1 kWh	2 kWh	Determines the data reporting deadband settings for this measurement.
Reactive energy deadband	0.1...1000.0 kVar	0.1 kVar	2 kVar	Determines the data reporting deadband settings for this measurement.
Active power deadband	0.1...1000.0 kW	0.1 kW	2 kW	Determines the data reporting deadband settings for this measurement.
Reactive power deadband	0.1...1000.0 kVar	0.1 kVar	2 kVar	Determines the data reporting deadband settings for this measurement.

Name	Range	Step	Default	Description
Apparent power deadband	0.1...1000.0 kVA	0.1 kVA	2 kVA	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...1.00 Hz	0.01 Hz	0.1 Hz	Determines the data reporting deadband settings for this measurement.
Current deadband	0.01...50.00 A	0.01 A	5 A	Determines the data reporting deadband settings for this measurement.
Residual current deadband	0.01...50.00 A	0.01 A	0.2 A	Determines the data reporting deadband settings for this measurement.
Voltage deadband	0.01...5000.00 V	0.01 V	200 V	Determines the data reporting deadband settings for this measurement.
Residual voltage deadband	0.01...5000.00 V	0.01 V	200 V	Determines the data reporting deadband settings for this measurement.
Angle measurement deadband	0.1...5.0 deg	0.1 deg	1 deg	Determines the data reporting deadband settings for this measurement.
Integration time	0...10 000 ms	1 ms	0 ms	Determines the integration time of the protocol. If this parameter is set to "0 ms", no integration time is in use.
GOOSE Ethernet port	<ul style="list-style-type: none"> <li>All</li> <li>COM A</li> <li>Double ethernet card</li> </ul>	-	All	Determines which ports can use GOOSE communication. Visible if double ethernet option card is found in the device.

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

### 5.3.2.1 GOOSE

Arcteq devices 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 status is "low" (that is, when the quality is marked as "0"). The value of the input quality can switch on 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.

These settings can be found from *Communication* → *Protocols* → *IEC61850*.

Table. 5.3.2.1 - 103. GOOSE input settings.

Name	Range	Description
In use	<ul style="list-style-type: none"> <li>No (Default)</li> <li>Yes</li> </ul>	Enables and disables the GOOSE input in question.
Application ID ("AppID")	0x0...0x3FFF	Defines the application ID that will be matched with the publisher's GOOSE control block.
Configuration revision ("ConfRev")	1...2 <sup>32</sup> -1	Defines the configuration revision that will be matched with the publisher's GOOSE control block.
Data index ("DataIdx")	0...99	Defines the data index of the value in the matched published frame. It is the status of the GOOSE input.
NextIdx is quality	<ul style="list-style-type: none"> <li>No (Default)</li> <li>Yes</li> </ul>	Selects whether or not the next received input is the quality bit of the GOOSE input.

## GOOSE input descriptions

Each of the GOOSE inputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix
- block settings
- 
- 
- etc.

These settings can be found from *Control → Device IO → Logical Signals → GOOSE IN Description*.

Table. 5.3.2.1 - 104. GOOSE input user description.

Name	Range	Default	Description
User editable description GI x	1...31 characters	GOOSE IN x	Description of the GOOSE input. This description is used in several menu types for easier identification.

## GOOSE events

GOOSE signals generate events from status changes. 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. The time stamp resolution is 1 ms.

Table. 5.3.2.1 - 105. GOOSE event

Event block name	Event name	Description
GOOSE1...GOOSE2	GOOSE IN 1...64 ON/OFF	Status change of GOOSE input.
GOOSE3...GOOSE4	GOOSE IN 1...64 quality Bad/Good	Status change of GOOSE inputs quality.



## 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.

### 5.3.3 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 device via the AQtivate software (*Tools* → *Communication* → *Modbus Map*). 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 device and the master. Modbus map can be edited with Modbus Configurator (*Tools* → *Communication* → *Modbus Configurator*).

Table. 5.3.3 - 106. Modbus/TCP settings.

Parameter	Range	Description
Enable Modbus/TCP	<ul style="list-style-type: none"> <li>• Disabled</li> <li>• Enabled</li> </ul>	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	<ul style="list-style-type: none"> <li>• Get oldest available</li> <li>• Continue previous connection</li> <li>• New events only</li> </ul>	Get oldest event possible (Default) Continue with the event idx from previous connection Get only new events from connection time and forward.

Table. 5.3.3 - 107. Modbus/RTU settings.

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

## Reading events

Modbus protocol does not support time-stamped events by standard definition. This means that every vendor must come up with their own definition how to transfer events from the device to the client. In AQ-200 series devices events can be read from HR17...HR22 holding registers. HR17 contains the event-code, HR18...20 contains the time-stamp in UTC, HR21 contains a sequential index and HR22 is reserved for future expansion. See the Modbus Map for more information. The event-codes and their meaning can be found from Event list (*Tools* → *Events ang Logs* → *Event list* in setting tool). The event-code in HR17 is 0 if no new events can be found in the device event-buffer. Every time HR17 is read from client the event in event-buffer is consumed and on following read operation the next un-read event information can be found from event registers. HR11...HR16 registers contains a back-up of last read event. This is because some users want to double-check that no events were lost

### 5.3.4 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 AQ-200 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 device 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...60 000 ms	1 ms	2000 ms	Defines the interval for the measurements update.

### 5.3.5 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/](http://www.arcteq.fi/downloads/) → AQ-200 series → Resources → "AQ-200 IEC101 & IEC104 interoperability").

## IEC 101 settings

Table. 5.3.5 - 108. 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.

Name	Range	Step	Default	Description
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. 5.3.5 - 109. IEC 104 settings.

Name	Range	Step	Default	Description
IEC 104 enable	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	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.
APDU timeout (t1)	0...3600 s	1 s	0 s	The maximum amount of time the slave waits for a transmitted Application Protocol Data Unit (APDU) to be confirmed as received by the master.
Idle timeout (t3)	0...3600 s	1 s	0 s	The slave outstation can use a test frame to determine if the channel is still available after a prolonged period of communications inactivity. Test frame is sent at an interval specified here.

## Measurement scaling coefficients

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

Table. 5.3.5 - 110. Measurements with scaling coefficient settings.

Name	Range
Active energy	<ul style="list-style-type: none"> <li>• No scaling</li> <li>• 1/10</li> <li>• 1/100</li> <li>• 1/1000</li> <li>• 1/10 000</li> <li>• 1/100 000</li> <li>• 1/1 000 000</li> <li>• 10</li> <li>• 100</li> <li>• 1000</li> <li>• 10 000</li> <li>• 100 000</li> <li>• 1 000 000</li> </ul>
Reactive energy	
Active power	
Reactive power	
Apparent power	
Power factor	
Frequency	
Current	
Residual current	
Voltage	
Residual voltage	
Angle	

### Deadband settings.

Table. 5.3.5 - 111. 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	
Active power deadband	0.1...1000.0kW	0.1kW	2kW	
Reactive power deadband	0.1...1000.0kVar	0.1kVar	2kVar	
Apparent power deadband	0.1...1000.0kVA	0.1kVA	2kVA	
Power factor deadband	0.01...0.99	0.01	0.05	
Frequency deadband	0.01...1.00Hz	0.01Hz	0.1Hz	
Current deadband	0.01...50.00A	0.01A	5A	
Residual current deadband	0.01...50.00A	0.01A	0.2A	
Voltage deadband	0.01...5000.00V	0.01V	200V	

Name	Range	Step	Default	Description
Residual voltage deadband	0.01...5000.00V	0.01V	200V	
Angle measurement deadband	0.1...5.0deg	0.1deg	1deg	
Integration time	0...10 000ms	1ms	-	Determines the integration time of the protocol. If this parameter is set to "0 ms", no integration time is in use.

### 5.3.6 SPA

The device can act as a SPA slave. SPA can be selected as the communication protocol for the RS-485 port (Serial COM1). When the device has a serial option card, the SPA protocol can also be selected as the communication protocol for the serial fiber (Serial COM2) ports or RS-232 (Serial COM3) port. 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*.

Table. 5.3.6 - 112. SPA setting parameters.

Name	Range	Description
SPA address	1...899	SPA slave address.
UTC time sync	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	Determines if UTC time is used when synchronizing time. When disabled it is assumed time synchronization uses local time. If enabled it is assumed that UTC time is used. When UTC time is used the timezone must be set at <i>Commands</i> → <i>Set time zone</i> .



#### NOTICE!

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

### 5.3.7 DNP3

DNP3 is a protocol standard which is controlled by the DNP Users Group ([www.dnp.org](http://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/](http://www.arcteq.fi/downloads/) → AQ-200 series → Resources).

#### Settings

The following table describes the DNP3 setting parameters.

Table. 5.3.7 - 113. Settings.

Name	Range	Step	Default	Description
Enable DNP3 TCP	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Enables and disables the DNP3 TCP communication protocol when the Ethernet port is used for DNP3. If a serial port is used, the DNP3 protocol can be enabled from <i>Communication</i> → <i>DNP3</i> .
IP port	0...65 535	1	20 000	Defines the IP port used by the protocol.
Slave address	1...65 519	1	1	Defines the DNP3 slave address of the unit.
Master address	1...65 534	1	2	Defines the address for the allowed master.
Link layer time-out	0...60 000ms	1ms	0ms	Defines the length of the time-out for the link layer.
Link layer retries	1...20	1	1	Defines the number of retries for the link layer.
Diagnostic - Error counter	0...2 <sup>32</sup> -1	1	-	Counts the total number of errors in received and sent messages.
Diagnostic - Transmitted messages	0...2 <sup>32</sup> -1	1	-	Counts the total number of transmitted messages.
Diagnostic - Received messages	0...2 <sup>32</sup> -1	1	-	Counts the total number of received messages.

## Default variations

Table. 5.3.7 - 114. Default variations.

Name	Range	Default	Description
Group 1 variation (BI)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> </ul>	Var 1	Selects the variation of the binary signal.
Group 2 variation (BI change)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> </ul>	Var 2	Selects the variation of the binary signal change.
Group 3 variation (DBI)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> </ul>	Var 1	Selects the variation of the double point signal.
Group 4 variation (DBI change)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> </ul>	Var 2	Selects the variation of the double point signal.
Group 20 variation (CNTR)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> <li>Var 5</li> <li>Var 6</li> </ul>	Var 1	Selects the variation of the control signal.

Name	Range	Default	Description
Group 22 variation (CNTR change)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> <li>Var 5</li> <li>Var 6</li> </ul>	Var 5	Selects the variation of the control signal change.
Group 30 variation (AI)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> <li>Var 3</li> <li>Var 4</li> <li>Var 5</li> </ul>	Var 5	Selects the variation of the analog signal.
Group 32 variation (AI change)	<ul style="list-style-type: none"> <li>Var 1</li> <li>Var 2</li> <li>Var 3</li> <li>Var 4</li> <li>Var 5</li> <li>Var 7</li> </ul>	Var 5	Selects the variation of the analog signal change.

## Setting the analog change deadbands

Table. 5.3.7 - 115. 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	
Active power deadband	0.1...1000.0kW	0.1kW	2kW	
Reactive power deadband	0.1...1000.0kVar	0.1kVar	2kVar	
Apparent power deadband	0.1...1000.0kVA	0.1kVA	2kVA	
Power factor deadband	0.01...0.99	0.01	0.05	
Frequency deadband	0.01...1.00Hz	0.01Hz	0.1Hz	
Current deadband	0.01...50.00A	0.01A	5A	
Residual current deadband	0.01...50.00A	0.01A	0.2A	
Voltage deadband	0.01...5000.00V	0.01V	200V	
Residual voltage deadband	0.01...5000.00V	0.01V	200V	
Angle measurement deadband	0.1...5.0deg	0.1deg	1deg	

Name	Range	Step	Default	Description
Integration time	0...10 000ms	1ms	0ms	Determines the integration time of the protocol. If this parameter is set to "0 ms", no integration time is in use.

### 5.3.8 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. 5.3.8 - 116. 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	<ul style="list-style-type: none"> <li>ADAM-4018+</li> <li>ADAM-4015</li> </ul>	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. 5.3.8 - 117. Channel settings.

Name	Range	Step	Default	Description
Thermocouple type	<ul style="list-style-type: none"> <li>+/- 20mA</li> <li>4...20mA</li> <li>Type J</li> <li>Type K</li> <li>Type T</li> <li>Type E</li> <li>Type R</li> <li>Type S</li> </ul>	-	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	<ul style="list-style-type: none"> <li>Invalid</li> <li>OK</li> </ul>	-	-	Displays the input status of the selected channel.

## 5.4 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. 5.4 - 118. Fault register settings.

Name	Range	Step	Default	Description
Select record source	Not in use I>, I>>, I>>>, I>>>> (IL1, IL2, IL3) Id>, Id>>, Id>>>, Id>>>> (IL1, IL2, IL3) IO>, IO>>, IO>>>, IO>>>> (IO) IOd>, IOd>>, IOd>>>, IOd>>>> (IO) FLX (Fault locator)	-	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	<ul style="list-style-type: none"> <li>TRIP signal</li> <li>START signal</li> <li>START and TRIP signals</li> </ul>	-	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.

## 5.5 Real-time measurements to communication

With the *Real-time signals to communication* menu the user can report measurements to SCADA in a faster interval. The real measurement update delay depends on the used communication protocol and equipment used. Up to ten (10) 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 device uses these values as the basis when it calculates the primary and secondary values of currents, voltages, powers, impedances and other values.

Table. 5.5 - 119. Available measured values.

Signals	Description
Currents	
IL1 (ff), IL2 (ff), IL3 (ff), IO1 (ff), IO2 (ff)	Fundamental frequency (RMS) current measurement values of phase currents and residual currents.
IL1 (TRMS), IL2 (TRMS), IL3 (TRMS), IO1 (TRMS), IO2 (TRMS)	TRMS current measurement values of phase currents and residual currents.
IL1, IL2, IL3, IO1, IO2 & 2 <sup>nd</sup> h., 3 <sup>rd</sup> h., 4 <sup>th</sup> h., 5 <sup>th</sup> h., 7 <sup>th</sup> h., 9 <sup>th</sup> h., 11 <sup>th</sup> h., 13 <sup>th</sup> h., 15 <sup>th</sup> h., 17 <sup>th</sup> h., 19 <sup>th</sup> h.	Magnitudes of the phase current components: 2 <sup>nd</sup> harmonic, 3 <sup>rd</sup> harmonic, 4 <sup>th</sup> harmonic, 5 <sup>th</sup> harmonic, 7 <sup>th</sup> harmonic, 9 <sup>th</sup> harmonic, 11 <sup>th</sup> harmonic, 13 <sup>th</sup> harmonic, 15 <sup>th</sup> harmonic, 17 <sup>th</sup> harmonic, 19 <sup>th</sup> harmonic current.
I1, I2, IOZ	Positive sequence current, negative sequence current and zero sequence current.
IOCalcMag	Residual current calculated from phase currents.

Signals	Description
IL1Ang, IL2Ang, IL3Ang, I01Ang, I02Ang, I0CalcAng I1Ang, I2Ang	Angles of each measured current.
<b>Voltages</b>	
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.
<b>Powers</b>	
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 ( $\phi$ ) of three-phase powers and phase powers.
cosfi3PH cosfiL1 cosfiL2 cosfiL3	Cos ( $\phi$ ) of three-phase powers and phase powers.
<b>Impedances and admittances</b>	
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.
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.

Signals	Description
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

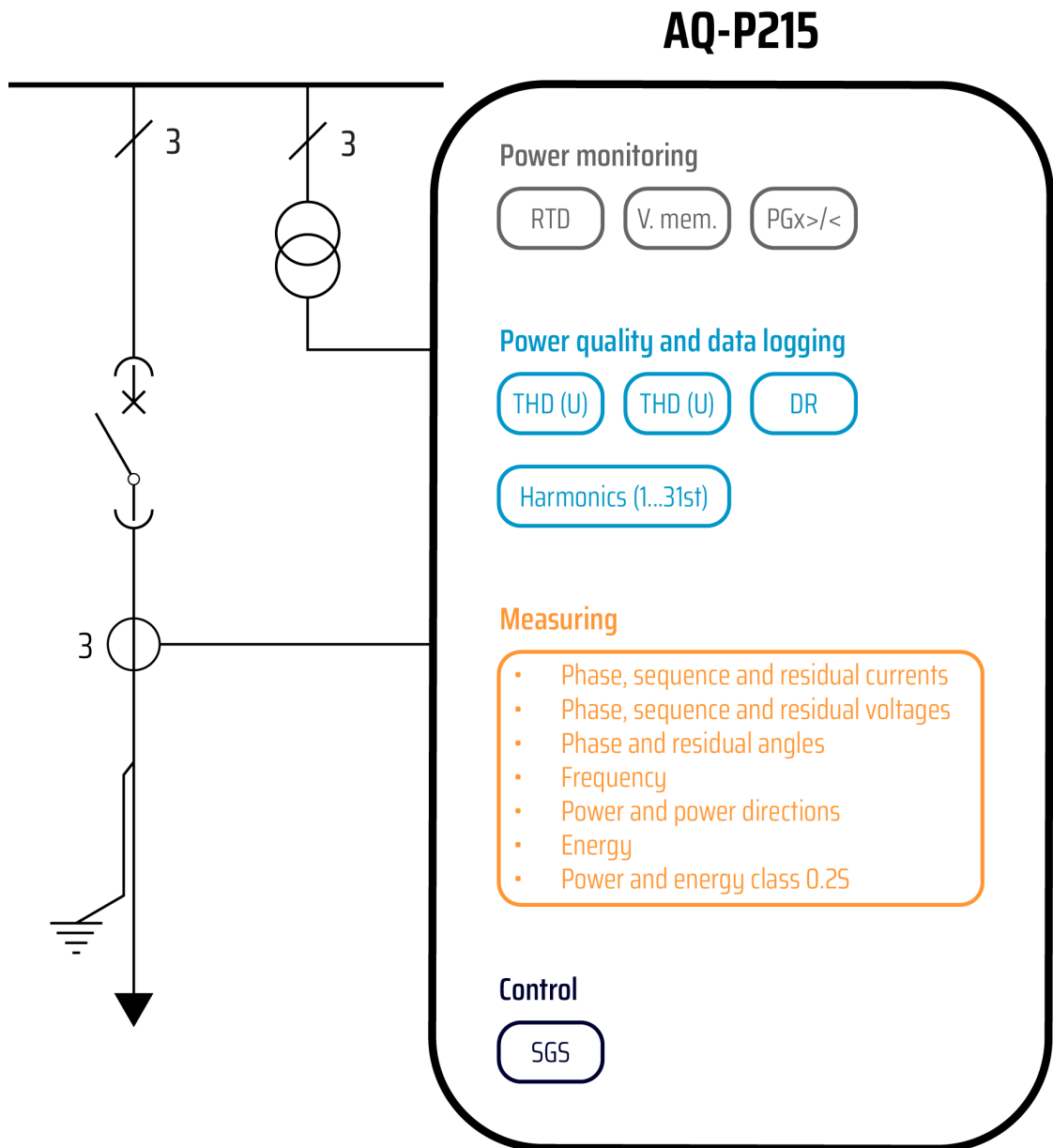
Table. 5.5 - 120. Settings.

Name	Range	Step	Default	Description
Measurement value recorder mode	<ul style="list-style-type: none"> <li>Disabled</li> <li>Activated</li> </ul>	-	Disabled	Activates and disables the real-time signals to communication.
Scale current values to primary	<ul style="list-style-type: none"> <li>No</li> <li>Yes</li> </ul>	-	No	Selects whether or not values are scaled to primary.
Slot X magnitude selection	<ul style="list-style-type: none"> <li>Currents</li> <li>Voltages</li> <li>Powers</li> <li>Impedance (ZRX) and admittance (YGB)</li> <li>Others</li> </ul>	-	Currents	Selects the measured magnitude category of the chosen slot.
Slot X magnitude	Described in table above ("Available measured values")	-	-	Selects the magnitude in the previously selected category.
Magnitude X	-10 000 000.000...10 000 000.000	0.001	-	Displays the measured value of the selected magnitude of the selected slot. The unit depends on the selected magnitude (either amperes, volts, or per-unit values).

## 6 Connections and application examples

### 6.1 Connections of AQ-P215

Figure. 6.1 - 84. AQ-P215 application example with function block diagram.

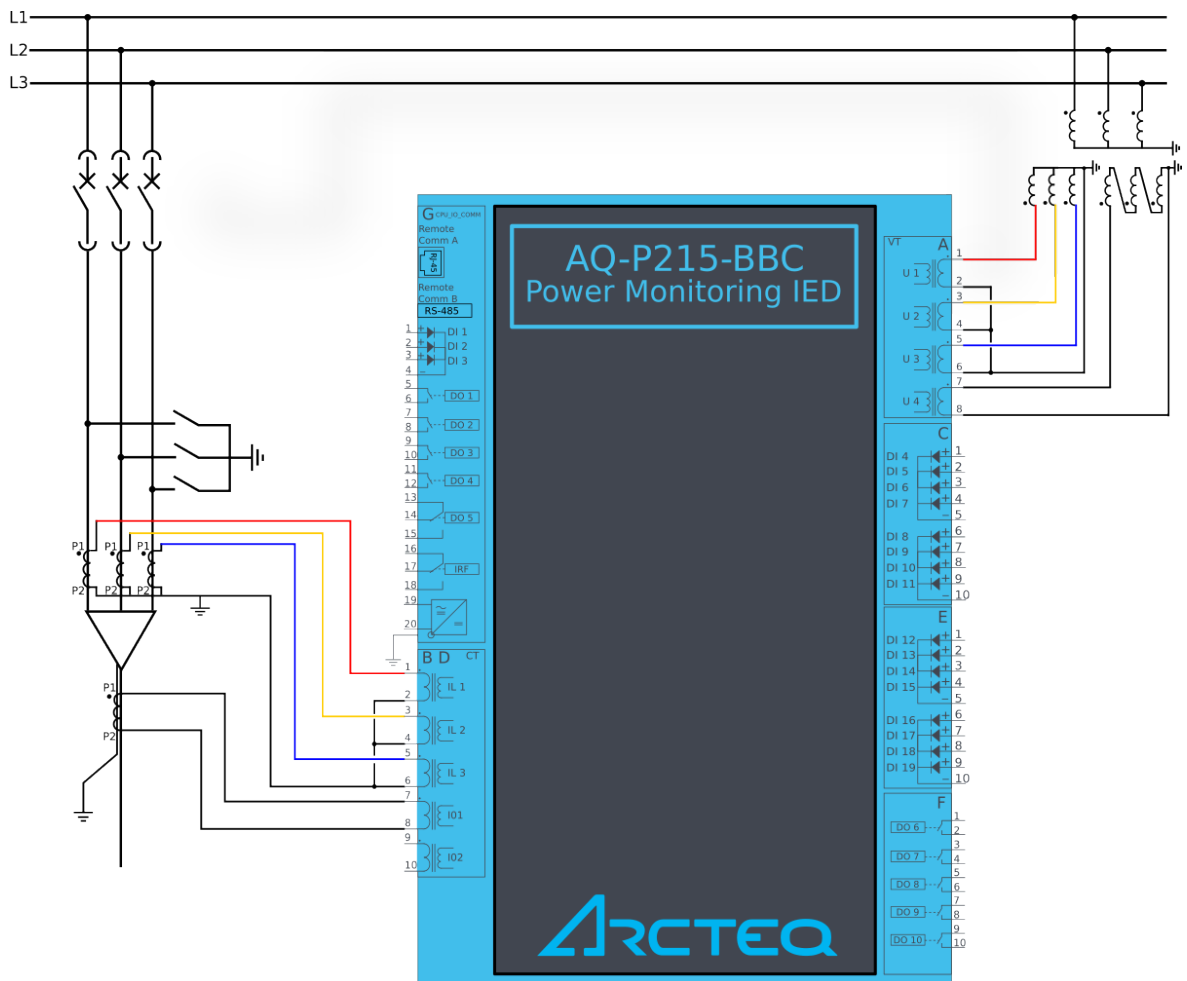


### 6.2 Application example and its connections

This chapter presents an application example for the power monitoring device. The example is of power metering.

Since three line-to-neutral voltages and the zero sequence voltage (U4) are connected, this application uses the voltage measurement mode "3LN+U0" (see the image below). Additionally, the three phase currents and the residual current (I01) are also connected.

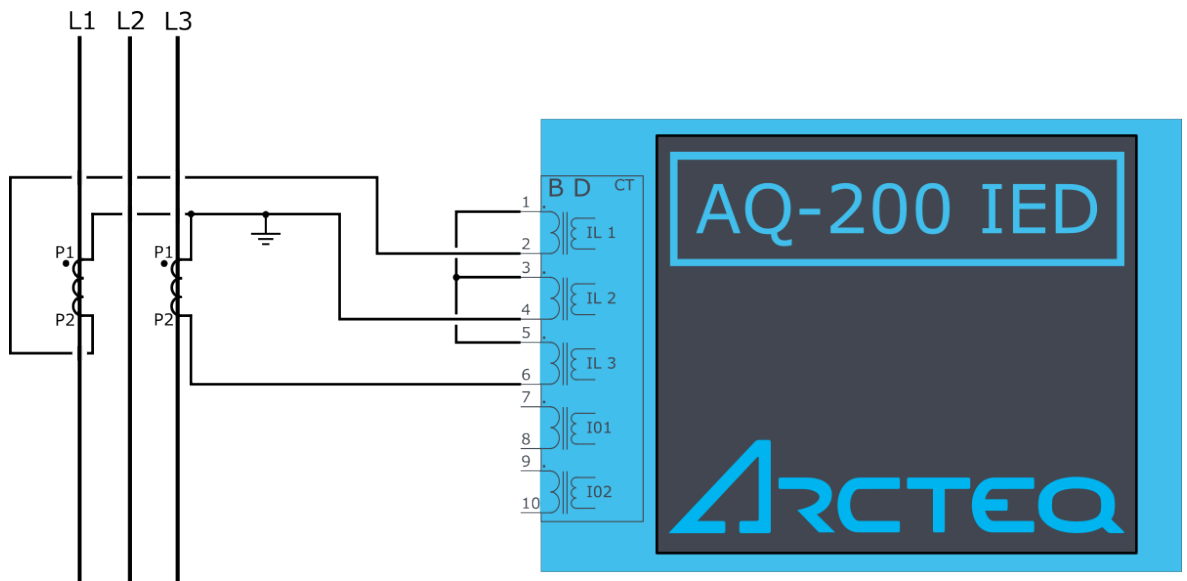
Figure. 6.2 - 85. Application example and its connections.



### 6.3 Two-phase, three-wire ARON input connection

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

Figure. 6.3 - 86. ARON connection.



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

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

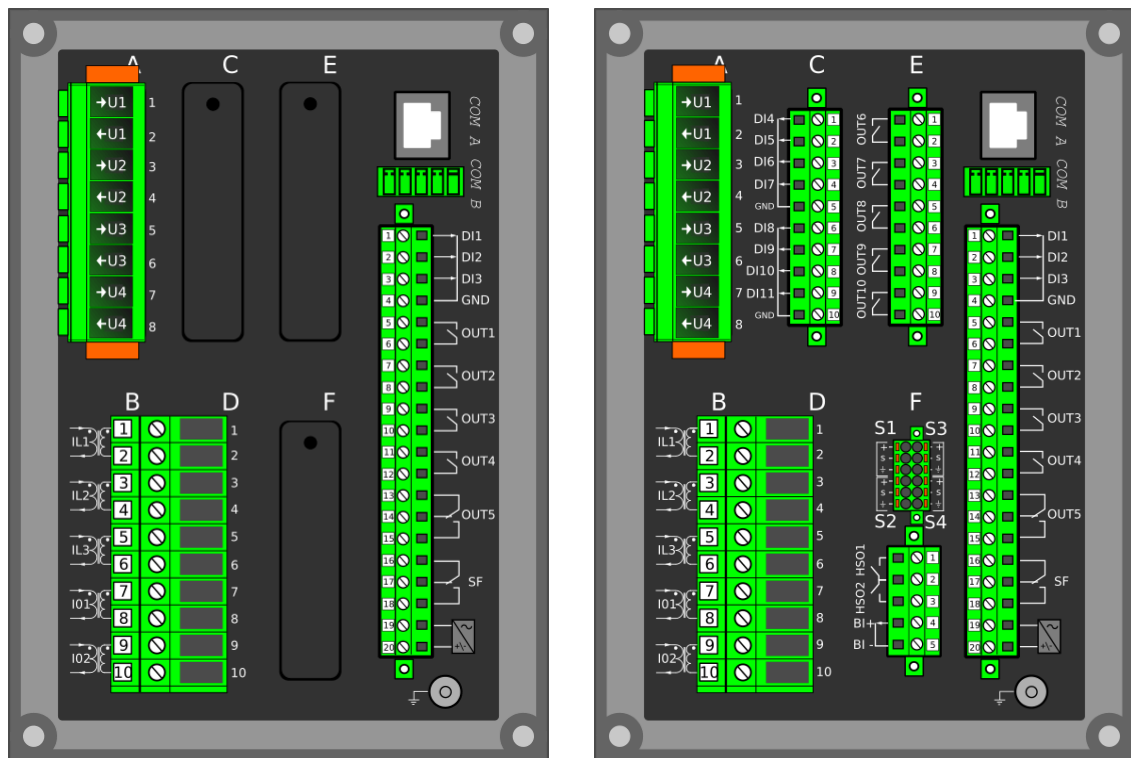
## 7 Construction and installation

### 7.1 Construction

AQ-X215 is a member of the modular and scalable AQ-200 series, and it includes three (3) configurable and modular add-on card slots. As a standard configuration the device includes the CPU module (which consists of the CPU, a number of inputs and outputs, and the power supply) as well as one separate voltage measurement module and one separate current measurement module.

The images below present the modules of both the non-optioned model (AQ-X215-XXXXXXX-AAA, on the left) and the fully optioned model (AQ-X215-XXXXXXX-BCD, on the right).

Figure. 7.1 - 87. Modular construction of AQ-X215.



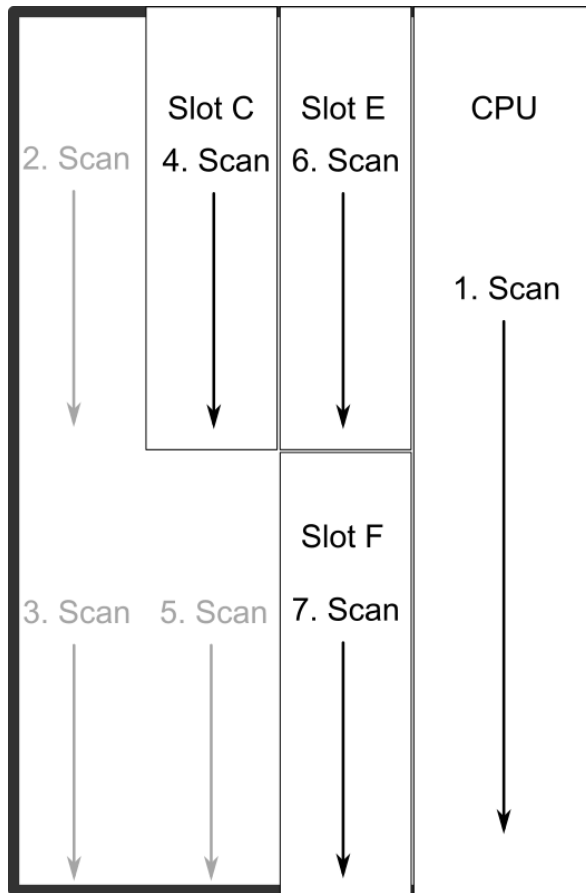
The modular structure of AQ-X215 allows for scalable solutions for different application requirements. In non-standard configurations Slots C, E and F accept all available add-on modules, such as digital I/O modules, integrated arc protection and other special modules. The only difference between the slots affecting device scalability is that Slots E and F also support communication options.

Start-up scan searches for modules according to their type designation code. If the module content is not what the device expects, the device issues a hardware configuration error message. In field upgrades, therefore, add-on modules 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.

When an I/O module is inserted into the device, the module location affects the naming of the I/O. The I/O scanning order in the start-up sequence is as follows: the CPU module I/O, Slot C, Slot E, and Slot F. This means that the digital input channels DI1, DI2 and DI3 as well as the digital output channels OUT1, OUT2, OUT3, OUT4 and OUT5 are always located in the CPU module. If additional I/O cards are installed, their location and card type affect the I/O naming.

The figure below presents the start-up hardware scan order of the device as well as the I/O naming principles.

Figure. 7.1 - 88. AQ-X215 hardware scanning and I/O naming principles.



1. Scan  
The start-up system; detects and self-tests the CPU module, voltages, communication and the I/O; finds and assigns "DI1", "DI2", "DI3", "OUT1", "OUT2", "OUT3", "OUT4" and "OUT5".
2. Scan  
Scans Slot A and finds the four channels of the VT module (fixed for AQ-X215). If the VTM is not found, the device issues an alarm.
3. Scan  
Scans Slot B, which should always remain empty in AQ-X215 devices. If it is not empty, the device issues an alarm.
4. Scan  
Scans Slot C, and moves to the next slot if Slot C is empty. If the scan finds an 8DI module (that is, a module with eight digital inputs), it reserves the designations "DI4", "DI5", "DI6", "DI7", "DI8", "DI9", "DI10" and "DI11" to this slot. If the scan finds a DO5 module (that is, a module with five digital outputs), it reserves the designations "OUT6", "OUT7", "OUT8", "OUT9" and "OUT10" to this slot. The I/O is then added if the type designation code (e.g. AQ-P215-PH0AAAA-BBC) matches with the existing modules in the device. If the code and the modules do not match, the device issues an alarm. An alarm is also issued if the device expects to find a module here but does not find one.
5. Scan  
Scans Slot D and finds the five channels of the CT module (fixed for AQ-X215). If the CTM is not found, the device issues an alarm.



## 6. Scan

Scans Slot E, and moves to the next slot if Slot E is empty. If the scan finds an 8DI module, it reserves the designations "DI4", "DI5", "DI6", "DI7", "DI8", "DI9", "DI10" and "DI11" to this slot. If Slot C also has an 8DI module (and therefore has already reserved these designations), the device reserves the designations "DI12", "DI13", "DI14", "DI15", "DI16", "DI17", "DI18" and "DI19" to this slot. If the scan finds a 5DO module, it reserves the designations "OUT6", "OUT7", "OUT8", "OUT9" and "OUT10" to this slot. Again, if Slot C also has a 5DO and has therefore already reserved these designations, the device reserves the designations "OUT11", "OUT12", "OUT13", "OUT14" and "OUT15" to this slot. If the scan finds the arc protection module, it reserves the sensor channels ("S1", "S2", "S3", "S4"), the high-speed outputs ("HSO1", "HSO2"), and the digital input channel ("ArcBI") to this slot.

## 7. Scan

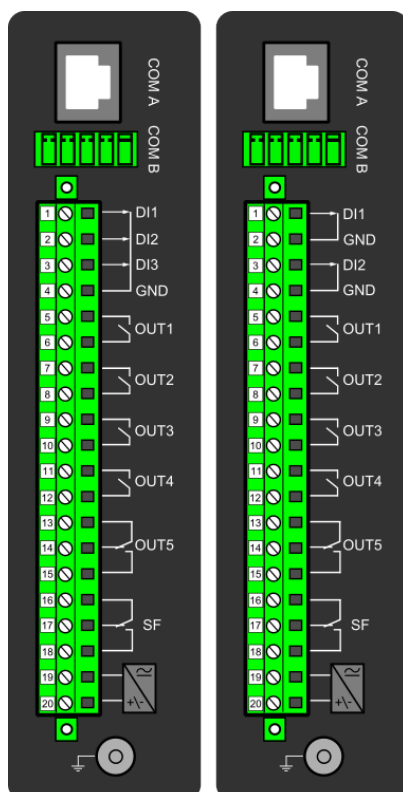
A similar operation to Scan 6 (checks which designations have been reserved by modules in previous slots and numbers the new ones accordingly).

Thus far this chapter has only explained the installation of I/O add-on cards to the option module slots. This is because all other module types are treated in a same way. For example, when an additional communication port is installed into the upper port of the communication module, its designation is Communication port 3 or higher, as Communication ports 1 and 2 already exist in the CPU module (which is scanned, and thus designated, first). After a communication port is detected, it is added into the device's communication space and its corresponding settings are enabled.

The fully optioned example case of AQ-X215-XXXXXXX-BCD (the first image pair, on the right) has a total of 11 digital input channels available: three (DI1...DI3) in the CPU module, and eight (DI4...DI11) in Slot C. It also has a total of 10 digital output channels available: five (DO1...DO5) in the CPU module, and five (DO6...DO10) in Slot E. These same principles apply to all non-standard configurations in the AQ-X215 devices.

## 7.2 CPU module

Figure. 7.2 - 89. CPU module.



## Module connectors

Table. 7.2 - 121. 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	Signaling relay 5, with a changeover contact. Not to be used in trip coil control.	
X 16:17:18	System fault's signaling 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 80...265 VAC/DC (model A; order code "H") or 18...75 DC (model B; order code "L"). <b>Positive side (+) to Pin 20.</b>	
GND	The device's earthing connector.	

By default, the CPU module (combining the CPU, the I/O and the power supply) is included in all AQ-200 devices to provide two standard communication ports and the device's basic digital I/O. The module can be ordered to include 2 or 3 digital inputs.

The digital output controls are also set by the user with software. 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 (80...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 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 settings described in the table below can be found at *Control* → *Device I/O* → *Digital input settings* in the device settings.

Table. 7.2 - 122. Digital input settings.

Name	Range	Step	Default	Description
Dlx Polarity	<ul style="list-style-type: none"> <li>NO (Normally open)</li> <li>NC (Normally closed)</li> </ul>	-	NO	Selects whether the status of the digital input is 1 or 0 when the input is energized.
Dlx Activation delay	0.000...1800.000 s	0.001 s	0.000 s	Defines the delay for the status change from 0 to 1.
Dlx Drop-off time	0.000...1800.000 s	0.001 s	0.000 s	Defines the delay for the status change from 1 to 0.
Dlx AC mode	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Selects whether or not a 30-ms deactivation delay is added to account for alternating current.

## Digital input and output descriptions

CPU card digital inputs and outputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix
- block settings
- 
- 
- etc.

Table. 7.2 - 123. Digital input and output user description.

Name	Range	Default	Description
User editable description DIx	1...31 characters	DIx	Description of the digital input. This description is used in several menu types for easier identification.
User editable description OUTx		OUTx	Description of the digital output. This description is used in several menu types for easier identification.

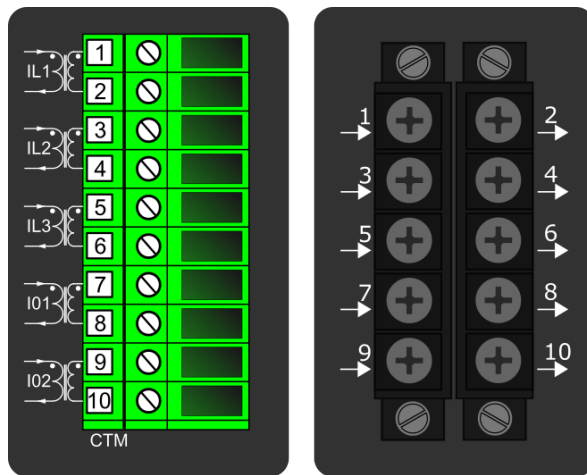
## Scanning cycle

All digital inputs are scanned in a 5 ms cycle, meaning that the state of an input is updated every 0...5 milliseconds. When an input is used internally in the device (either in setting group change or logic), it takes additional 0...5 milliseconds to operate. Theoretically, therefore, it takes 0...10 milliseconds to change the group when a digital input is used for group control or a similar function. In practice, however, the delay is between 2...8 milliseconds about 95 % of the time. When a digital input is connected directly to a digital output (T1...Tx), it takes an additional 5 ms round. Therefore, when a digital input controls a digital output internally, it takes 0...15 milliseconds in theory and 2...13 milliseconds in practice.

Please note that the mechanical delay of the relay is not included in these approximations.

## 7.3 Current measurement module

Figure. 7.3 - 90. Module connections with standard and ring lug terminals.



Connector	Description
CTM 1-2	Phase current measurement for phase L1 (A).
CTM 3-4	Phase current measurement for phase L2 (B).
CTM 5-6	Phase current measurement for phase L3 (C).
CTM 7-8	Coarse residual current measurement IO1.
CTM 9-10	Fine residual current measurement IO2.

A basic current measurement module with five channels includes three-phase current measurement inputs as well as coarse and fine residual current inputs. The CT module is available with either standard or ring lug connectors.

The current measurement module is connected to the secondary side of conventional current transformers (CTs). The nominal current for the phase current inputs is 5 A. The input nominal current can be scaled for secondary currents of 1...10 A. The secondary currents are calibrated to nominal currents of 1 A and 5 A, which provide  $\pm 0.5\%$  inaccuracy when the range is  $0.005...4 \times I_n$ .

The measurement ranges are as follows:

- Phase currents 25 mA...250 A (RMS)
- Coarse residual current 5 mA...150 A (RMS)

- Fine residual current 1 mA...75 A (RMS)

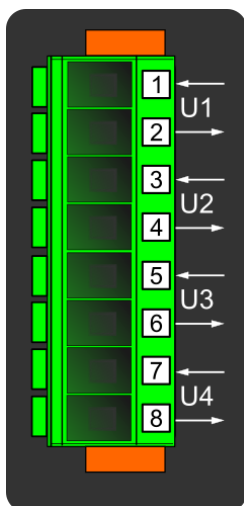
The characteristics of phase current inputs are as follows:

- The angle measurement inaccuracy is less than  $\pm 0.2$  degrees with nominal current.
- The frequency measurement range of the phase current inputs is 6...1800 Hz with standard hardware.
- The quantization of the measurement signal is applied with 18-bit AD converters, and the sample rate of the signal is 64 samples/cycle when the system frequency ranges from 6 Hz to 75 Hz.

For further details please refer to the "Current measurement" chapter in the "Technical data" section of this document.

## 7.4 Voltage measurement module

Figure. 7.4 - 91. Voltage measurement module.



Connector	Description
VTM 1-2	Configurable voltage measurement input U1.
VTM 3-4	Configurable voltage measurement input U2.
VTM 5-6	Configurable voltage measurement input U3.
VTM 7-8	Configurable voltage measurement input U4.

A basic voltage measurement module with four channels includes four voltage measurement inputs that can be configured freely.

The voltage measurement module is connected to the secondary side of conventional voltage transformers (VTs) or directly to low-voltage systems secured by fuses. The nominal voltage can be set between 100...400 V. Voltages are calibrated in a range of 0...240 V, which provides  $\pm 0.2$  % inaccuracy in the same range.

The voltage input characteristics are as follows:

- The measurement range is 0.5...480.0 V per channel.
- The angle measurement inaccuracy is less than  $\pm 0.5$  degrees within the nominal range.
- The frequency measurement range of the voltage inputs is 6...1800 Hz with standard hardware.

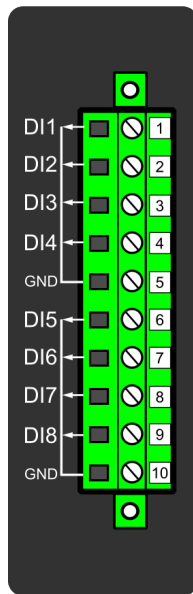
- The quantization of the measurement signal is applied with 18-bit AD converters, and the sample rate of the signal is 64 samples/cycle when the system frequency ranges from 6 Hz to 75 Hz.

For further details please refer to the "Voltage measurement" chapter in the "Technical data" section of this document.

## 7.5 Option cards

### 7.5.1 Digital input module (optional)

Figure. 7.5.1 - 92. Digital input module (DI8) with eight add-on digital inputs.



Connector	Description (x = the number of digital inputs in other modules that precede this one in the configuration)
X 1	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 scanned in 5 ms program cycles, and their pick-up and release delays as well as their NO/NC selection can be set with software.

For the naming convention of the digital inputs provided by this module please refer to the chapter titled "Construction and installation".

For technical details please refer to the chapter titled "Digital input module" in the "Technical data" section of this document.

### Setting up the activation and release delays

The settings described in the table below can be found at *Control* → *Device I/O* → *Digital input settings* in the device settings.

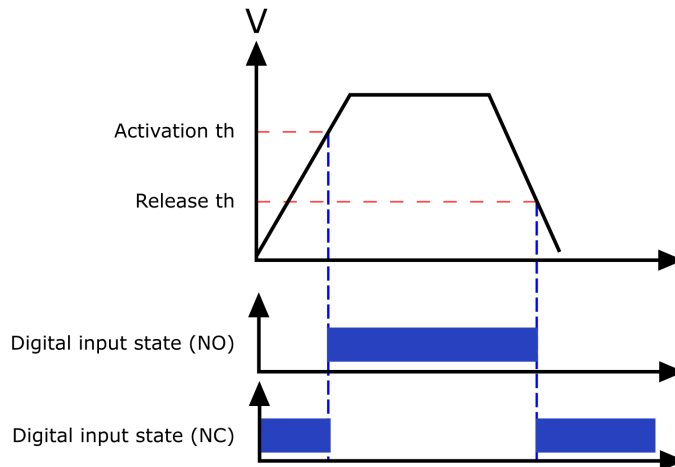
Table. 7.5.1 - 124. Digital input settings of DI8 module.

Name	Range	Step	Default	Description
Dlx Polarity	<ul style="list-style-type: none"> <li>NO (Normally open)</li> <li>NC (Normally closed)</li> </ul>	-	NO	Selects whether the status of the digital input is 1 or 0 when the input is energized.
Dlx Activation threshold	16.0...200.0 V	0.1 V	88 V	Defines the activation threshold for the digital input. When "NO" is the selected polarity, the measured voltage exceeding this setting activates the input. When "NC" is the selected polarity, the measured voltage exceeding this setting deactivates the input.
Dlx Release threshold	10.0...200.0 V	0.1 V	60V	Defines the release threshold for the digital input. When "NO" is the selected polarity, the measured voltage below this setting deactivates the input. When "NC" is the selected polarity, the measured voltage below this setting activates the input.
Dlx Activation delay	0.000...1800.000 s	0.001 s	0.000 s	Defines the delay when the status changes from 0 to 1.
Dlx Drop-off time	0.000...1800.000 s	0.001 s	0.000 s	Defines the delay when the status changes from 1 to 0.
Dlx AC Mode	<ul style="list-style-type: none"> <li>Disabled</li> <li>Enabled</li> </ul>	-	Disabled	Selects whether or not a 30-ms deactivation delay is added to take the alternating current into account. The "Dlx Release threshold" parameter is hidden and forced to 10 % of the set "Dlx Activation threshold" parameter.
Dlx Counter	0...2 <sup>32</sup> -1	1	0	Displays the number of times the digital input has changed its status from 0 to 1.
Dlx Clear counter	<ul style="list-style-type: none"> <li>-</li> <li>Clear</li> </ul>	-	-	Resets the Dlx counter value to zero.

The user can set the activation threshold individually for each digital input. When the activation and release thresholds have been set properly, they will result in the digital input states to be activated and released reliably. The selection of the normal state between normally open (NO) and normally closed (NC) defines whether or not the digital input is considered activated when the digital input channel is energized.

The diagram below depicts the digital input states when the input channels are energized and de-energized.

Figure. 7.5.1 - 93. Digital input state when energizing and de-energizing the digital input channels.



## Digital input descriptions

Option card inputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix
- block settings
- 
- 
- etc.

Table. 7.5.1 - 125. Digital input user description.

Name	Range	Default	Description
User editable description Dlx	1...31 characters	Dlx	Description of the digital input. This description is used in several menu types for easier identification.

## 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*.

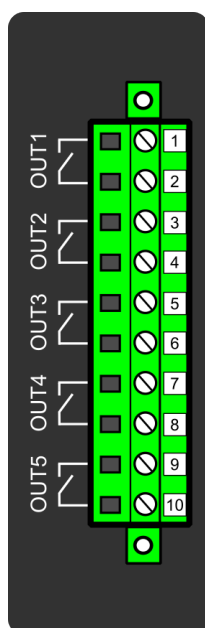
Table. 7.5.1 - 126. Digital input channel voltage measurement.

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



## 7.5.2 Digital output module (optional)

Figure. 7.5.2 - 94. Digital output module (DO5) with five add-on digital outputs.



Connector	Description
X 1–2	OUTx + 1 (1 <sup>st</sup> and 2 <sup>nd</sup> pole NO)
X 3–4	OUTx + 2 (1 <sup>st</sup> and 2 <sup>nd</sup> pole NO)
X 5–6	OUTx + 3 (1 <sup>st</sup> and 2 <sup>nd</sup> pole NO)
X 7–8	OUTx + 4 (1 <sup>st</sup> and 2 <sup>nd</sup> pole NO)
X 9–10	OUTx + 5 (1 <sup>st</sup> and 2 <sup>nd</sup> 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.

### Digital output descriptions

Option card outputs can be given a description. The user defined description are displayed in most of the menus:

- logic editor
- matrix

Version: 2.12

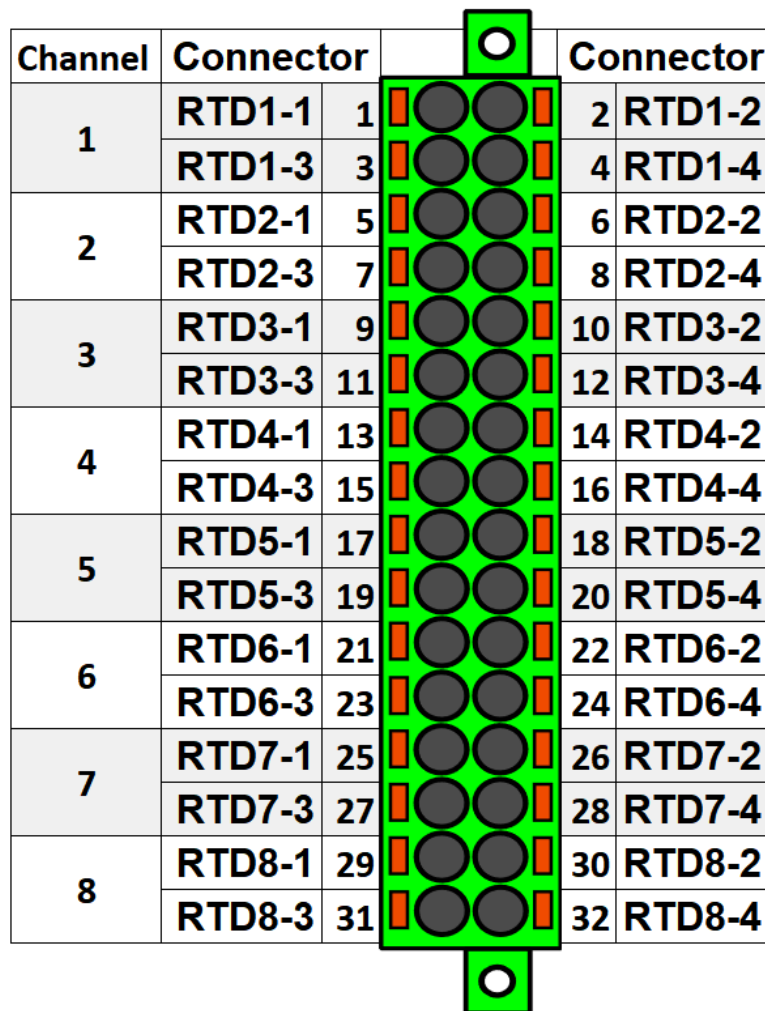
- block settings
- 
- 
- etc.

Table. 7.5.2 - 127. Digital output user description.

Name	Range	Default	Description
User editable description OUTx	1...31 characters	OUTx	Description of the digital output. This description is used in several menu types for easier identification.

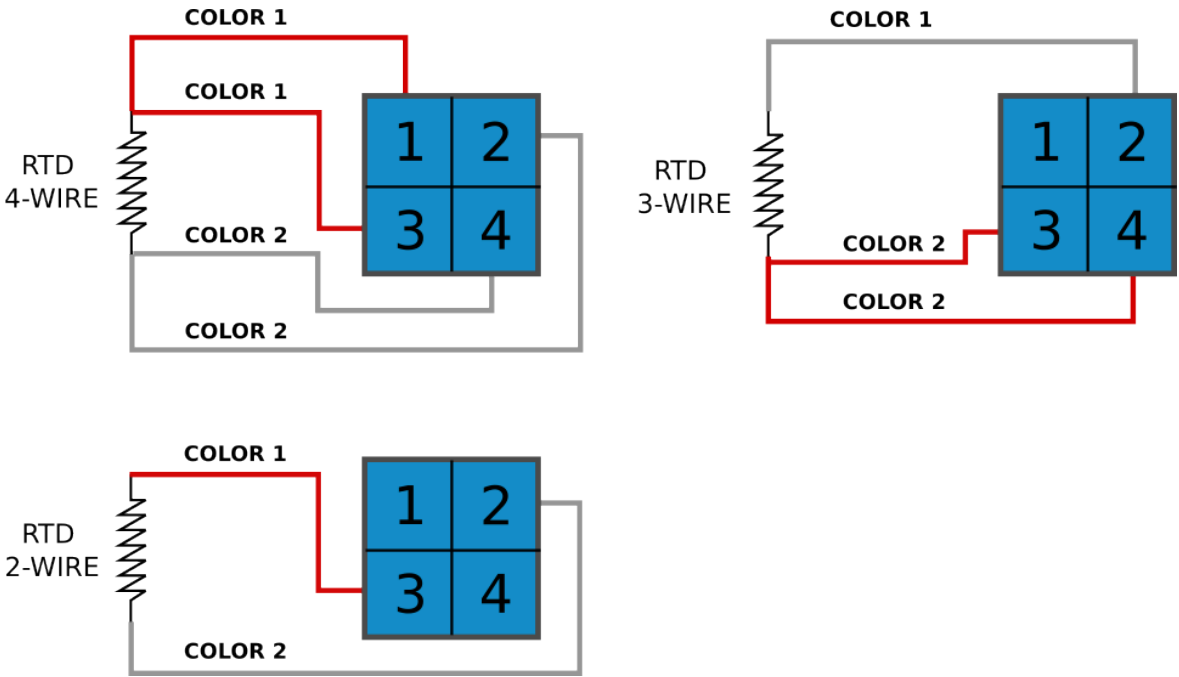
### 7.5.3 RTD input module (optional)

Figure. 7.5.3 - 95. RTD input module connectors.



The RTD input module is an add-on module with eight (8) RTD input channels. Each input supports 2-wire, 3-wire and 4-wire RTD sensors. The sensor type can be selected with software for two groups, four channels each. The card supports Pt100 and Pt1000 sensors

Figure. 7.5.3 - 96. RTD sensor connection types.



### 7.5.4 Serial RS-232 communication module (optional)

Figure. 7.5.4 - 97. Serial RS-232 module connectors.

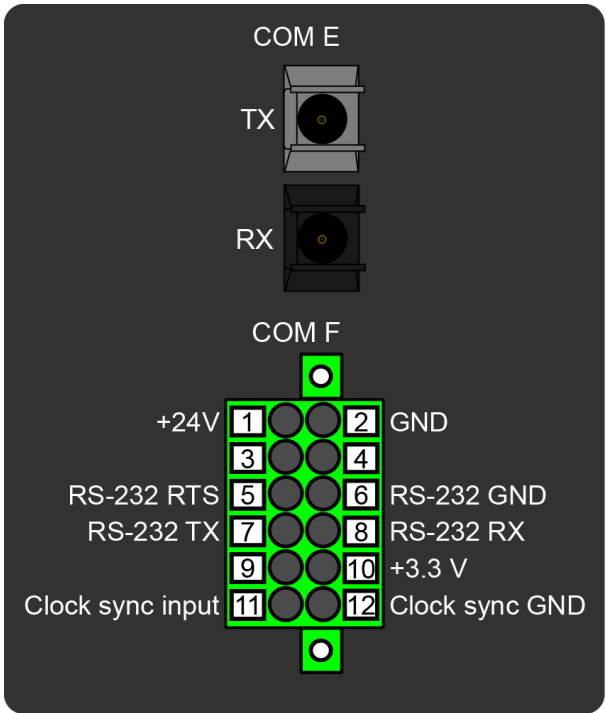


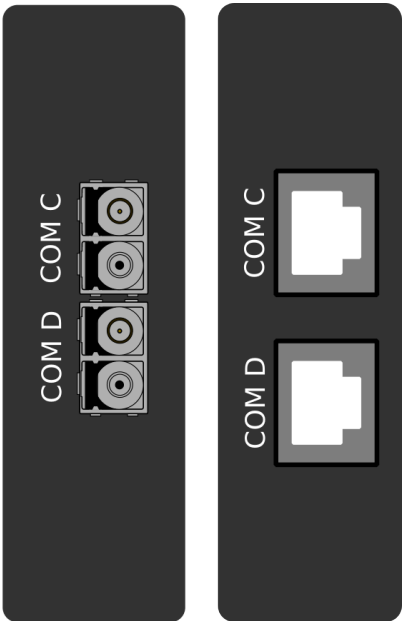
Table. 7.5.4 - 128. Module connections.

Connector	Pin	Name	Description
COM E	-	Serial fiber	<ul style="list-style-type: none"> <li>Serial-based communications</li> <li>Port options: <ul style="list-style-type: none"> <li>Glass/glass</li> <li>Plastic/plastic</li> <li>Glass/plastic</li> <li>Plastic/glass</li> </ul> </li> <li>Wavelength 660 nm</li> <li>Compatible with 50/125 <math>\mu\text{m}</math>, 62.5/125 <math>\mu\text{m}</math>, 100/140 <math>\mu\text{m}</math>, and 200 <math>\mu\text{m}</math> Plastic-Clad Silica (PCS) fiber</li> <li>Compatible with ST connectors</li> </ul>
COM F	1	+24 V input	Optional external auxiliary voltage for serial fiber.
	2	GND	
	3	-	Not in use.
	4		
	5	RS-232 RTS	Serial based communications.
	6	RS-232 GND	
	7	RS-232 TX	
	8	RS-232 RX	
	9	-	Not in use.
	10	+3.3 V output (spare)	Spare power source for external equipment (45 mA).
	11	Clock sync input	Clock synchronization input (supports IRIG-B).
	12	Clock sync GND	

The option card includes two serial communication interfaces: COM E is a serial fiber interface with glass/glass, plastic/plastic, glass/plastic and plastic/glass options, COM F is an RS-232 interface.

7.5.5 LC or RJ45 100 Mbps Ethernet communication module (optional)

Figure. 7.5.5 - 98. LC and RJ45 100 Mbps Ethernet module connectors.

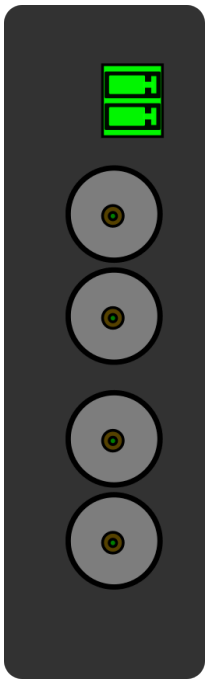


Connector	Description (LC ports)	Description (RJ45)
COM C:	<ul style="list-style-type: none"> <li>Communication port C, 100 MbpsLC fiber connector.</li> <li>62.5/125 μm or 50/125 μm multimode (glass).</li> <li>Wavelength 1300 nm.</li> </ul>	<ul style="list-style-type: none"> <li>RJ-45 connectors</li> <li>10BASE-T and 100BASE-TX</li> </ul>
COM D:	<ul style="list-style-type: none"> <li>Communication port D, 100 Mbps LC fiber connector.</li> <li>62.5/125 μm or 50/125 μm multimode (glass).</li> <li>Wavelength 1300 nm.</li> </ul>	<ul style="list-style-type: none"> <li>RJ-45 connectors</li> <li>10BASE-T and 100BASE-TX</li> </ul>

Both cards support both HSR and PRP protocols.

7.5.6 Double ST 100 Mbps Ethernet communication module (optional)

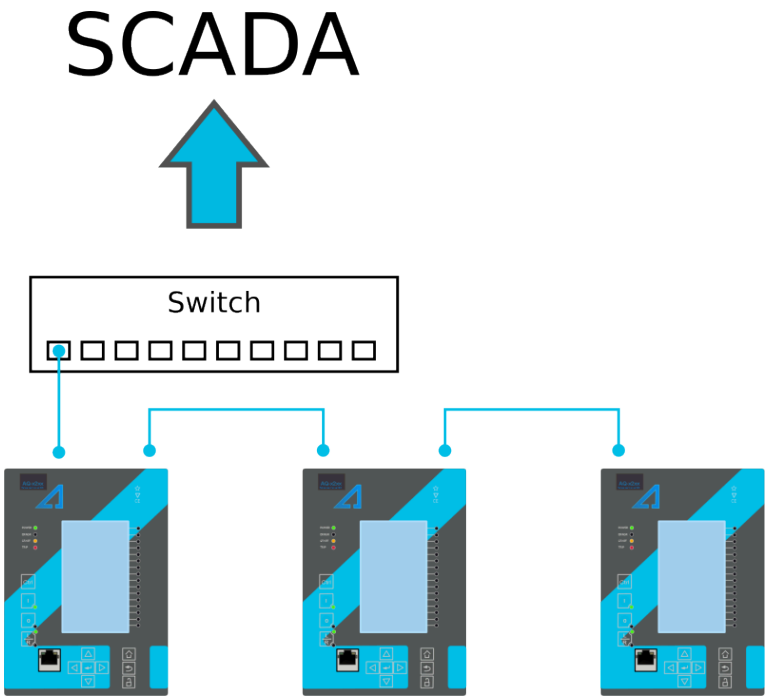
Figure. 7.5.6 - 99. Double ST 100 Mbps Ethernet communication module connectors.



Connector	Description
Two-pin connector	<ul style="list-style-type: none"><li>• IRIG-B input</li></ul>
ST connectors	<ul style="list-style-type: none"><li>• Duplex ST connectors</li><li>• 62.5/125 μm or 50/125 μm multimode fiber</li><li>• Transmitter wavelength: 1260...1360 nm (nominal: 1310 nm)</li><li>• Receiver wavelength: 1100...1600 nm</li><li>• 100BASE-FX</li><li>• Up to 2 km</li></ul>

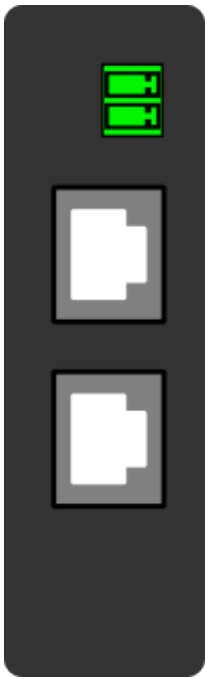
This option cards supports redundant ring configuration and multidrop configurations. Please note that each ring can only contain AQ-200 series devices, and any third party devices must be connected to a separate ring.

Figure. 7.5.6 - 100. Example of a multidrop configuration.



7.5.7 Double RJ45 10/100 Mbps Ethernet communication module (optional)

Figure. 7.5.7 - 101. Double RJ-45 10/100 Mbps Ethernet communication module.

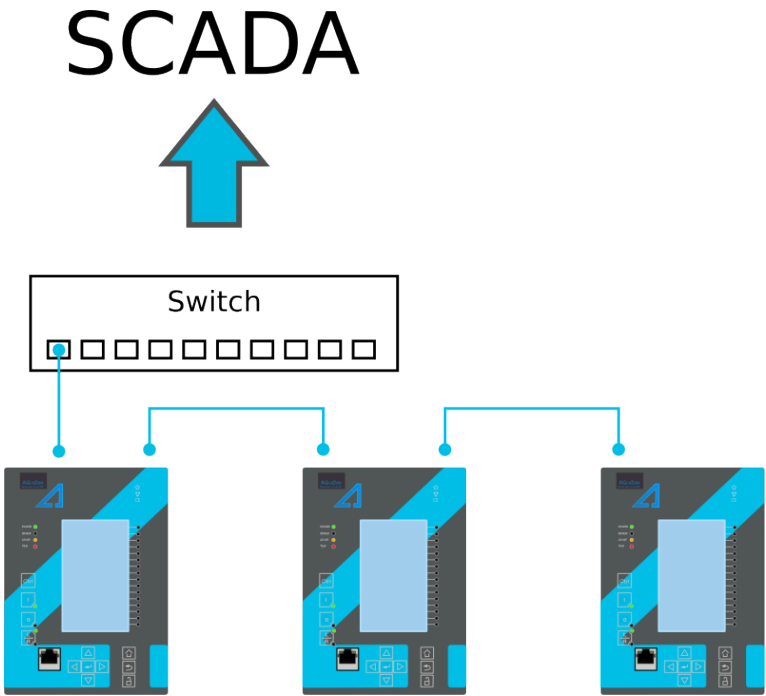


Connector	Description
Two-pin connector	<ul style="list-style-type: none"><li>IRIG-B input</li></ul>

Connector	Description
RJ-45 connectors	<ul style="list-style-type: none"><li>• Two Ethernet ports</li><li>• RJ-45 connectors</li><li>• 10BASE-T and 100BASE-TX</li></ul>

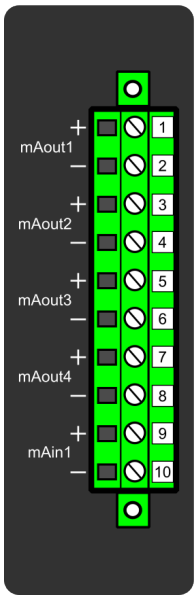
This option card supports multidrop configurations.

Figure. 7.5.7 - 102. Example of a multidrop configuration.



### 7.5.8 Milliampere output (mA) I/O module (optional)

Figure. 7.5.8 - 103. Milliampere output (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)
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 device configuration settings.

## 7.6 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 ( $\frac{1}{4}$ ) of the rack's width, meaning that a total of four devices can be installed to the same rack next to one another.

The figures below describe the device dimensions (first figure), the device installation (second), and the panel cutout dimensions and device spacing (third).

Figure. 7.6 - 104. Device dimensions.

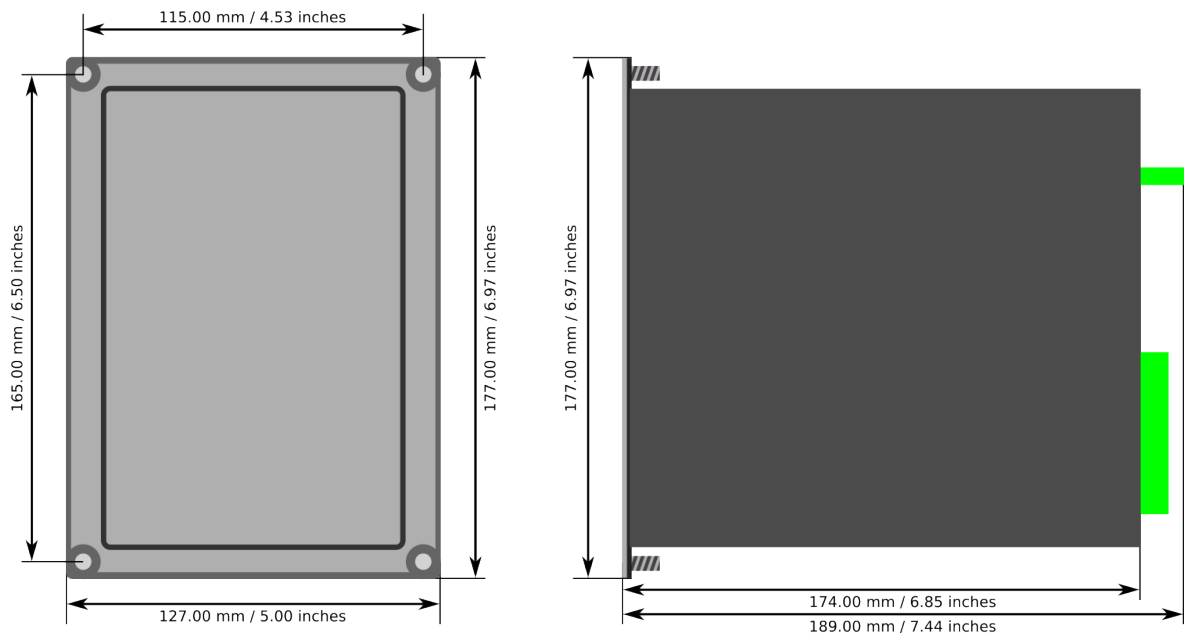


Figure. 7.6 - 105. Device installation.

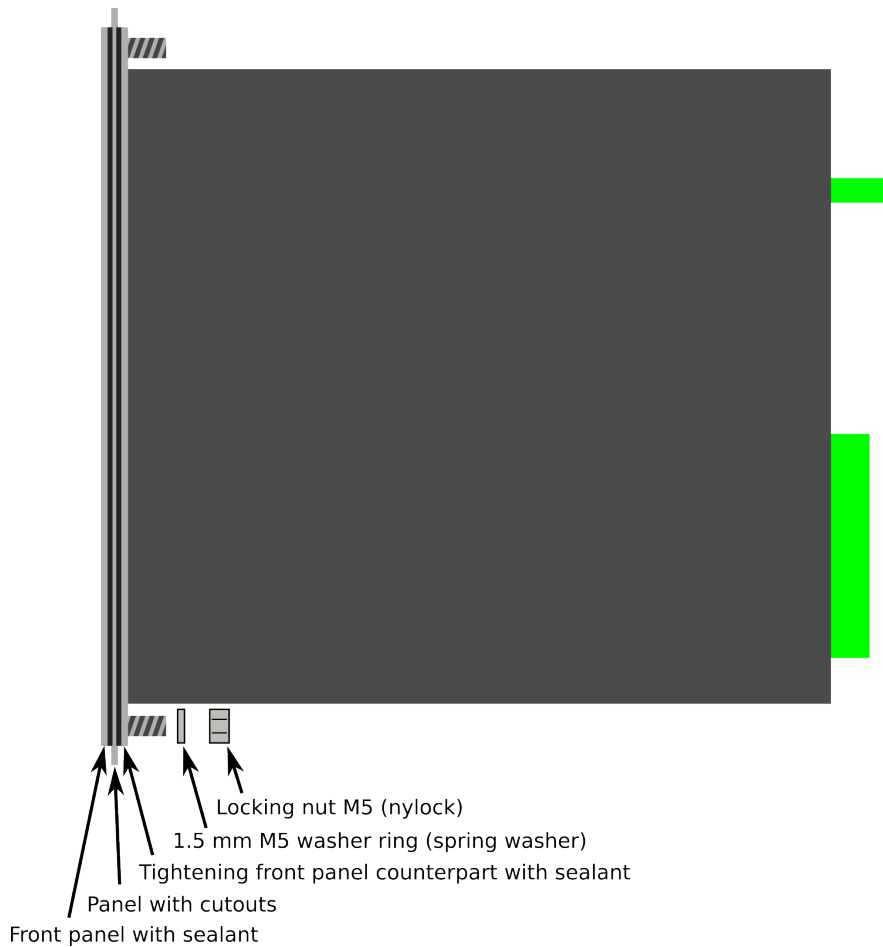
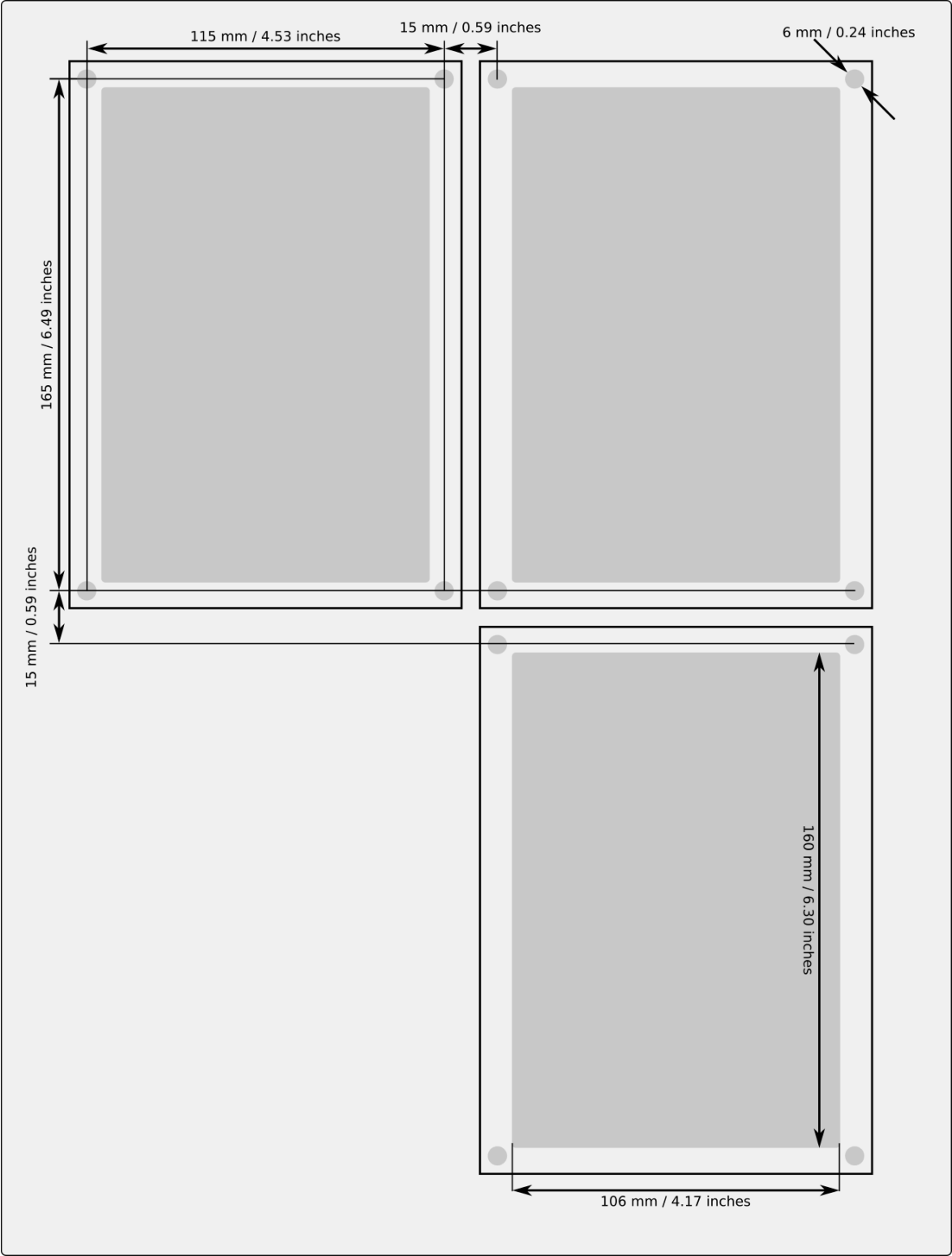


Figure. 7.6 - 106. Panel cutout dimensions and device spacing.



## 8 Technical data

### 8.1 Hardware

#### 8.1.1 Measurements

##### 8.1.1.1 Current measurement

Table. 8.1.1.1 - 129. Technical data for the current measurement module.

General information	
Spare part code	#SP-2XX-CM
Compatibility	AQ-210 and AQ-250 series models
Connections	
Measurement channels/CT inputs	Three phase current inputs: IL1 (A), IL2 (B), IL3 (C) Two residual current inputs: Coarse residual current input I01, Fine residual current input I02
Phase current inputs (A, B, C)	
Sample rate	64 samples per cycle in frequency range 6...75Hz
Rated current $I_N$	5 A (configurable 0.2...20 A)
Thermal withstand	20 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s)
Frequency measurement range	From 6...75Hz fundamental, up to the 31 <sup>st</sup> harmonic current
Current measurement range	25 mA...250 A (RMS)
Current measurement inaccuracy	$0.005...4.000 \times I_N < \pm 0.5 \%$ or $< \pm 15 \text{ mA}$ $4...20 \times I_N < \pm 0.5 \%$ $20...50 \times I_N < \pm 1.0 \%$
Angle measurement inaccuracy	$< \pm 0.2^\circ$ ( $I > 0.1 \text{ A}$ ) $< \pm 1.0^\circ$ ( $I \leq 0.1 \text{ A}$ )
Burden (50/60 Hz)	$< 0.1 \text{ VA}$
Transient overreach	$< 8 \%$
Coarse residual current input (I01)	
Rated current $I_N$	1 A (configurable 0.1...10 A)

Thermal withstand	25 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s)
Frequency measurement range	From 6...75 Hz fundamental, up to the 31 <sup>st</sup> harmonic current
Current measurement range	5 mA...150 A (RMS)
Current measurement inaccuracy	$0.002...10.000 \times I_N < \pm 0.5 \%$ or $< \pm 3 \text{ mA}$ $10...150 \times I_N < \pm 0.5 \%$
Angle measurement inaccuracy	$< \pm 0.2^\circ$ ( $I > 0.05 \text{ A}$ ) $< \pm 1.0^\circ$ ( $I \leq 0.05 \text{ A}$ )
Burden (50/60Hz)	$< 0.1 \text{ VA}$
Transient overreach	$< 5 \%$
Fine residual current input (I02)	
Rated current $I_N$	0.2 A (configurable 0.001...10 A)
Thermal withstand	25 A (continuous) 100 A (for 10 s) 500 A (for 1 s) 1250 A (for 0.01 s)
Frequency measurement range	From 6...75 Hz fundamental, up to the 31 <sup>st</sup> harmonic current
Current measurement range	1 mA...75 A (RMS)
Current measurement inaccuracy	$0.002...25.000 \times I_N < \pm 0.5 \%$ or $< \pm 0.6 \text{ mA}$ $25...375 \times I_N < \pm 1.0 \%$
Angle measurement inaccuracy	$< \pm 0.2^\circ$ ( $I > 0.01 \text{ A}$ ) $< \pm 1.0^\circ$ ( $I \leq 0.01 \text{ A}$ )
Burden (50/60Hz)	$< 0.1 \text{ VA}$
Transient overreach	$< 5 \%$
Screw connection terminal block (standard)	
Terminal block	Phoenix Contact FRONT 4-H-6,35
Solid or stranded wire Nominal cross section	4 mm <sup>2</sup>
Ring lug terminal block connection (option)	
Ring terminal dimensions	Max 8mm diameter, with minimum 3,5mm screw hole

**NOTICE!**

Current measurement accuracy has been verified with 50/60 Hz.

The amplitude difference is 0.2 % and the angle difference is 0.5 degrees higher at 16.67 Hz and other frequencies.

## 8.1.1.2 Voltage measurement

Table. 8.1.1.2 - 130. Technical data for the voltage measurement module.

General information	
Spare part code	#SP-2XX-VT
Compatibility	AQ 200 series and AQ 250 series models
Connection	
Measurement channels/VT inputs	4 independent VT inputs (U1, U2, U3 and U4)
Measurement	
Sample rate	64 samples per cycle in frequency range 6...75Hz
Voltage measuring range	0.50...480.00 V (RMS)
Voltage measurement inaccuracy	1...2 V $\pm 1.5\%$ 2...10 V $\pm 0.5\%$ 10...480 V $\pm 0.35\%$
Angle measurement inaccuracy	$\pm 0.2$ degrees (15...300 V) $\pm 1.5$ degrees (1...15 V)
Voltage measurement bandwidth (freq.)	7...75 Hz fundamental, up to the 31 <sup>st</sup> harmonic voltage
Terminal block connection	
Screw connection terminal block (standard)	Phoenix Contact PC 5/ 8-STCL1-7,62
Spring cage terminal block (optional)	Phoenix Contact SPC 5/ 8-STCL-7,82
Solid or stranded wire Nominal cross section	6 mm <sup>2</sup>
Input impedance	$\sim 24.5\text{ M}\Omega$
Burden (50/60 Hz)	<0.02 VA
Thermal withstand	630 V <sub>RMS</sub> (continuous)



### NOTICE!

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.

## 8.1.1.3 Voltage memory

Table. 8.1.1.3 - 131. Technical data for the voltage memory function.

Measurement inputs
--------------------

Voltage inputs	$U_{L1}, U_{L2}, U_{L3}$ $U_{L12}, U_{L23}, U_{L31} + U_0$
Current inputs (back-up frequency)	Phase current inputs: $I_{L1}$ (A), $I_{L2}$ (B), $I_{L3}$ (C)
<b>Pick-up</b>	
Pick-up voltage setting Pick-up current setting (optional)	2.00...50.00 % $U_N$ , setting step $0.01 \times \%U_N$ 0.01...50.00 $\times I_N$ , setting step $0.01 \times I_N$
Inaccuracy: - Voltage - Current	$\pm 1.5 \%U_{SET}$ or $\pm 30$ mV $\pm 0.5 \%I_{SET}$ or $\pm 15$ mA ( $0.10...4.0 \times I_{SET}$ )
<b>Operation time</b>	
Angle memory activation delay	<20 ms (typically 5 ms)
Maximum active time	0.020...50.000 s, setting step 0.005 s
Inaccuracy: - Definite time ( $U_M/U_{SET}$ ratio >1.05)	$\pm 1.0 \%$ or $\pm 35$ ms
<b>Angle memory</b>	
Angle drift while voltage is absent	$\pm 1.0^\circ$ per 1 second
<b>Reset</b>	
Reset ratio: - Voltage memory (voltage) - Voltage memory (current)	103 % of the pick-up voltage setting 97 % of the pick-up current setting
Reset time	<50 ms

**NOTICE!**

Voltage memory is activated only when all line voltages fall below set pick-up value.

**NOTICE!**

Voltage memory activation captures healthy situation voltage angles, one cycle before actual activation (50Hz/20ms before “bolted” fault)

### 8.1.1.4 Power and energy measurement

Table. 8.1.1.4 - 132. Power and energy measurement accuracy

Power measurement P, Q, S	Frequency range 6...75 Hz
Inaccuracy	0.3 % $< 1.2 \times I_N$ or 3 VA secondary 1.0 % $> 1.2 \times I_N$ or 3 VA secondary
Energy measurement	Frequency range 6...75 Hz
Energy and power metering inaccuracy	0.5% down to 1A RMS (50/60Hz) as standard 0.2% down to 1A RMS (50/60Hz) option available (see the order code for details)

## 8.1.1.5 Frequency measurement

Table. 8.1.1.5 - 133. Frequency measurement accuracy.

Frequency measurement performance	
Frequency measuring range	6...75 Hz fundamental, up to the 31 <sup>st</sup> harmonic current or voltage
Inaccuracy	<1 mHz

## 8.1.2 CPU & Power supply

Table. 8.1.2 - 134. General information for the CPU module.

General information	
Spare part code	#SP-200-CPU
Compatibility	AQ-200 series models
Terminal block connection	
Screw connection terminal block (standard)	Phoenix Contact MSTB 2,5/5-ST-5,08
Spring cage terminal block (option)	Phoenix Contact FKC 2,5/20-STF-5,08
Solid or stranded wire Nominal cross section	2.5 mm <sup>2</sup>
RS-485 serial terminal block connection	
Screw connection terminal block (standard)	Phoenix Contact MC 1,5/ 5-ST-3,81
Spring cage terminal block (option)	Phoenix Contact FK-MCP 1,5/ 5-ST-3,81
Solid or stranded wire Nominal cross section	1.5 mm <sup>2</sup>

### 8.1.2.1 Auxiliary voltage

Table. 8.1.2.1 - 135. Power supply model A

Rated values	
Rated auxiliary voltage	80...265 V (AC/DC)
Power consumption	< 7 W (no option cards) < 15 W (maximum number of option cards)
Maximum permitted interrupt time	< 60 ms with 110 VDC
DC ripple	< 15 %
Other	
Minimum recommended fuse rating	MCB C2



Table. 8.1.2.1 - 136. Power supply model B

Rated values	
Rated auxiliary voltage	18...72 VDC
Power consumption	< 7 W (no option cards) < 15 W (maximum number of option cards)
Maximum permitted interrupt time	< 90 ms with 24 VDC
DC ripple	< 15 %
Other	
Minimum recommended fuse rating	MCB C2

### 8.1.2.2 CPU communication ports

Table. 8.1.2.2 - 137. 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/s
System integration	Cannot be used for system protocols, only for local programming

Table. 8.1.2.2 - 138. 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/s
System integration	Can be used for system protocols and for local programming

Table. 8.1.2.2 - 139. 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

### 8.1.2.3 CPU digital inputs

Table. 8.1.2.3 - 140. 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

### 8.1.2.4 CPU digital outputs

Table. 8.1.2.4 - 141. 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
<b>Settings</b>	
Polarity	Software settable: Normally Open / Normally Closed

Table. 8.1.2.4 - 142. Digital outputs (Change-Over)

<b>Rated values</b>	
Rated auxiliary voltage	265 V (AC/DC)
Continuous carry	2.5 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 0.3 A 0.15 A
Control rate	5 ms
<b>Settings</b>	
Polarity	Software settable: Normally Open / Normally Closed

**CAUTION!**

Please note, that signaling relay 5 and system fault's signaling relay are designed only for signaling purposes, and are not to be used in trip coil control.

## 8.1.3 Option cards

### 8.1.3.1 Digital input module

Table. 8.1.3.1 - 143. Technical data for the digital input module.

<b>General information</b>	
Spare part code	#SP-200-DI8
Compatibility	AQ-200 series models
<b>Rated values</b>	
Rated auxiliary voltage	5...265 V (AC/DC)
Current drain	2 mA

Scanning rate Activation/release delay	5 ms 5...11 ms
<b>Settings</b>	
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
<b>Terminal block connection</b>	
Screw connection terminal block (standard)	Phoenix Contact MSTB 2,5/10-ST-5,08
Spring cage terminals block (option)	Phoenix Contact FKC 2,5/10-STF-5,08
Solid or stranded wire Nominal cross section	2.5 mm <sup>2</sup>

### 8.1.3.2 Digital output module

Table. 8.1.3.2 - 144. Technical data for the digital output module.

<b>General information</b>	
Spare part code	#SP-200-DO5
Compatibility	AQ-200 series models
<b>Rated values</b>	
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
<b>Settings</b>	
Polarity	Software settable: Normally On/Normally Off
<b>Terminal block connection</b>	
Screw connection terminal block (standard)	Phoenix Contact MSTB 2,5/10-ST-5,08
Spring cage terminals block (option)	Phoenix Contact FKC 2,5/10-STF-5,08

Solid or stranded wire Nominal cross section	2.5 mm <sup>2</sup>
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### 8.1.3.3 Milliampere output module (mA out & mA in)

Table. 8.1.3.3 - 145. Technical data for the milliampere output module.

General information	
Spare part code	#SP-2XX-MA
Compatibility	AQ-200 series & AQ-250 series models
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
Terminal block connection	
Screw connection terminal block (standard)	Phoenix Contact MSTB 2,5/10-ST-5,08
Spring cage terminals block (option)	Phoenix Contact FKC 2,5/10-STF-5,08
Solid or stranded wire Nominal cross section	2.5 mm <sup>2</sup>

### 8.1.3.4 RTD input module

Table. 8.1.3.4 - 146. Technical data for the RTD input module.

General information	
Spare part code	#SP-2xx-RTD

Compatibility	AQ-200 series & AQ-250 series models
Channels 1-8	
2/3/4-wire RTD	
Pt100 or Pt1000	
Terminal block connection	
Spring cage terminals block	Phoenix Contact DFMC 1,5/ 16-STF-3,5
Solid or stranded wire Nominal cross section	1.5 mm <sup>2</sup>

### 8.1.3.5 RS-232 & serial fiber communication module

Table. 8.1.3.5 - 147. Technical data for the RS-232 & serial fiber communication module.

General information	
PP Spare part code	#SP-2XX-232PP
PG Spare part code	#SP-2XX-232PG
GP Spare part code	#SP-2XX-232GP
GG Spare part code	#SP-2XX-232GG
Compatibility	AQ-200 series & AQ-250 series models
Ports	
RS-232	
Serial fiber (GG/PP/GP/PG)	
Serial port wavelength	
660 nm	
Cable type	
1 mm plastic fiber	
Terminal block connections	
Spring cage terminals block	Phoenix Contact DFMC 1,5/ 6-STF-3,5
Solid or stranded wire Nominal cross section	1.5 mm <sup>2</sup>

### 8.1.3.6 Double LC 100 Mbps Ethernet communication module

Table. 8.1.3.6 - 148. Technical data for the double LC 100 Mbps Ethernet communication module.

General information
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Spare part code	#SP-2XX-2XLC
Compatibility	AQ-200 series & AQ-250 series models
<b>Protocols</b>	
Protocols	HSR and PRP
<b>Ports</b>	
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)

### 8.1.3.7 Double ST 100 Mbps Ethernet communication module

Table. 8.1.3.7 - 149. Technical data for the double ST 100 Mbps Ethernet communication module.

<b>General information</b>	
Spare part code	#SP-2XX-2XST
Compatibility	AQ-200 series & AQ-250 series models
Dimensions	74 mm X 179 mm
Ports	ST connectors (2) and IRIG-B connector (1)
<b>Protocols</b>	
Protocols	IEC61850, DNP/TCP, Modbus/TCP, IEC104 & FTP
<b>ST connectors</b>	
Connector type	Duplex ST connectors 62.5/125 µm or 50/125 µm multimode fiber 100BASE-FX
Transmitter wavelength	1260...1360 nm (nominal: 1310 nm)
Receiver wavelength	1100...1600 nm
Maximum distance	2 km
<b>IRIG-B Connector</b>	
Screw connection terminal block	Phoenix Contact MC 1,5/ 2-ST-3,5 BD:1-2
Solid or stranded wire Nominal cross section	1.5 mm <sup>2</sup>

## 8.1.4 Display

Table. 8.1.4 - 150. Technical data for the HMI LCD display.

General information	
Spare part code	#SP-200-DISP
Compatibility	AQ-200 series models
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

## 8.2 Functions

### 8.2.1 Control functions

#### 8.2.1.1 Setting group selection

Table. 8.2.1.1 - 151. 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 binary 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

### 8.2.2 Monitoring functions

#### 8.2.2.1 Disturbance recorder

Table. 8.2.2.1 - 152. Technical data for the disturbance recorder function.

Recorded values
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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)
<b>Performance</b>	
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

### 8.2.2.2 Event logger

Table. 8.2.2.2 - 153. Technical data for the event logger function.

<b>General information</b>	
Event history capacity	15 000 events
Event timestamp resolution	1 ms

## 8.3 Tests and environmental

### Electrical environment compatibility

Table. 8.3 - 154. Disturbance tests.

<b>All tests</b>	<b>CE-approved and tested according to EN 60255-26</b>
<b>Emissions</b>	
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
<b>Immunity</b>	
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. 8.3 - 155. 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. 8.3 - 156. 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. 8.3 - 157. 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. 8.3 - 158. 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. 8.3 - 159. 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

## 9 Ordering information

	AQ - P 2 1 5 - P X X X A X A - X X X
<b>Model</b>	
P Power measurement	
<b>Device size</b>	
1 1/4 of 19" rack	
<b>Analog measurement</b>	
5 5 Current measurement channels and 4 voltage measurement channel	
<b>Mounting</b>	
P Panel mounting	
<b>Auxiliary voltage</b>	
H 80...265 VAC/DC	
L 18...72 VDC	
<b>Measurement accuracy</b>	
2 Power/Energy measurement accuracy 0.2%	
<b>Terminals</b>	
A Standard	
B Ring lug terminals	
C Standard current terminals, spring cage voltage and I/O terminals	
D Ring-lug current terminals, spring cage voltage and I/O terminals	
<b>Reserved for future use</b>	
A N/A	
<b>Digital inputs on power supply module</b>	
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	
<b>Reserved for future use</b>	
A N/A	
<b>Slots C, E, F (3 pcs)</b>	
A Empty	
B 8 Digital inputs	
C 5 Output relays (max. 2 pcs)	
F 8 x RTD input (max. 2 pcs)	
G 2 x RJ-45 100Mb Ethernet & IRIG-B (max. 1 pcs) *	
H 2 x ST 100Mb Ethernet & IRIG-B (max. 1 pcs) *	
I 4 x mA outputs - 1 x mA input (max. 2 pcs)	
J Double LC 100Mb Ethernet (HSR, PRP redundant protocols) (max. 1 pcs) * / **	
K Double RJ45 100Mb Ethernet (HSR, PRP redundant protocols) (max. 1 pcs) *	
L RS-232 - Serial fiber (Plastic-Plastic) (max. 1 pcs) *	
M RS-232 - Serial fiber (Plastic-Glass) (max. 1 pcs) *	
N RS-232 - Serial fiber (Glass-Plastic) (max. 1 pcs) *	
O RS-232 - Serial fiber (Glass-Glass) (max. 1 pcs) *	

\* Can only be applied to the last slot

\*\* Can't be applied when type "L" (18...72 VDC) auxiliary voltage is selected

### Accessories

Order code	Description	Note
AX007	External 6-channel 2 or 3 wires RTD Input module, pre-configured	Requires an external 24 VDC supply.

AX008	External 8-ch Thermocouple mA Input module, pre-configured	Requires an external 24 VDC supply.
AQX009	Raising frame 87 mm	-
AX010	Raising frame 40 mm	-
AQX011	AQ-210 series combiflex frame	-
AQX012	AQ-210 series wall mounting bracket	-

## 10 Contact and reference information

### Manufacturer

Arcteq Relays Ltd.

### Visiting and postal address

Kvartsikatu 2 A 1  
65300 Vaasa, Finland

### Contacts

Phone:	+358 10 3221 370
Website:	<a href="http://arcteq.com">arcteq.com</a>
Technical support:	<a href="http://arcteq.com/support-login">arcteq.com/support-login</a> +358 10 3221 388 (EET 9:00 – 17.00)
E-mail (sales):	<a href="mailto:sales@arcteq.fi">sales@arcteq.fi</a>