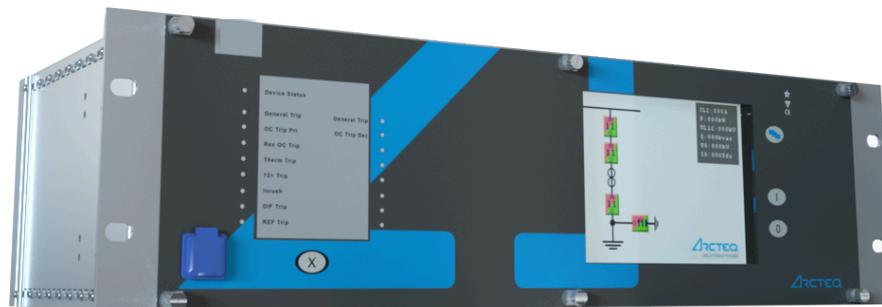


# AQ-B398

Busbar protection 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.

Nothing contained in this document shall increase the liability or extend the warranty obligations of the manufacturer Arcteq Relays Ltd. The manufacturer expressly disclaims any and all liability for any damages and/or losses caused due to a failure to comply with the instructions contained herein or caused by persons who do not fulfil the aforementioned requirements. Furthermore, the manufacturer shall not be liable for possible errors in this document.

Please note that you must always comply with applicable local legislation and regulations. The manufacturer gives no warranties that the content of this document is in all respects in line with local laws and regulations and assumes no liability for such possible deviations.

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# 1 Document information

Table. 1 - 1. History of Revision 1.

<b>Revision</b>	<b>1.00</b>
Date	January 2012
Changes	<ul style="list-style-type: none"> <li>The first revision of the manual.</li> </ul>
<b>Revision</b>	<b>1.01</b>
Date	February 2015
Changes	<ul style="list-style-type: none"> <li>Current and voltage measurement descriptions were revised.</li> </ul>
<b>Revision</b>	<b>1.02</b>
Date	December 2019
Changes	<ul style="list-style-type: none"> <li>The "Construction and installation" chapter was updated.</li> </ul>

Table. 1 - 2. History of Revision 2.

<b>Revision</b>	<b>2.00</b>
Date	February 2023
Changes	<ul style="list-style-type: none"> <li>Updated the Arcteq logo on the cover.</li> <li>An overall visual update for the manual's layout and design.</li> <li>Added the "Safety information" chapter.</li> <li>Added the "Abbreviations" chapter.</li> <li>Added the previously separate documents "AQ 300 Operator's manual" and "AQ 300 Web server description" into the "IED user interface" chapter.</li> <li>Various images updated.</li> <li>Updated contact and reference information.</li> </ul>

## 2 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.

## 3 Abbreviations

<b>AC</b>	alternating current
<b>AVR</b>	automatic voltage regulator
<b>CB</b>	circuit breaker
<b>CBFP</b>	circuit breaker failure protection
<b>CPU</b>	central processing unit
<b>CT</b>	current transformer
<b>CTS</b>	current transformer supervision
<b>CVT</b>	capacitive voltage transformer
<b>DC</b>	direct current
<b>DI</b>	digital input(s)
<b>DLD</b>	dead line detection
<b>DO</b>	digital output(s)
<b>EFT</b>	electronic fast transients
<b>EMC</b>	electromagnetic compatibility
<b>EOB</b>	Ethernet Overboard
<b>ESD</b>	electrostatic discharge
<b>HMI</b>	human—machine interface
<b>IDMT</b>	inverse definite minimum time

Version: 2.00

<b>IED</b>	intelligent electronic device
<b>IO</b>	inputs and outputs
<b>LCD</b>	liquid-crystal display
<b>LED</b>	light-emitting diode
<b>NC</b>	normally closed
<b>NO</b>	normally open
<b>NTP</b>	Network Time Protocol
<b>RF</b>	radio frequency
<b>RCA</b>	relay characteristic angle
<b>RMS</b>	root mean square
<b>SCADA</b>	supervisory control and data acquisition
<b>SDRAM</b>	synchronous dynamic random access memory
<b>SLD</b>	single-line diagram
<b>SOTF</b>	switch-on-to-fault
<b>TMS</b>	time multiplier setting
<b>VT</b>	voltage transformer
<b>VTS</b>	voltage transformer supervision

## 4 General

The AQ-B398 busbar protection IED is a member of the AQ-300 product line. The AQ-300 protection product line in respect of hardware and software is a modular device. The hardware modules are assembled and configured according to the application IO requirements and the software determines the available functions. This manual describes the specific application of the AQ-B398 busbar protection IED. All generic AQ 300 series features such as colour touch screen HMI and wide range of communication protocols including IEC 61850 are available in this particular device as well.

The AQ 398 busbar protection IED is intended for busbar differential protection in extra-high voltage, high voltage and medium voltage applications. The AQ 398 comes in two alternative configurations, either as centralized busbar protection or as distributed (de-centralized) busbar protection. In both configurations the AQ B398 provides three phase biased low impedance type of bus-bar differential protection and circuit breaker failure protection functions. The protection algorithm is identical in both configurations. The difference between the configurations is that in distributed system the bay related information is transferred to AQ B398 unit from bay units via fiber optic links whereas in centralized system the bay information is wired directly to AQ B398 unit.

## 5 IED user interface

### 5.1 Front panel

The figure below presents the front panel structure for AQ-300 series units, while the table below the image describes the functions of the front panel's various elements.

Figure. 5.1 - 1. AQ-300 front panel structure.

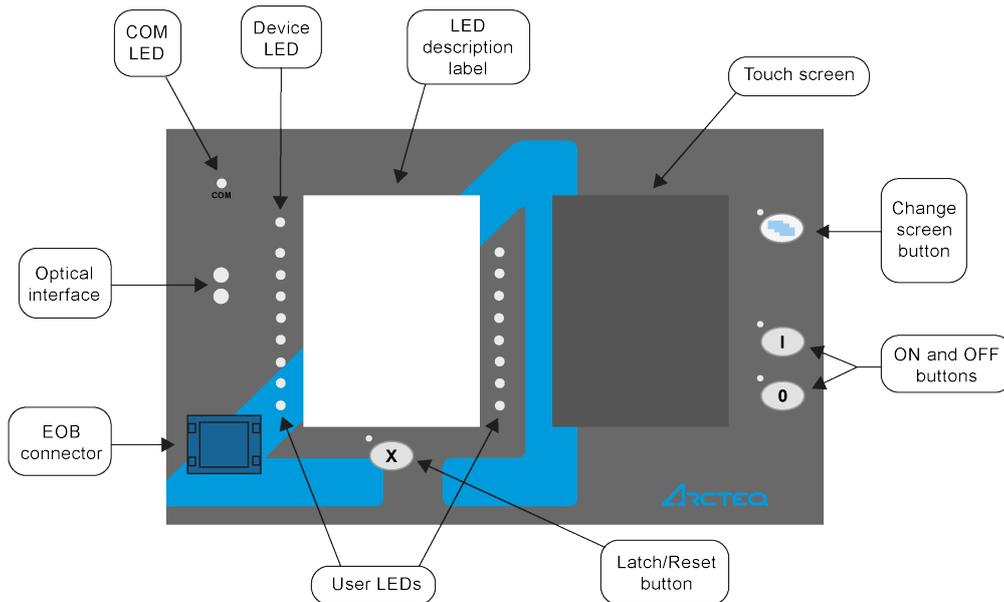


Table. 5.1 - 3. Elements of the front panel.

Function	Description
Device LED	One (1) three-colored circular LED. <ul style="list-style-type: none"> <li>• Green = normal operation</li> <li>• Yellow = warning state</li> <li>• Red = alarm state</li> </ul>
COM LED	One (1) yellow circular LED, which indicates the EOB communication link and activity.
User LEDs	Three-colored circular LEDs. Their number depends on the relay model.
LED description label	A changable label with LED functionality descriptions.
Optical interface	(for factory usage)
EOB connector	Ethernet Overboard communication interface. It attains an isolated and non-galvanic Ethernet connection with the help of a magnetic EOB device. The EOB device has an RJ-45 type connector which supports 10Base-T Ethernet connection to the user's computer.
Touch screen	The main screen, a 3.5" (320 x 240 pixels) portrait-oriented TFT display with a resistive touch screen interface. Optionally, the touch screen can be 5.7" and landscape-oriented.

Function	Description
Operation buttons	<p>The device has four (4) capacitive operational buttons:</p> <ul style="list-style-type: none"> <li>• "X" (below the LED label) latches and resets the LEDs.</li> <li>• The button with a blue icon (top right) changes the touch screen menus.</li> <li>• "ON" and "OFF" (bottom right).</li> </ul> <p>Pushing a button causes an audible buzzer pressure feedback. All four buttons also have an LED off their top-left corner to indicate their status.</p>

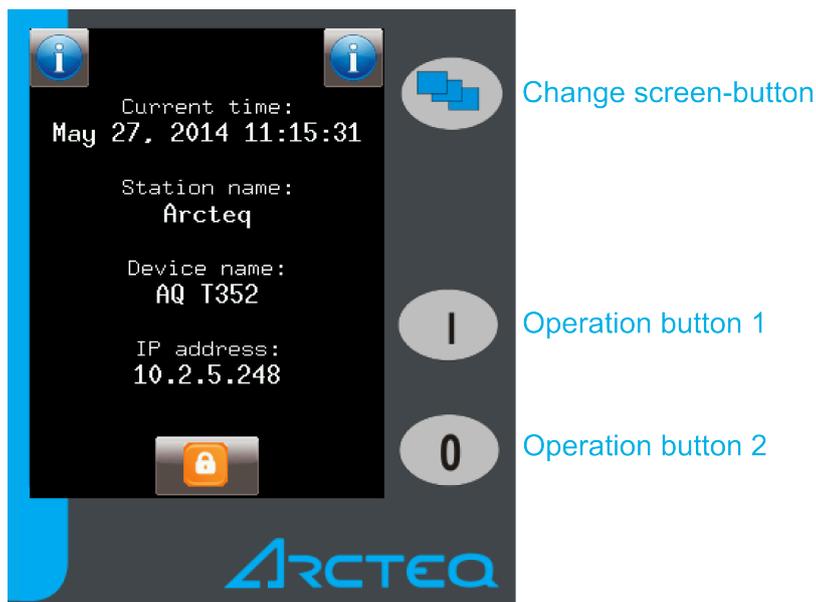
## 5.2 LED assignment

## 5.3 Touch screen

The touch screen comes with a variety of powerful features, including the ability to make customized menus. It also supports single-line diagrams (SLD). The touch screen can be accessed and controlled remotely via the device's web interface. For more information on the remote user interface, please refer to "The embedded web server" chapter below.

The image below depicts the main screen of the front panel as well as the "ON", "OFF" and "Change screen" buttons.

Figure. 5.3 - 2. The main menu and three operation buttons.



The touch screen is the main control where you can enable functions and input values.

The "Change screen" button changes the menu shown on the main display. The menus are in the following order by default: the main menu, the parameter menu, the online measurement menu, the events menu, and the system settings menu. You can also add a number of customized menus which can be created with EuroCAP software. Pushing the button moves the displayed menu by one, in a cycle.

The operation buttons can be used to define certain functions on customer-defined menus. For example, you can set up these buttons to turn a circuit breaker on or off, or to increment and decrement the position of a transformer's tap changer. For more information, please refer to the "Custom user-defined menus" chapter.

## Main menu

The main menu is the first one shown when the device is turned on. It displays general information such as the device and station names, the current time, and language options (when available).

Figure. 5.3 - 3. Lock status indicator, as displayed in the main menu.



The **lock status indicator** shows whether a password is required to unlock the device before parameters or settings can be changed. By default, the device is not password-protected. However, if such a functionality is needed, you can set the password application via the web interface.



### NOTICE!

The password **cannot** be set with the touch screen.

When a device is protected by a password, push the lock icon. This brings up a password input screen (see the image below) where you can enter the password. When the password is entered correctly, the lock status indicator on the main menu becomes unlocked, as does the menu in question. The device can be unlocked from any of the menus.

Figure. 5.3 - 4. The password input screen.



**NOTICE!**

The lock icon is displayed even when the device has no password!

### Parameter menu

In the parameters menu (below) you can view, set and edit certain parameters within the device. You can also choose which of the parameter sets the device uses.

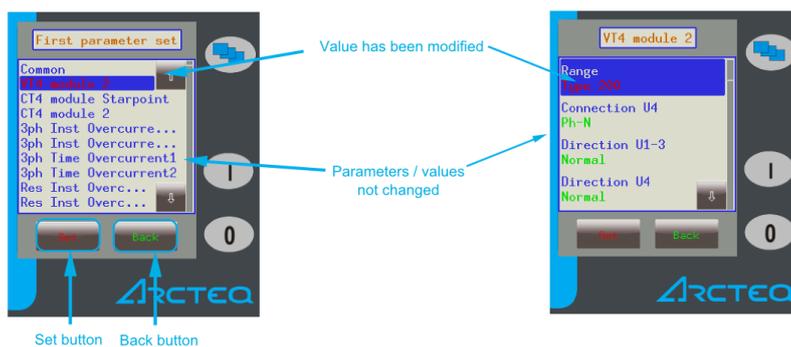
The parameter set that is currently active has a red box around it (see the figure below). When you want to edit or activate a parameter set, touching its name to select and highlight it and then press the "Edit" or "Activate" button.

Figure. 5.3 - 5. The parameter set menu.



The **Activate** button activated the selected parameter set, which the device will now use. Depending on the device's configuration, the "Activate" button may not be available. The **Edit** button takes you to another screen where you can choose which function blocks the parameter set uses. Please note that when there is only one parameter set, the device takes you immediately to the parameter set edit screen (below).

Figure. 5.3 - 6. The parameter set edit screen (left) and the function block screen (right).



Normally, the various function blocks appear blue. However, if any value has been changed within a function block, its listing appears red to notify the user. This also happens in the function block screen, where unmodified parameter values appear green but modified values appear red.

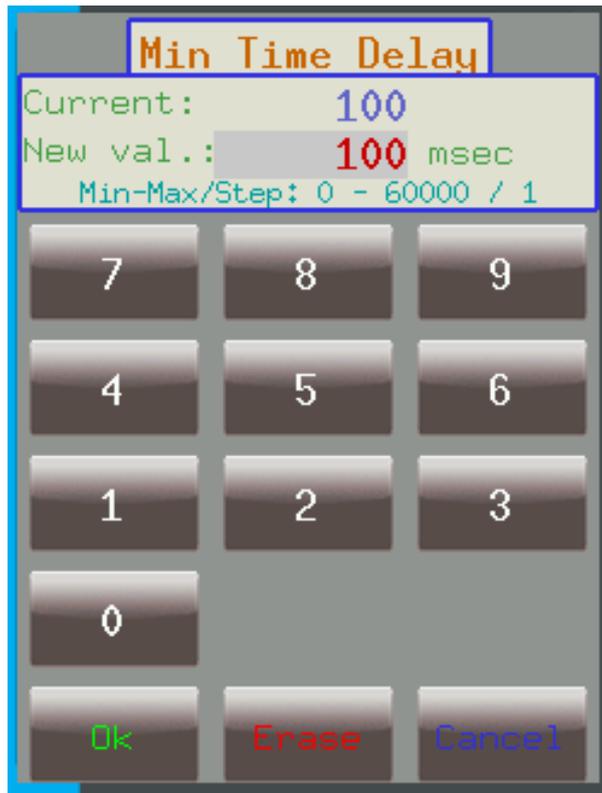
The **Set** button brings up a screen where you can modify a value. If there is a lock icon instead of the "Set" button, the device must first be unlocked. The **Back** button returns you to the previous screen.

Within all function blocks, the parameter values can have one of the following four types of input:

- Integer  
A whole number, entered with the number pad.

- Floating-point number  
A number with a decimal point, entered with the number pad. Please note that the pad has the decimal point available only when the value can be entered as a floating-point number!
- List item  
The parameter lists the available options as a list, and the user selects the desired option from them.
- Checkbox  
The user can enable and disable the parameter as a whole.

Figure. 5.3 - 7. Editing the parameter values.



The new parameter value is put in the "New value" field. The "Current value" field shows the parameter value that is currently in use. The "Min-Max/Step" field shows the range within which the parameter's value can be modified, as well as the step with which the value can be incremented or decremented. For example, in the image above, the range is between 1 000 and 10 000 with a step value of 1. This means that the value can be 1 001, 1 002, 1 003,...,9 999, 10 000. If the step value were 5, the field would only accept values such as 1 005, 1 010, 1 015, and so on.

The **OK button** confirms the value in the "New value" field and returns the user to the previous screen. The **Cancel button** deletes a single digit from the "New value" field. The **Erase button** discards any changes to the current parameter and returns the user to the previous menu item.



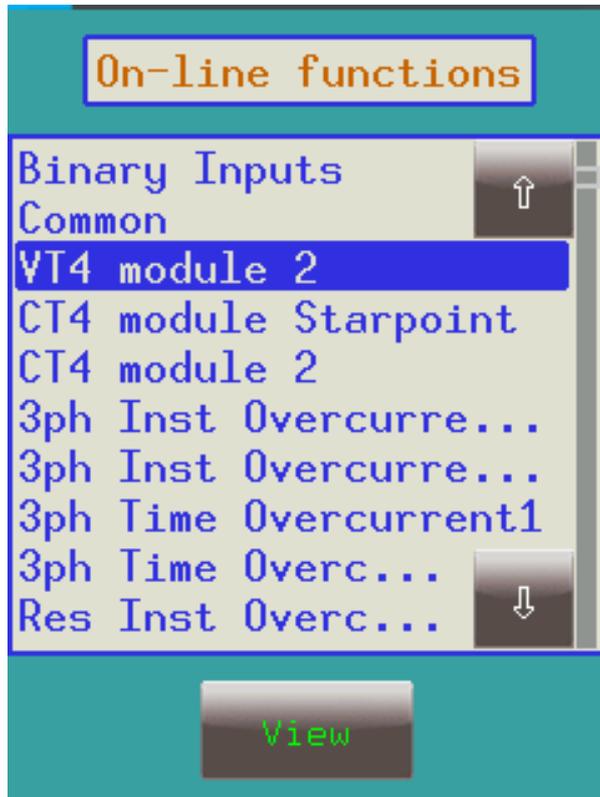
**CAUTION!**

Make sure that only one person edits the parameters at any one time, either in the touch screen or in the web interface! Simultaneous editing leads to confusion as to what the values of a parameter set actually are.

## Online measurement menu

The online measurement menu displays real-time data depending on what is connected to the device. When you have selected a specific function block from the online functions list, clicking the **View button** takes you to a new window that displays the parameters and their current values. The image below shows the values of VT4 module 2: the voltages and angles for channels U1 and U2.

Figure. 5.3 - 8. Online measurement menu.

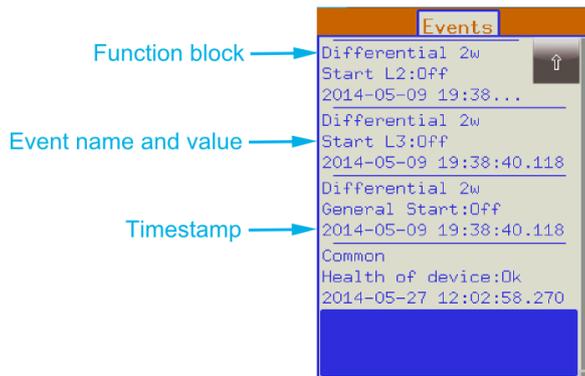


## Events menu

The events menu displays a list of events that have occurred within and in relation to the device. This menu screen is continuously updated. If the scrollbar on the right is at the bottom, the screen shifts as a new event occurs. However, if the scrollbar is not on the bottom, the screen stays in place even when a new event occurs. This allows you to take a closer look at the events.

The first row of an event displays the function block's name, the second row displays the event's name and value, and the third row displays the event's time stamp (see the image below).

Figure. 5.3 - 9. Event structure.



 **NOTICE!**  
The events menu does not display the whole event log, only the first few hundred items in the log!

### System settings menu

Figure. 5.3 - 10. System settings menu.



In the system settings menu you can set certain parameter values that are related to the device itself (as opposed to its protection functions and operations). The menu works similarly to the parameters menu and the same properties apply.

Table. 5.3 - 4. The system settings.

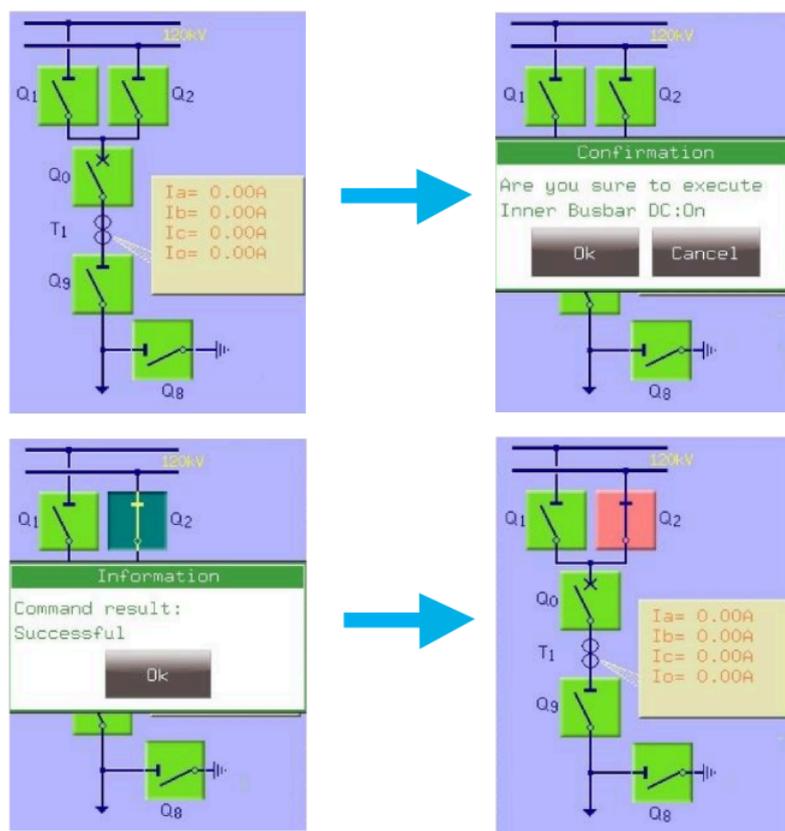
Setting	Description
System parameters and station bus settings (IP address, netmask, default gateway, DNS servers)	Please contact your local network administrator for further information about these settings.
Ethernet communication (IEC 61850 enabled, IEC 104 enabled)	Enables or disables the IEC 61850 and IEC 104 communication protocols.
Serial communication	Selects which serial protocol the device uses. The "Serial baudrate" field sets the baudrate to a specific amount. Please note that this and link address only apply to legacy protocols!
Time synchronization	When time synchronization via NTP server addresses is enabled, the device uses Network Time Protocol to synchronize time with one of the servers. The device also supports other, non-NTP time synchronization methods, such as pin and serial.
Time zone settings	"GMT offset" defines the positive or negative offset for Greenwich Mean Time. "Use DST" and "DST start/stop" define the daylight savings time setting. As DST is different in each country, set these as appropriate.
LCD backlight	Changes the brightness of the touch screen's back illumination.

### Custom user-defined menus

You can add menus based on your application needs with the help of the AQtivate 300 software. You can also set up the operation buttons "I" and "O" to perform specific functions.

For example, let us say we have the following network depicted in the top-left image in the figure below as a single-line drawing. We have set the operation buttons to function as "ON" and "OFF", and now we would like to switch the line disconnecter Q2 on.

Figure. 5.3 - 11. Turning on Q2.



(1) First, we press Q2 on the touch screen to highlight the object. This causes Q2 to start blinking for a short while; if an action is not performed within this time, the object deselects on its own. So, while Q2 is highlighted and blinking, we press the "I" button (configured to function as an "ON" button) to turn it on. (2) A window pops up to confirm we want to do this action; again, we have a short time to give an answer (in this case, to press "Yes") before the requested operation is automatically cancelled. (3) Another window pops up to state that the operation was successful. (4) After acknowledging this window, the display is updated as appropriate, with the Q2 line disconnector in the "ON" position.

Just as the online measurement and events menus, this menu is also updated continuously. Therefore, any kind of change in the states or in the measured parameters are shown and updated accordingly. If there is an error with an operation, the device signals the user of this with an error pop-up window that includes the error code and the reason for the error.

## 5.4 The embedded web server

### Introduction

This product offers the ability to remotely monitor and modify various parameters and settings within the device. You can access the front panel and choose other options with the help of a web browser. With the user-friendly interface, you can easily manage the device. Password protection is available to grant certain privileges and access to special functions.

You can perform the following actions with the embedded web server:

- modify user parameters
- check the event list and disturbance records
- manage the password
- display the measured data and the generated binary information
- perform commands

- provide remote or local firmware upgrades
- perform administrative tasks.

## System requirements

In order to access the device interface you need a compatible web browser as well as an Ethernet connection. It is recommended that the screen resolution is at least 1024 x 768 so that the screen can display data properly.

You can use any of the following web browsers:

- Microsoft Internet Explorer, version 7.0 or higher
- Mozilla Firefox, version 1.5 or higher (**version 3.0 or higher recommended!**)
- Apple Safari, version 2.0.4 or higher
- Google Chrome, version 1.0 or higher
- Opera, version 9.25 or higher

You must also enable JavaScript within your browser. For security reasons the device is only allowed a limited number of connections over the network.

To access the device via a web browser write the correct IP address on the browser's address bar. You can find the device's IP address on the main menu of the device's touch screen.

### 5.4.1 Ethernet connections

#### Properties of the Ethernet connection

An AQ-300 unit has five (5) Ethernet ports built into the device, allowing it to be connected to IP/Ethernet-based networks. The unit has the following Ethernet ports available (the first is located in the front panel, the others on the rear side of the CPU unit):

- Ethernet over board (EOB) 10Base-T user interface
- Station Bus (100Base-FX Ethernet)
- Redundant Station Bus (100Base-FX Ethernet)
- Process Bus (100Base-FX Ethernet, in preparation)
- 10/100Base-Tx port via the RJ45 connector

There are three different types of interfaces for the communication ports:

- The EOB interface is attachable to the device's front panel by a proprietary magnetic connector. The connector box ends in a RJ45 8/8 plug, and the interface is a 10Base-T full duplex interface.
- The 100Base-FX Ethernet interface is of type ST, which offers 1 300 nm/MM for a 50 µm/125 µm (or, 62.5 µm/125 µm) fiber.
- The 10/100Base-Tx Ethernet interface is an RJ45 8/8 plug.

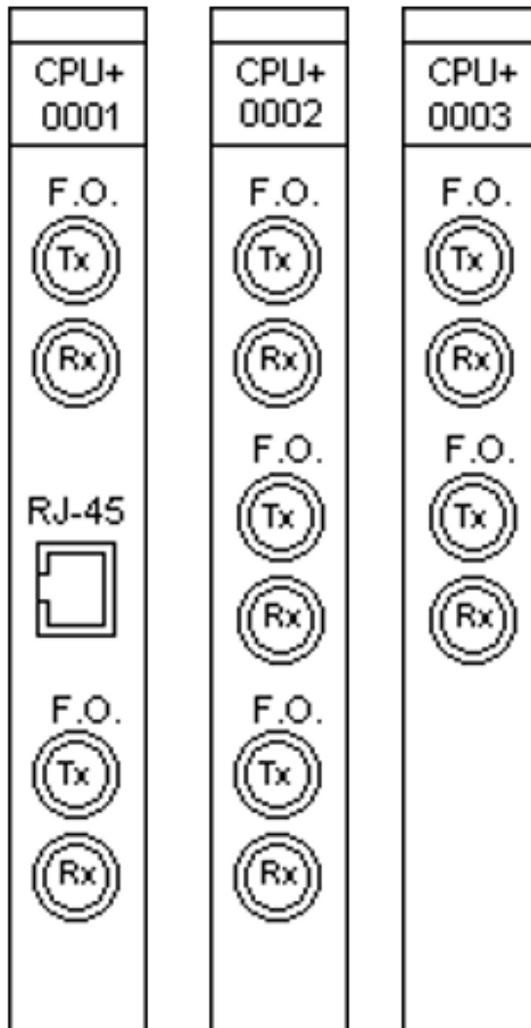
The following table catalogues the different Ethernet communication versions available for the different AQ-300 CPU versions.

Table. 5.4.1 - 5. The available Ethernet communication in different CPU versions.

CPU version	EOB	Station Bus	Redundant Station Bus	Process Bus	RJ45	Legacy port/protocol
CPU+0001	Yes	Yes	No	Prep	Yes	No
CPU+0002	Yes	Yes	Yes	Prep	No	No
CPU+0003	Yes	Yes	Yes	No	No	No

The diagram below depicts the three (3) different CPU versions and their structures:

Figure. 5.4.1 - 12. The three CPU versions.



## Settings needed for Ethernet connection

The AQ-300 devices can only be accessed over Ethernet-based communication protocols. This is why it is very important for the network to be set up correctly before accessing the device.

### IP settings

The device operates with fixed IPv4 addressing. At the moment dynamically assigned IP addresses are not supported. We recommend using the private address range as defined in RFC 1918. All addresses must be in the same network range. Additionally, the computer should be set to use fixed IP settings.

You can connect to a stand-alone device by plugging the EOB cable into your computer or by using the RJ45 connector at the back of the device (this requires a crossover UTP cable). When you want to connect the device to a station or corporate network, contact the system administrator for all the required information: an available IP address, the gateway address, the netmask, the DNS and NTP server addresses.

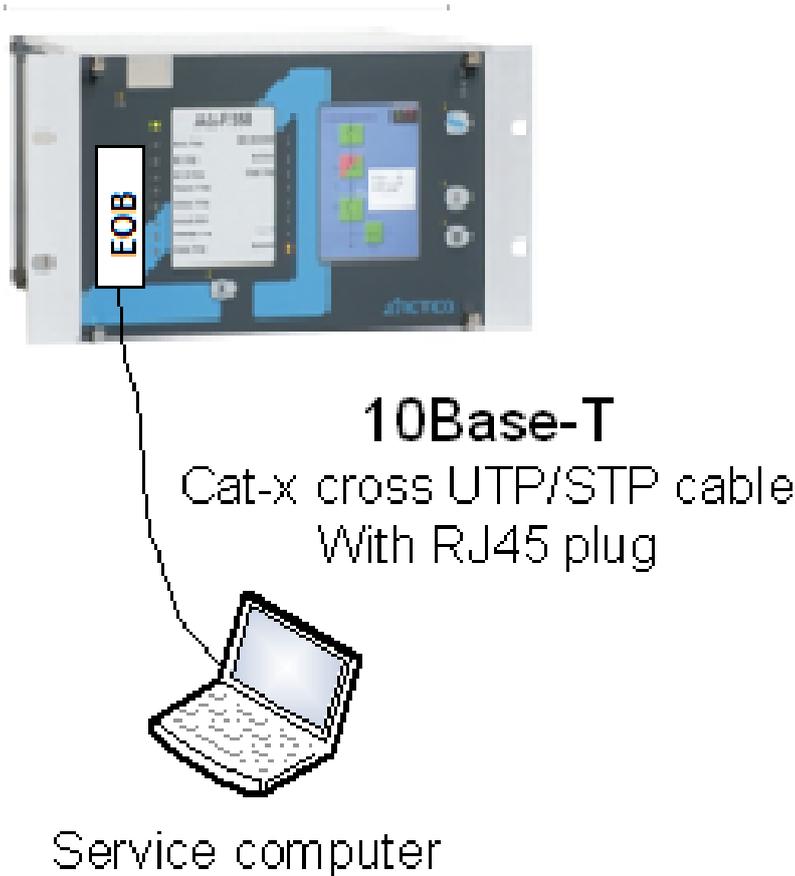
### Web browser settings

Make sure that your browser does **NOT** use a proxy server while accessing an AQ-300 device. However, if there is a proxy server in your network, contact the system administrator and have them add an exception.

### EOB connection

Attach the magnetic EOB connector to the front panel of the device; the magnets assure that the adapter is in the correct position. Next, connect the other end of the cable to a computer's RJ45 port (see the figure below).

Figure. 5.4.1 - 13. Using the EOB connection.

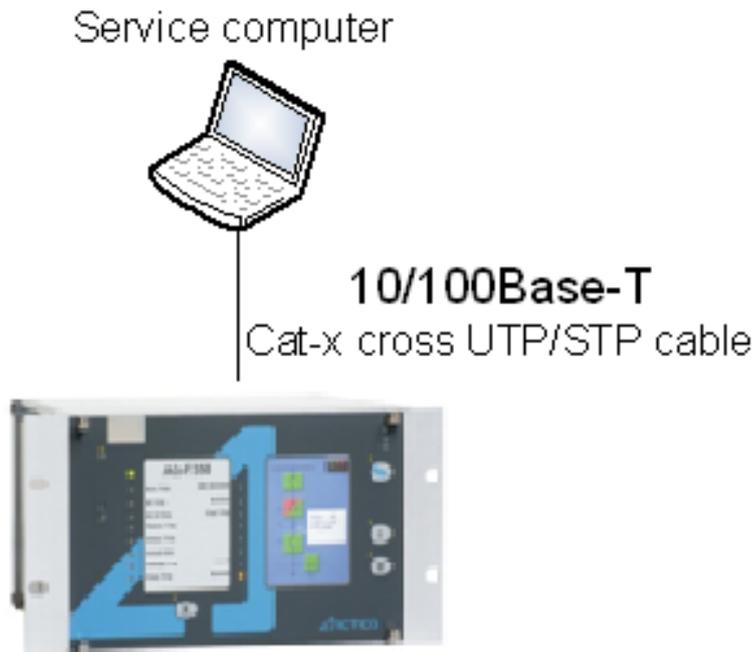


Please note that the RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

### RJ45 connection

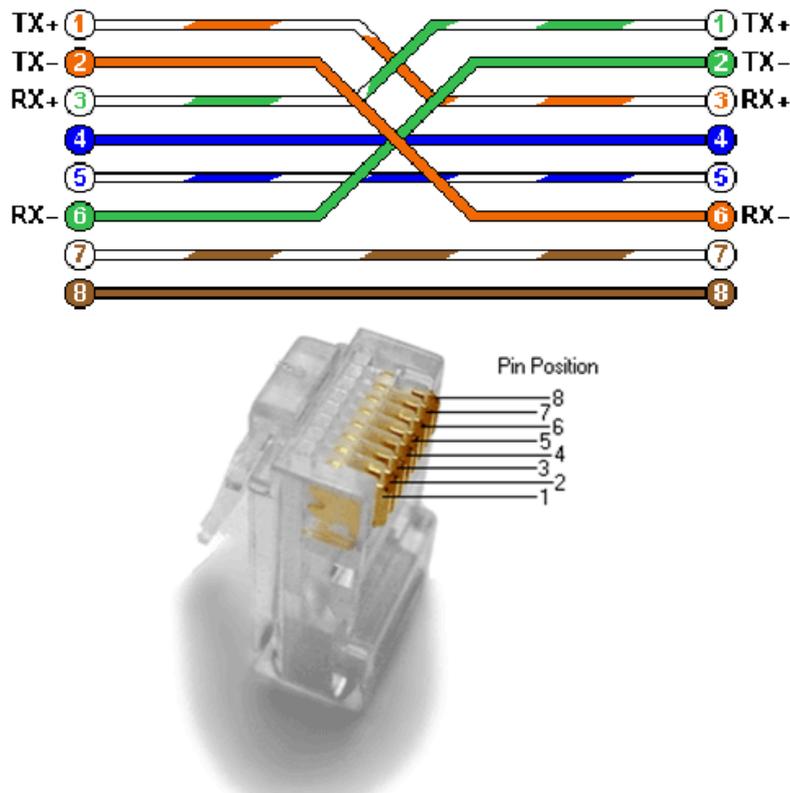
As seen in the beginning of this chapter, the CPU version "+0001" also has an integrated RJ4 port. When using a UTP crossover cable with RJ45 connectors at both ends, you can connect the device directly to a computer (see the figure below).

Figure. 5.4.1 - 14. Using the RJ45 connection.



The crossover cable's pinout has been depicted in the diagram below:

Figure. 5.4.1 - 15. The pinout of the crossover cable.

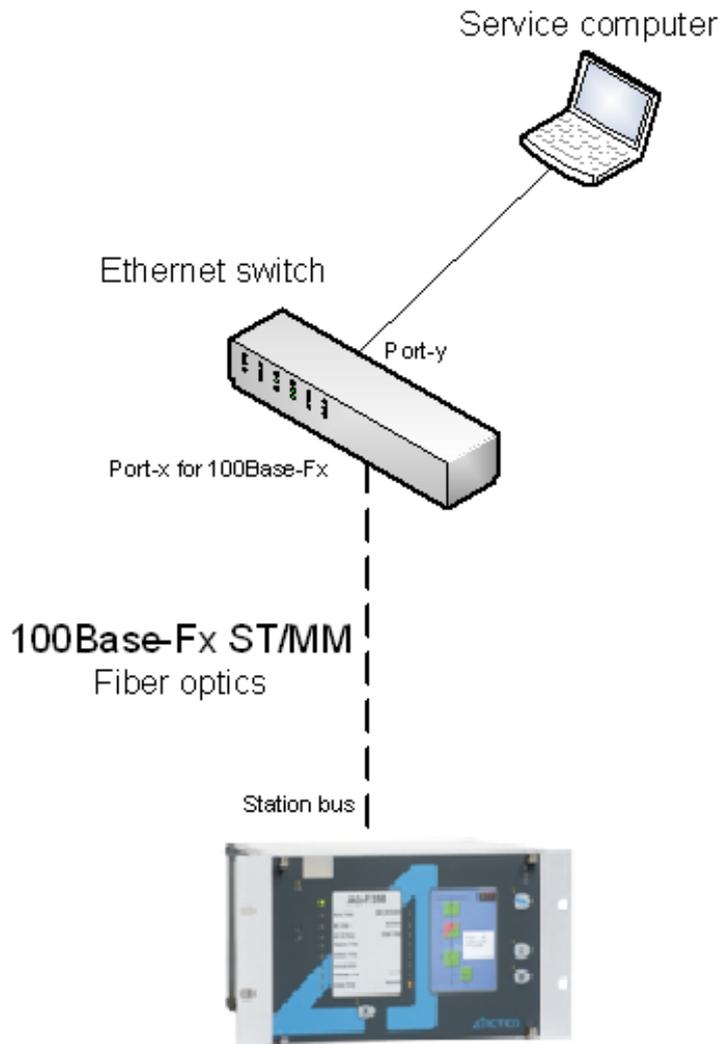


Please note that the cable's RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

## ST-type fiber optic connection

The ST-type fiber optic connector of the 100Base-FX Ethernet provides a connection to an Ethernet switch with an identical fiber optic input. When using this connection, all the network's IEDs with client functionalities (e.g. a computer) have access to the device (see the figure below).

Figure. 5.4.1 - 16. Using the ST-type fiber optic connection to connect computers via an optical Ethernet switch.



### 5.4.2 Getting started

Make sure you are connected to your AQ-300 device and that you have JavaScript enabled within your web browser. Type the IP address of the device into your browser's address bar to access its embedded web server (see the image below).

Figure. 5.4.2 - 17. Web server elements.



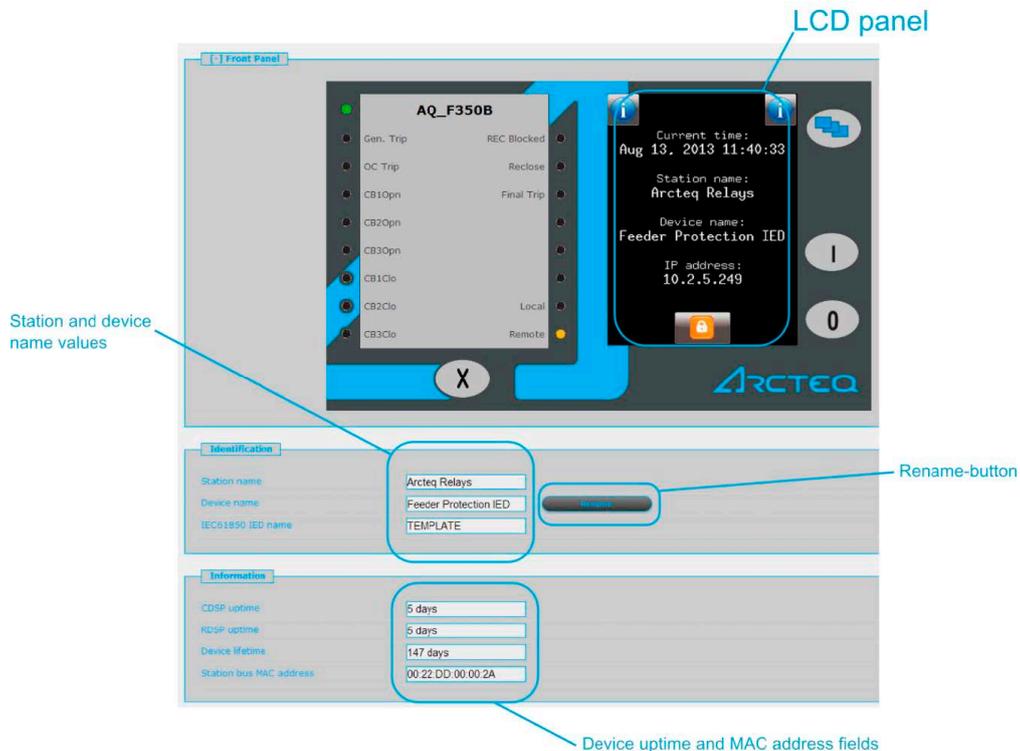
The menu that is currently selected is highlighted in black (in the image above, the main menu is selected). If the content area is too long to fit the browser window, you can scroll down; the menu bar will always be visible as it follows the user.

In some configurations the language that is currently displayed can be changed; to do this, click one of the other available languages represented by flags, located at the top of the touch screen. The page automatically refreshes in the chosen language. Please note that changing the display language only affects the local browser, NOT other browser or the language of the touch screen.

### 5.4.3 Menu items

#### Main menu

Figure. 5.4.3 - 18. The main menu and its elements.



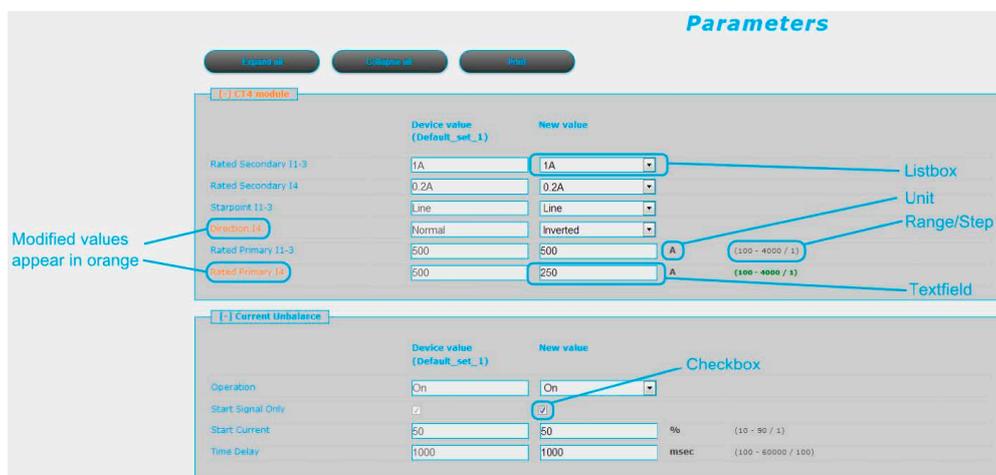
In the main menu you can control the device's front panel. The image of a touch screen (located on the right) behaves the same way as the actual touch screen. For more information on the touch screen, please refer to the "Touch screen" subchapter in the "IED user interface" main chapter.

In the "Identification" section of the view, you can change the station name and the device name. Type the desired name in the relevant field and click the **Rename** button.

The "Information" section shows additional information about the device. The uptime fields show how much time has passed since the device was last powered on. The "Station bus MAC address" displays the network card's MAC address, which is a unique identification number assigned by Arcteq (the address range assigned by the IEEE authority). Please note that these fields are read-only and cannot be modified!

## Parameters menu

Figure. 5.4.3 - 19. The parameters menu and its elements.



You can view and change various parameters and variables in this menu. You can manage the different parameter sets by resetting, renaming, exporting and importing them. You can also apply a password for importing, exporting and setting.

All parameters are part of specific function blocks. You can expand and collapse the individual function block information boxes by clicking the [+] and [-] signs in front of its name. You can also use the button at the top to expand all function blocks, collapse them all, or print out a printer-friendly layout of the function blocks (opens in a new browser window).

The parameter sheet has the following general layout

- The first column contains the name of the parameter. In multilingual devices changing the language also changes this name.
- The second column displays the current values of the selected parameter set stored in the device. Changing the parameter does NOT activate it, it only loads to the fields.
- The third column is used to give parameters user-desired values. When changed, the color changes to blue to draw attention to the change. The expected value range and step are located to the right of the parameter line.

The parameter values are displayed in text fields, checkboxes, or listboxes. All of these can be modified; the name of the parameter whose value has been modified appears in orange, as does the name of the function block (see the image above). When modifying *text fields*, please be mindful of the parameter range and step, although the device does alert the user when an improper value is entered. The new value is displayed in red. *Checkboxes* (Boolean parameter type) enable and disable certain functions and properties; a ticked checkbox means that the parameter is enabled. *Listboxes* (enumerated parameter type) open a drop-down menu with a number of predetermined values. When a value that is not the default is selected, both the letters and the box outline become red.



### NOTICE!

A parameter line has the unit between the new value textfield and the range/step information when applicable. Some parameters do not have units!

The parameter values are checked for changes when you navigate away from the parameter page or when you try to load another parameter set. A pop-up window notifies you if you have made changes and try to leave the page without saving them. Clicking **Cancel** returns you to the parameter page, whereas clicking **OK** ignores the changes.

In the "Parameter set" section of the page there are options for managing the parameter sets. The section lists all the available parameter sets, and each can be manipulated with the buttons located on the right of the line.

Figure. 5.4.3 - 20. Managing multiple parameter sets.



With the **Activate** button, you can enable the selected parameter set. The device will now use the values from this set. The **Rename** button, unsurprisingly, renames the selected parameter set. The names can include alphanumeric characters, spaces, dashes and underscores. Please note that two or more parameter sets **CANNOT** share the same name! The **Save parameters** button saves the selected parameter set in a separate file, which can be loaded into the device at any time.

The **Set parameters** button (located below the menu bar on the left) overwrites the selected parameter set with the values that are on the screen. Note that this only modifies the values of the selected set; to have the device use these values you must also activate the set! You can also set a password that is required before overwriting can be done.

The "Editable fields" section has two buttons. The **Reset to defaults** button replaces the values on the screen with the factory default settings. With the **Load parameters** button you can import values from a parameter set file. These values must be saved after loading by pressing the **Set parameters** button.



**NOTICE!**

These buttons and functions only appear if the device is configured to have more than one parameter set. The available buttons and functions depend on the configuration.

### System settings menu

In the system settings menu you can adjust the miscellaneous device settings. This menu can also be password protected. The text fields, checkboxes and listboxes function the same as in the parameter menu. The column structure is also the same.

The **Set settings** button (located below the menu bar on the left) enabled the device to use the values displayed on the screen at the time the button was clicked. Please note that if the device's IP address has changed, the device must first be accessed through the new IP address.

Figure. 5.4.3 - 21. The system settings menu.

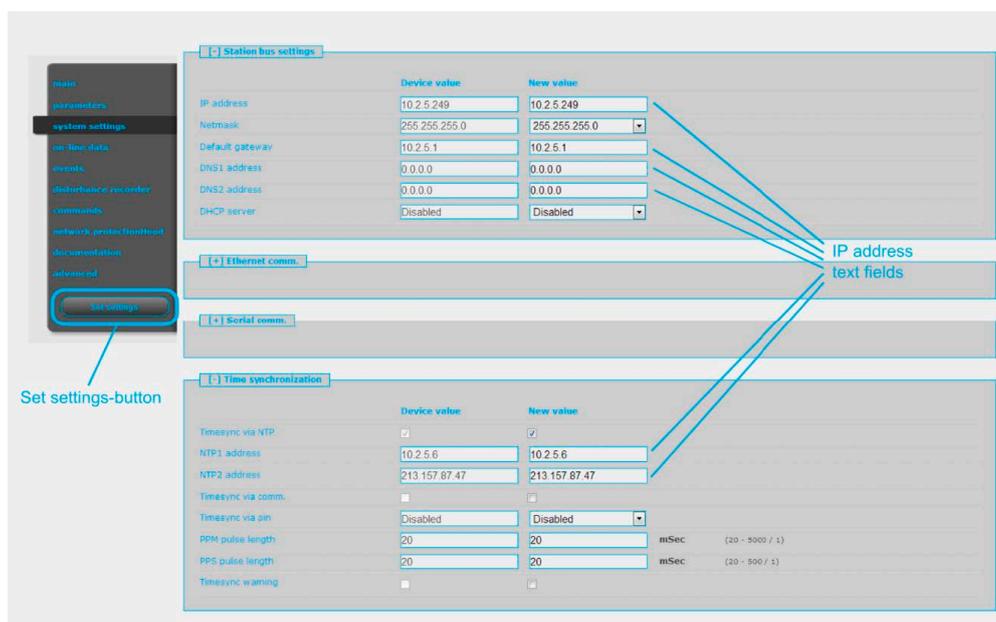


Table. 5.4.3 - 6. The system setting sections and their content.

Section name	Description
Safe settings	If enabled, the device asks you to confirm the saving of new settings by pressing the "I" (ON) button on the device's front panel. Pressing "O" (OFF) discards the changes. This selection must be made within 300 seconds.
Power system frequency	Sets the power system frequency. By default it is 50 Hz, can be changed to 60 Hz. <b>CAUTION!</b> Changing this parameter initiates a system restart!
Station bus settings	Contains the settings for IPv4-based communication (IP address, mask, gateway, DNS address). The DHCP server function can be switched on with a combo-box. <b>CAUTION!</b> Uncontrolled use of the DHCP server function can cause serious communication failures!
Ethernet communication	The device can communicate using several Ethernet-based protocols at the same time. Only IEC 61850 is licensed, other protocols are available by default. You can adjust the T0 time of GOOSE messaging with the GOOSE repeat rate combo-box.
Serial communication	Contains the physical parameters for serial communication (only one protocol can be selected!). Note that serial communication requires a proper CPU card!
Time synchronization	Contains the settings for a broad range of time synchronization protocols (NTP, serial communication, pulse inputs). If the "Time sync warning" parameter is enabled and the device is not synchronized, an alarm is raised (that is, the "Status" LED becomes yellow).
Time zone settings	Contains the settings to offset GMT and to define daylight savings time.

Section name	Description
LCD backlight	Contain the parameters to control the LCD panel's behaviour. The light switches off after its set timeout. The "Backlight group" parameter is useful when you have two or more devices close to each other: touching one switches on all devices that have been configured to belong to the same group.

## Online data menu

Figure. 5.4.3 - 22. The online data menu.



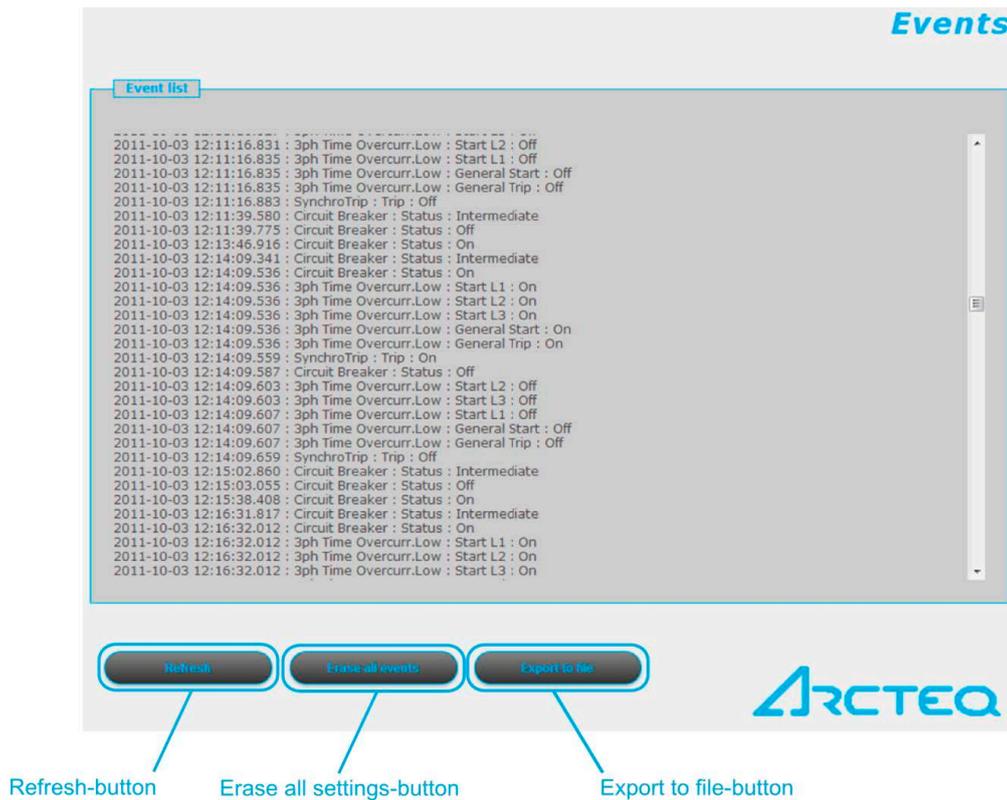
This menu displays the data measured by the device. Each block has their own section, and these sections can be expanded and collapsed individually as needed with the [+] and [-] signs in front of their names. The values on screen are updated every second, which may cause older systems to slow down or halt the browser altogether. All data is strictly read-only, and cannot be modified. If there is a counter on the page, next to it will be a button that resets it.

Binary data is displayed as a checkbox (for example, the "SystemWarning" parameter in the first section in the image above), whereas enumerated data is presented as text information. If you are using a browser compatible with HTML5, analogue measurements are drawn as vectors.

## Events menu

This page displays the events that have occurred in the device. The events are listed in the following format: [local time] : [function block] : [channel] : [new value].

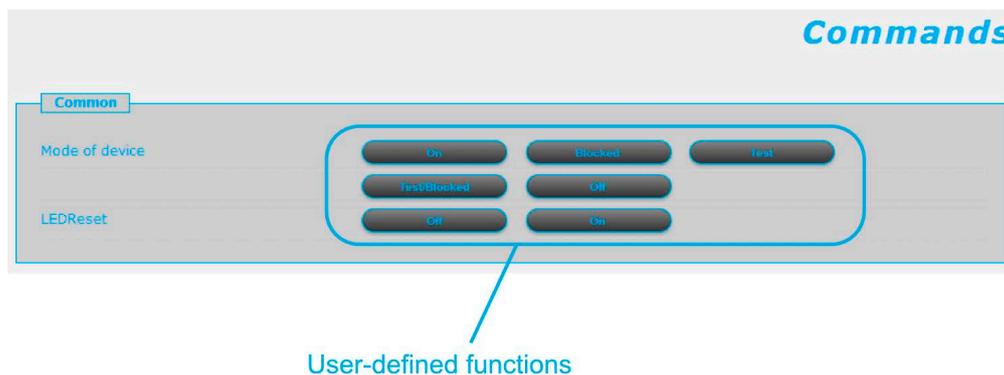
Figure. 5.4.3 - 23. Elements of the events menu.



With the **Refresh** button you can refresh the list displaying the events, the **Erase all events** button clears the list on the screen, and the **Export to file** button downloads the events and saves them as a .txt file.

### Commands menu

Figure. 5.4.3 - 24. The commands menu.



In the commands menu you can instruct the processor to carry out customized, user-defined commands. You can use the various mode buttons (**On**, **Blocked**, **Test**, **Test/Blocked**, **Off**) and LED buttons (**On**, **Off**) to define functions. A status update is always generated with a command, regardless of whether the command was successful or not. If the command was unsuccessful, the device gives the reason for the error.

### Disturbance recorder

This page displays a list of the disturbance records that the device has recorded.

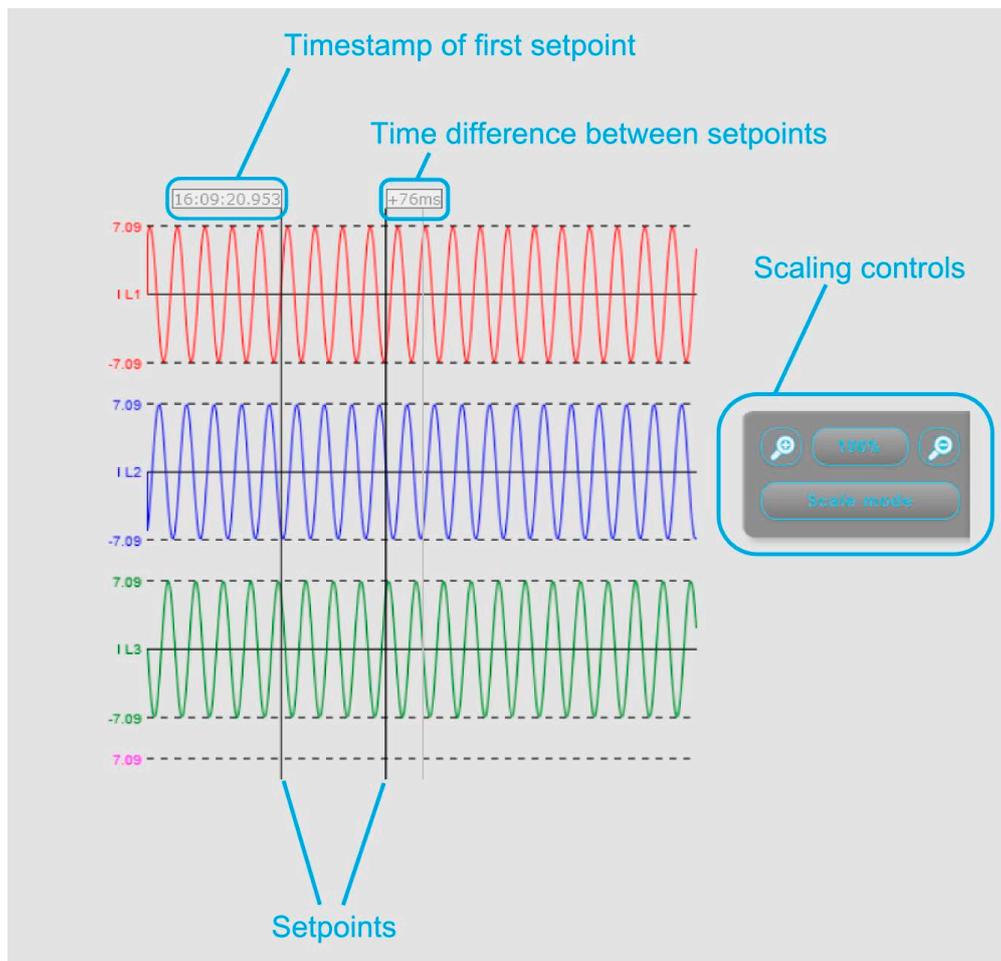
Figure. 5.4.3 - 25. Disturbance recorder.



The "Recorded disturbances" section lists all disturbance records. You can refresh the list with the **Refresh** button to display any new disturbance records that have occurred after the page was opened or refreshed last. You can also clear the list with the **Erase all records** button. Additionally, you can create a disturbance record manually by clicking the **Manual start** button.

There is one record per line. You can download the chosen record by clicking the **Download** button on its line; the device downloads you a COMTRADE file which you can then open with any supporting software for further evaluation. You can also click the **View** button to open a new browser window which then displays a simple preview of the disturbance record (see the image below).

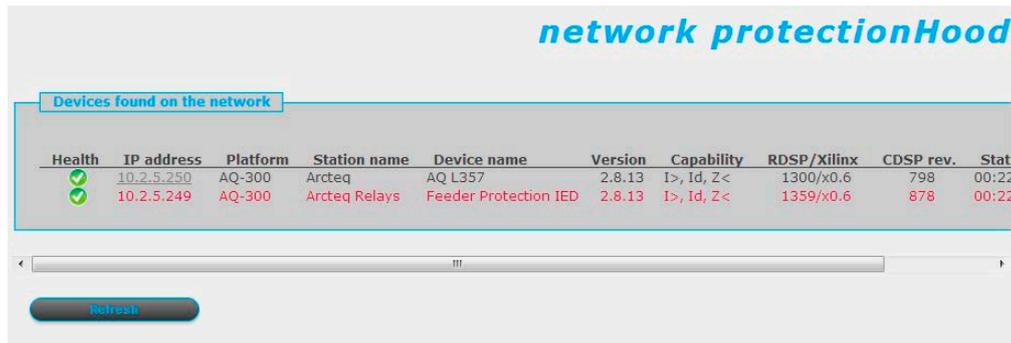
Figure. 5.4.3 - 26. Example of a disturbance record preview.



You can set a setpoint by clicking anywhere on the graph, and the positioning the cursor to a desired second point. The preview then displays the timestamp of the first setpoint, and the time difference between the two setpoints. You can also scale the time axis with the scaling controls (the plus and minus magnifying glasses), or by clicking the **Scale mode** button to switch between standard and scaled modes. The scaled mode stretches the Y axis of all recorded values.

## Network protectionHood

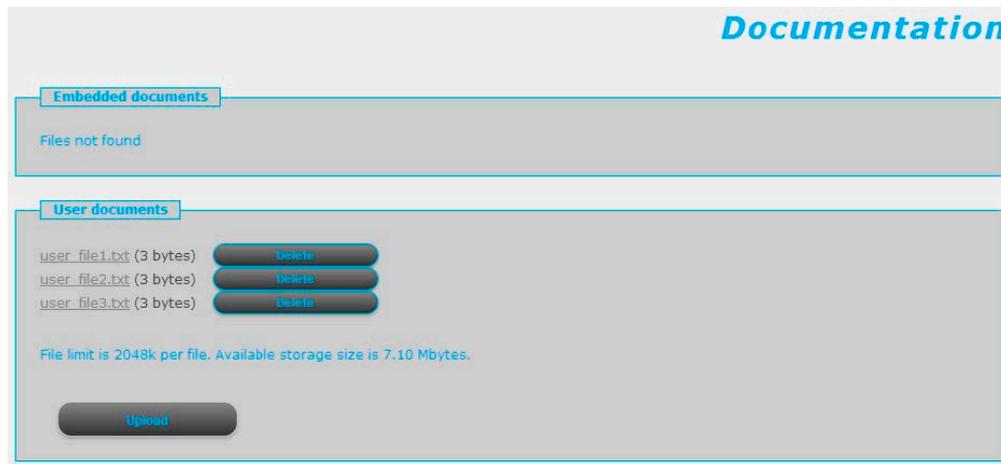
Figure. 5.4.3 - 27. The network protectionHood menu.



This page shows all other devices that are located in the same network with the AQ-300 unit. The page identifies compatible devices and displays information about them, such as their IP address and version. The device that is currently accessed is highlighted in red in the list. You are redirected to other devices by clicking their corresponding links. The **Refresh** button scans the network for connected devices.

## Documentation

Figure. 5.4.3 - 28. The documentation menu.

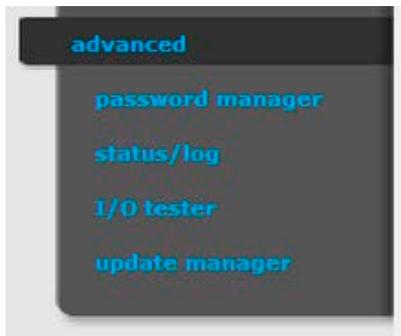


This page displays the documentation files on the device. You can upload other documents and files on the device, which are then saved and can be accessed later. One file can be up to 2048K , and there is storage for up to 8 MB of documentation.

The "Embedded documentation" section displays all the documents that have been preloaded into the device. You cannot delete these. The "User documents" section lists all the files the user has uploaded into the device, and you can delete them with the **Delete** button. You can upload a selected file with the **Upload** button. Please ensure that the file size is below the limit and that you have enough storage left before commencing the upload.

## Advanced

Figure. 5.4.3 - 29. The Advanced menu.

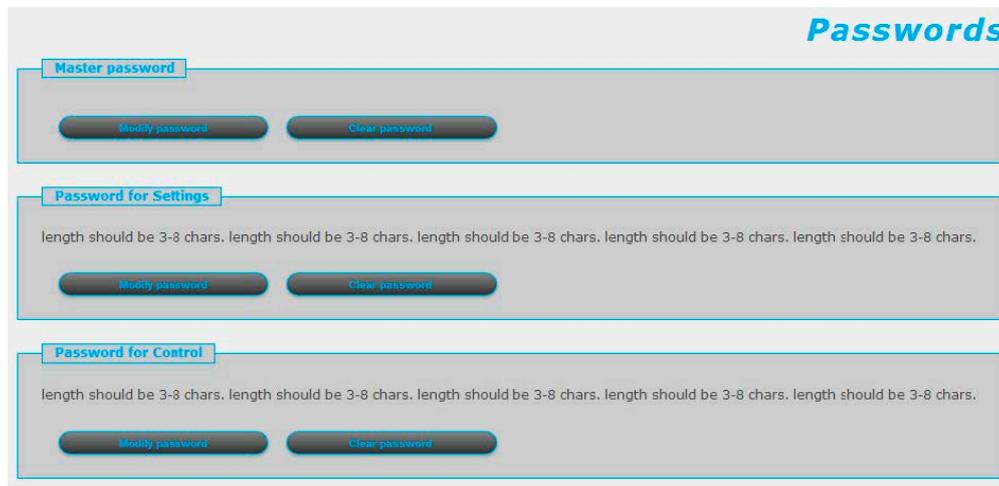


This menu displays the additional, more advanced options. You can set a password request before a user is allowed access to these options.

### Password manager

You can modify and clear the three available passwords. The *master password* is used for accessing the Advanced menu. The *password for settings* is required when a user wants to set parameters or settings, or wants to clear counters in the Online data menu. The *password for control* is required when executing commands in the Commands menu. If no password has been created, you can create one with the **Modify password** button.

Figure. 5.4.3 - 30. Password manager.



### Status/log

The Status/log submenu displays information from various logs. The log files are primarily meant for the manufacturer, but a user can also view them.

Figure. 5.4.3 - 31. Status/log.



The **Get report** button generates a .zip file that has all of the log files archived together. The files have valuable information and they can help in analyzing errors and malfunctions; see the table below for the different log types and their contents.

Table. 5.4.3 - 7. Log types.

Log name	Description
Relay CPU	Displays the logged events that are connected to the relay's CPU.
SPORT	Displays the log file from the SPORT communication interface.
System startup	Displays the events that have occurred when the system was started up.
Serial Comm	Displays the log file from the serial communication interface.
LCD display	Displays the log file about the events that have occurred with the LCD display.
IEC 61850	Displays the log file from the IEC 61850 communication interface.
Access	Displays information about the users who have accessed the device remotely through the embedded web browser interface.
Error	Displays the errors that have occurred with the remote user interface.



**NOTICE!**

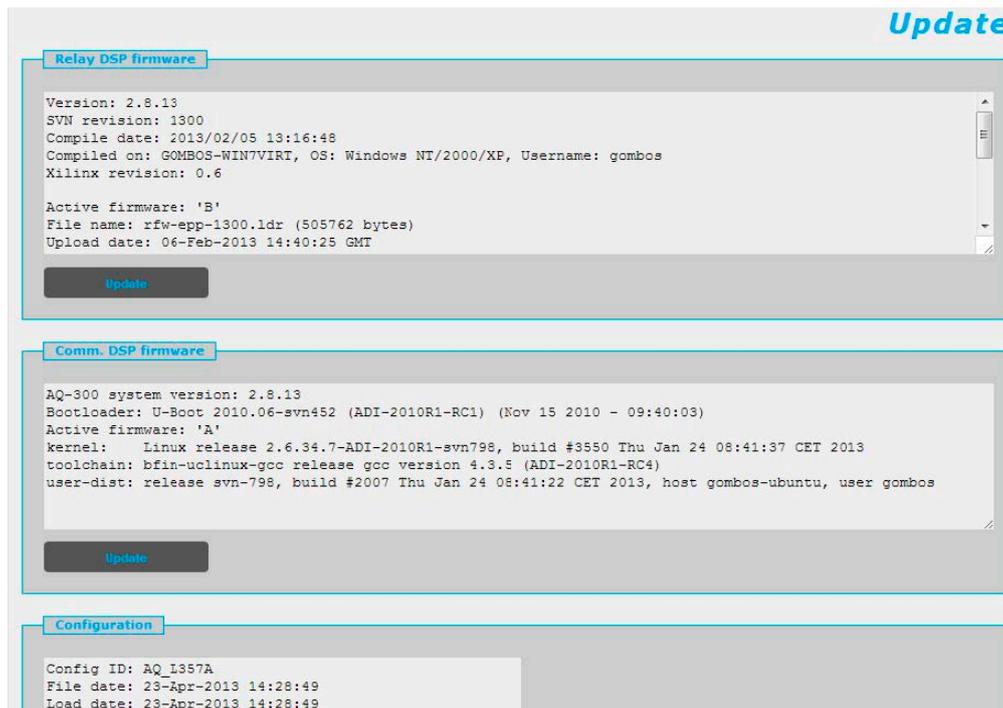
All log files are in English, regardless of your language selection!

**Update manager**

When a new version of the firmware is available, it can be updated in this submenu. Click the **Update** button of the correct section to select the new firmware file and upload it into the device. Please make sure that you are updating the right firmware; for example, do not attempt to update the "Relay DSP firmware" section with a "Comm. DSP firmware" file!

This page also displays information about the firmware currently in use as well as of the configuration of the device.

Figure. 5.4.3 - 32. Update manager.



## 5.4.4 Troubleshooting

Some browsers have a tendency to handle and cache various JavaScript function improperly, and this may cause anomalies and errors in the interface. If you notice improper functionalities, try to clear both the browser history and cache, and refresh the web page.

If this does not clear the problem, please contact Arcteq for further instructions.

## 6 Main characteristics of the AQ-B398 busbar protection system

- Low impedance biased busbar differential protection algorithm
- Dynamic internal busbar replica, based on disconnecter status signals
- High stability in case of external faults in spite of current transformer saturation
- Selectivity for internal fault, only the bays connected to the faulty busbar section are disconnected, all other bays remain in continuous operation
- Easy adaptation of the function for different primary bus systems:
  - Single busbar
  - Up to quadruple busbar
  - Ring bus
  - 1½ circuit breaker arrangement
  - Bus couplers
  - Bus sectionalizers with one or two current transformers
  - Transfer bus
- Individual numerical calculation and decision for all three phases
- Saturated waveform compensation
- Directionality check
- CT supervision
- Undervoltage/voltage breakdown criteria
- Independent check zone
- Typical trip <20ms
- Built-in breaker failure protection
- Optional redundant power supply
- Wide range of communication protocols, including IEC 61850

## 7 Software setup

### 7.1 Functions included in AQ-B398

In this chapter are presented the protection and control functions as well as the monitoring functions.

The implemented protection functions are listed in the table below. The function blocks are described in detail in following chapters.

Table. 7.1 - 8. Available protection functions

Function Name	IEC	ANSI	Description
DIF87B	3I <sub>d</sub> B>	87B	Low impedance biased busbar differential protection
BRF50MV	CBFP	50BF	Breaker failure protection

### 7.2 Measurements

#### 7.2.1 Current measurement and scaling

If the factory configuration includes a current transformer hardware module, the current input function block is automatically configured among the software function blocks. Separate current input function blocks are assigned to each current transformer hardware module.

A current transformer hardware module is equipped with four special intermediate current transformers. As usual, the first three current inputs receive the three phase currents (IL1, IL2, IL3), the fourth input is reserved for zero sequence current, for the zero sequence current of the parallel line or for any additional current. Accordingly, the first three inputs have common parameters while the fourth current input needs individual setting.

The role of the current input function block is to

- set the required parameters associated to the current inputs,
- deliver the sampled current values for disturbance recording,
- perform the basic calculations
  - Fourier basic harmonic magnitude and angle,
  - True RMS value;
- provide the pre-calculated current values to the subsequent software function blocks,
- deliver the calculated Fourier basic component values for on-line displaying.

The current input function block receives the sampled current values from the internal operating system. The scaling (even hardware scaling) depends on parameter setting, see parameters **Rated Secondary I1-3** and **Rated Secondary I4**. The options to choose from are 1A or 5A (in special applications, 0.2A or 1A). This parameter influences the internal number format and, naturally, accuracy. A small current is processed with finer resolution if 1A is selected.

If needed, the phase currents can be inverted by setting the parameter **Starpoint I1-3**. This selection applies to each of the channels IL1, IL2 and IL3. The fourth current channel can be inverted by setting the parameter **Direction I4**. This inversion may be needed in protection functions such as distance protection, differential protection or for any functions with directional decision.

Figure. 7.2.1 - 33. Example connection.

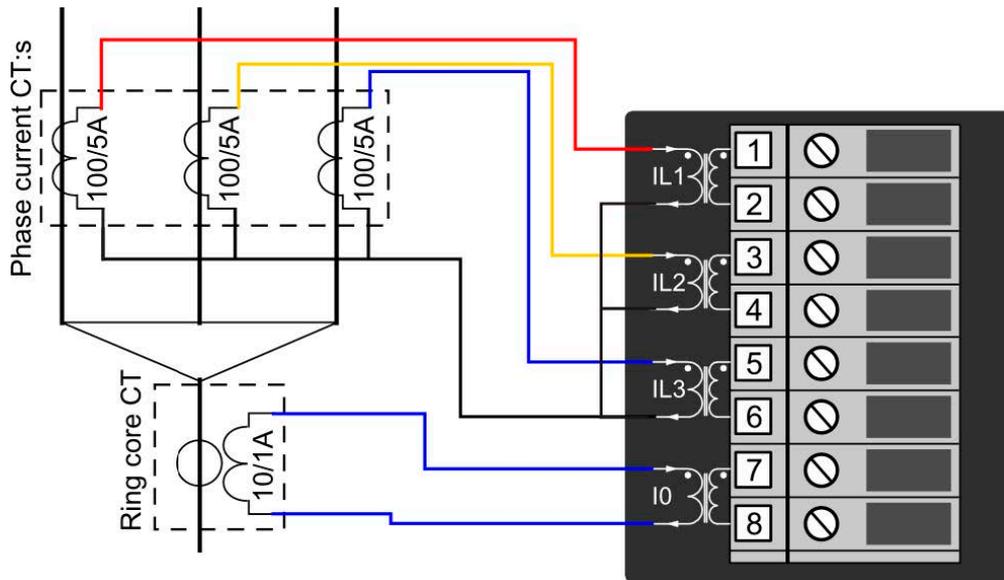


Table. 7.2.1 - 9. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: IOCT primary 10A IOCT secondary 1A
Phase current CT secondary currents starpoint is towards the line.	

Figure. 7.2.1 - 34. Example connection with phase currents connectef into summing "Holmgren" connection into the IO residual input.

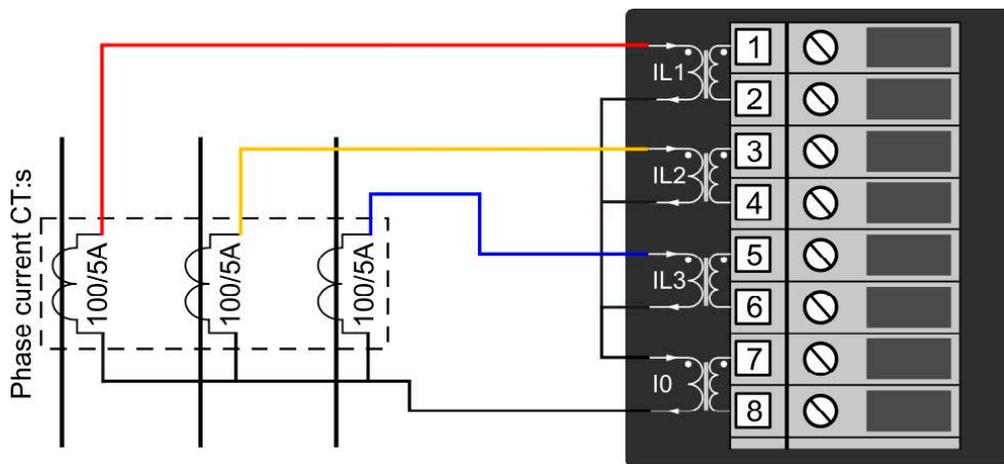


Table. 7.2.1 - 10. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: IOCT primary 100A IOCT secondary 5A
Phase currents are connected to summing "Holmgren" connection into the I0 residual input.	

The sampled values are available for further processing and for disturbance recording.

The performed basic calculation results the Fourier basic harmonic magnitude and angle and the true RMS value. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

The function block also provides parameters for setting the primary rated currents of the main current transformer (Rated Primary I1-3 and Rated Primary I4). This function block does not need that parameter settings. These values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc.

Table. 7.2.1 - 11. Enumerated parameters of the current input function

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A (0.2A, 1A) is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A, 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table. 7.2.1 - 12. Floating point parameters of the current input function

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1-3					
CT4_Pri13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_Pri4_FPar_	Rated Primary I4	A	100	4000	1000

Table. 7.2.1 - 13. Online measurements of the current input function

Measured value	Dim.	Explanation
Current Ch - I1	A(secondary)	Fourier basic component of the current in channel IL1
Angle Ch - I1	degree	Vector position of the current in channel IL1
Current Ch - I2	A(secondary)	Fourier basic component of the current in channel IL2
Angle Ch - I2	degree	Vector position of the current in channel IL2
Current Ch - I3	A(secondary)	Fourier basic component of the current in channel IL3

Measured value	Dim.	Explanation
Angle Ch - I3	degree	Vector position of the current in channel IL3
Current Ch - I4	A(secondary)	Fourier basic component of the current in channel I4
Angle Ch - I4	degree	Vector position of the current in channel I4

**NOTICE!**



The scaling of the Fourier basic component is such that if pure sinusoid 1A RMS of the rated frequency is injected, the displayed value is 1A. The displayed value does not depend on the parameter setting values "Rated Secondary".

**NOTICE!**



The reference of the vector position depends on the device configuration. If a voltage input module is included, then the reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. If no voltage input module is configured, then the reference vector (vector with angle 0 degree) is the vector calculated for the first current input channel of the first applied current input module. (The first input module is the one, configured closer to the CPU module.)

## 7.2.2 Voltage measurement and scaling

If the factory configuration includes a voltage transformer hardware module, the voltage input function block is automatically configured among the software function blocks. Separate voltage input function blocks are assigned to each voltage transformer hardware module.

A voltage transformer hardware module is equipped with four special intermediate voltage transformers. As usual, the first three voltage inputs receive the three phase voltages (UL1, UL2, UL3), the fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchro switching.

The role of the voltage input function block is to

- set the required parameters associated to the voltage inputs,
- deliver the sampled voltage values for disturbance recording,
- perform the basic calculations
  - Fourier basic harmonic magnitude and angle,
  - True RMS value;
- provide the pre-calculated voltage values to the subsequent software modules,
- deliver the calculated basic Fourier component values for on-line displaying.

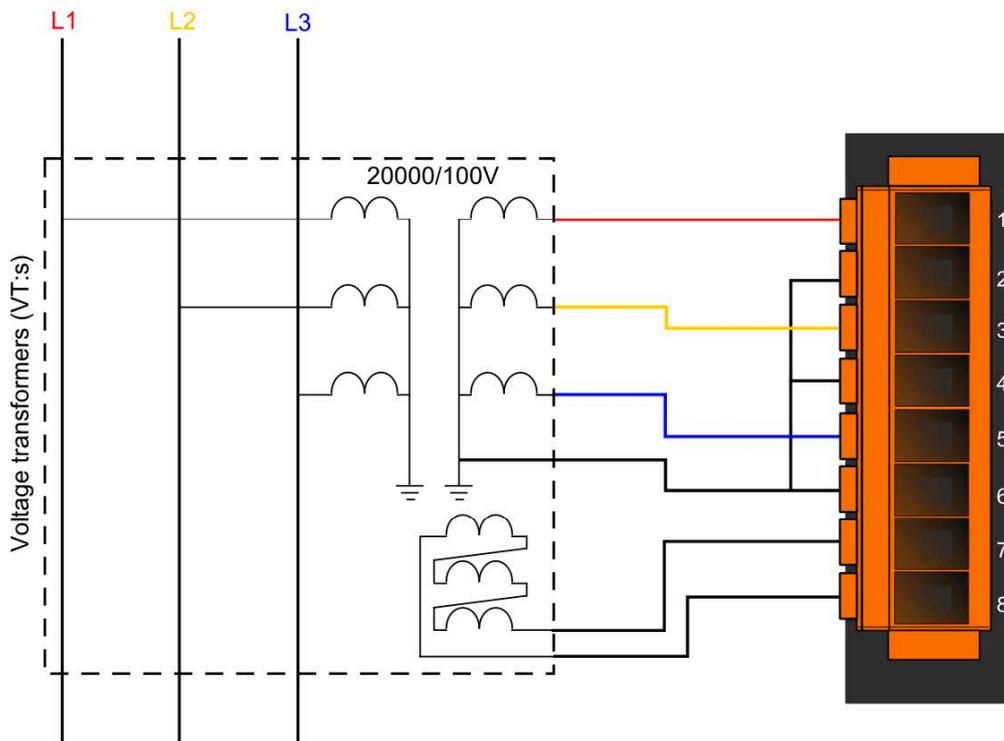
The voltage input function block receives the sampled voltage values from the internal operating system. The scaling (even hardware scaling) depends on a common parameter "Range" for type selection. The options to choose from are 100V or 200V, no hardware modification is needed. A small voltage is processed with finer resolution if 100V is selected. This parameter influences the internal number format and, naturally, accuracy.

There is a correction factor available if the rated secondary voltage of the main voltage transformer (e.g. 110V) does not match the rated input of the device. The related parameter is "VT correction". As an example: if the rated secondary voltage of the main voltage transformer is 110V, then select Type 100 for the parameter "Range" and the required value to set here is 110%.

The connection of the first three VT secondary windings must be set to reflect actual physical connection of the main VTs. The associated parameter is "Connection U1-3". The selection can be: Ph-N, Ph-Ph or Ph-N-Isolated.

The Ph-N option is applied in solidly grounded networks, where the measured phase voltage is never above  $1.5 \cdot U_n$ . In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

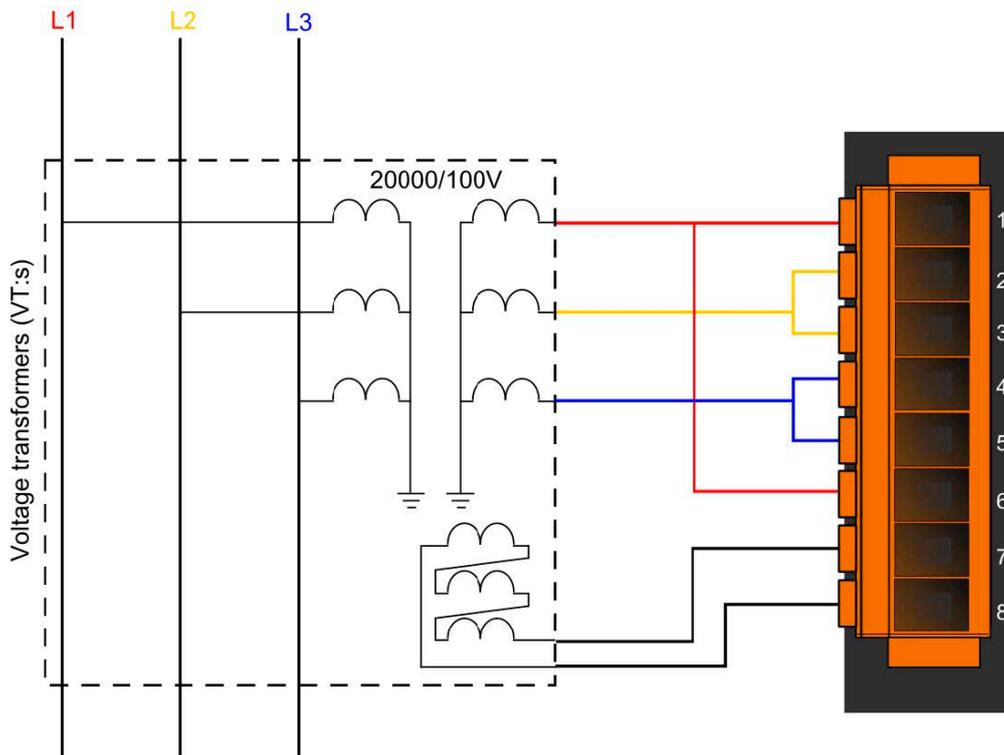
Figure. 7.2.2 - 35. Phase to neutral connection. Connection U1-3.



Ph-N Voltage: Rated Primary U1-3: $11.55\text{kV} (=20\text{kV}/\sqrt{3})$ Range: Type 100	Residual voltage: Rated Primary U4: 11.54A
--	---

If phase-to-phase voltage is connected to the VT input of the device, then the Ph-Ph option is to be selected. Here, the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage. This option must not be selected if the distance protection function is supplied from the VT input.

Figure. 7.2.2 - 36. Phase-to-phase connection.



Ph-N Voltage: Rated Primary U1-3: 20kV Range: Type 100	Residual voltage: Rated Primary U4: 11.54A ( $=20kV/\sqrt{3}$ )
--	--

The fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchron switching. Accordingly, the connected voltage must be identified with parameter setting "Connection U4". Here, phase-to-neutral or phase-to-phase voltage can be selected: Ph-N, Ph-Ph.

If needed, the phase voltages can be inverted by setting the parameter "Direction U1-3". This selection applies to each of the channels UL1, UL2 and UL3. The fourth voltage channel can be inverted by setting the parameter "Direction U4". This inversion may be needed in protection functions such as distance protection or for any functions with directional decision, or for checking the voltage vector positions.

These modified sampled values are available for further processing and for disturbance recording.

The function block also provides parameters for setting the primary rated voltages of the main voltage transformers. This function block does not need that parameter setting but these values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc.

Table. 7.2.2 - 14. Enumerated parameters of the voltage input function

Parameter name	Title	Selection range	Default
Rated secondary voltage of the input channels. 100 V or 200V type is selected by parameter setting, no hardware modification is needed.			
VT4_Type_EPar_	Range	Type 100,Type 200	Type 100
Connection of the first three voltage inputs (main VT secondary)			

Parameter name	Title	Selection range	Default
VT4_Ch13Nom_EPar_	Connection U1-3	Ph-N, Ph-Ph, Ph-N-Isolated	Ph-N
Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage			
VT4_Ch4Nom_EPar_	Connection U4	Ph-N,Ph-Ph	Ph-Ph
Definition of the positive direction of the first three input channels, given as normal or inverted			
VT4_Ch12Dir_EPar_	Direction U1-3	Normal,Inverted	Normal
Definition of the positive direction of the fourth voltage, given as normal or inverted			
VT4_Ch4Dir_EPar_	Direction U4	Normal,Inverted	Normal

Table. 7.2.2 - 15. Integer parameters of the voltage input function

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage correction						
VT4_CorrFact_IPar_	VT correction	%	100	115	1	100

Table. 7.2.2 - 16. Float point parameters of the voltage input function

Parameter name	Title	Dim.	Min	Max	Default
Rated primary voltage of channel1					
VT4_PriU1_FPar_	Rated Primary U1	kV	1	1000	100
Rated primary voltage of channel2					
VT4_PriU2_FPar_	Rated Primary U2	kV	1	1000	100
Rated primary voltage of channel3					
VT4_PriU3_FPar_	Rated Primary U3	kV	1	1000	100
Rated primary voltage of channel4					
VT4_PriU4_FPar_	Rated Primary U4	kV	1	1000	100



**NOTICE!**

The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

Table. 7.2.2 - 17. On-line measured analogue values of the voltage input function

Measured value	Dim.	Explanation
Voltage Ch - U1	V(secondary)	Fourier basic component of the voltage in channel UL1
Angle Ch - U1	degree	Vector position of the voltage in channel UL1
Voltage Ch - U2	V(secondary)	Fourier basic component of the voltage in channel UL2

Measured value	Dim.	Explanation
Angle Ch - U2	degree	Vector position of the voltage in channel UL2
Voltage Ch - U3	V(secondary)	Fourier basic component of the voltage in channel UL3
Angle Ch - U3	degree	Vector position of the voltage in channel UL3
Voltage Ch - U4	V(secondary)	Fourier basic component of the voltage in channel U4
Angle Ch - U4	degree	Vector position of the voltage in channel U4



**NOTICE!**

The scaling of the Fourier basic component is such if pure sinusoid 57V RMS of the rated frequency is injected, the displayed value is 57V. The displayed value does not depend on the parameter setting values "Rated Secondary".



**NOTICE!**

The reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. The first voltage input module is the one, configured closer to the CPU module.

## 7.3 Busbar differential protection function

### 7.3.1 Busbar replica evaluation

The busbar protection algorithm continuously evaluates the status signals of the disconnectors and if there are changes in the status signals then based on the received signals the algorithm performs "configuration", which means determination of the busbar replica of the substation and an assignment of "Measuring elements" to each interconnected bus sections.



**NOTICE!**

If bus sections are interconnected with each other then only one of the assigned measuring elements performs the calculation and the results are passed to all other measuring elements of interconnected bus sections. It means that the on-line displayed values will be the same for these bus sections.

The busbar protection function performs synchronous sampling of all analog signals. These values are used by the assigned "Measuring elements" of the busbar protection functions. The "Measuring elements" are explained in following chapters.

### 7.3.2 Differential current calculation

The method of the differential current calculation is as follows:

- Summation of the sampled  $I_p$  momentary current values for the bays connected to the "Measuring element". The result is the calculated momentary value of the differential current.

$$I_{d.p} = \sum I_p$$

- Filtering the current DC component by subtracting from the actual value the value sampled 10ms before, and the difference is divided by two. The result is the calculated momentary value of the differential current without the DC component.

$$I_{d.p1} = \frac{I_{d.p} - I_{d.p-10ms}}{2}$$

- The magnitudes of the ten last calculated values are averaged, receiving the  $I_d$  trip current. The result is the “rectified average” of the differential current. (The method is the numerical realization of the measuring principle of the Depres measuring instruments.)

$$I_d = \frac{\sum_{n=1}^{10} |I_{d.pn}|}{10}$$

### 7.3.3 Biasing current calculation

The method of the biasing current calculation is as follows:

- From the absolute value of the sampled  $I_p$  momentary current values a predetermined (with parameter setting) “ $Max.I\_load$ ” value is subtracted:

$$|I_p| - Max.I\_Load$$

Here  $Max.I\_load$  is a parameter setting, the proposed value of it is the expected maximum load current value of all bay currents. The result is that in normal operation, when all bay currents are below the maximum load current, the calculated values get negative.

- Out of these differences only the values above 0 (if  $(|I_p| - Max.I\_Load) > 0$ ) are summed:

$$I_{s.p} = \sum (|I_p| - Max.I\_Load)$$

The sum of these values can be positive only, if there are currents above the maximum load values, i.e. there is a fault (either external or internal of the busbar).

- Then the average of this value and that received 10 ms before is calculated:

$$I_{s.p1} = \frac{I_{s.p} + I_{s.p-10ms}}{2}$$

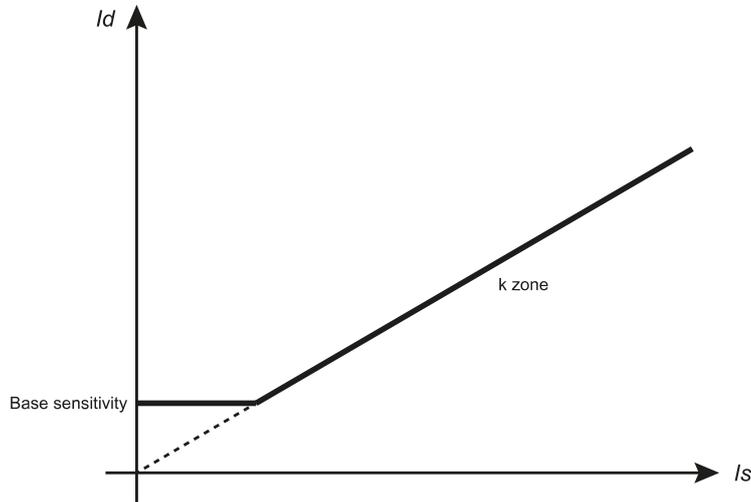
- The last ten calculated values stored in the memory are averaged, receiving the  $I_s$  biasing.

$$I_s = \frac{\sum_{n=1}^{10} |I_{s.pn}|}{10}$$

### 7.3.4 Differential characteristics

The trip characteristic for a measuring element is shown in the figure below:

Figure. 7.3.4 - 37. Trip characteristic of the busbar differential protection.



The setting parameters of the differential characteristics are listed in the table below:

Table. 7.3.4 - 18. Setting parameters of the differential characteristics.

Parameter name	Title	Unit	Min	Max	Step	Default
Percentage characteristic, base sensitivity						
Busbar_ZoneSens_IPar_	Base sensitivity	A	100	10,000	1	1,000
Percentage characteristic, slope*						
Busbar_ZoneK_IPar_	k zone*	%%	40	90	1	80

### 7.3.5 Offset setting ("Max.I\_Load")

There are two main requirements for the busbar differential protection:

- In case of busbar fault the operation shall be fast.
- In case of external faults the protection must be stable, no trip command may be generated.

Subtracting the "Max.I\_Load" value from all current samples serves both these aims. In normal operation all current samples are expected to be below this setting value, which is to be the maximum possible current peak value. Consequently in normal operation the bias current is zero.

If in this state an internal fault occurs then the current samples get very fast above "Max.I\_Load" value. Consequently the locus of the  $I_d-I_s$  points on the plane of the differential characteristics (see the figure above, "Trip characteristic of the busbar differential protection.") is at once above the line described by the slope "k" (parameter setting "k\_checkzone"). In this case the trip command needs a few checking points only, the trip command can be fast.

In case of external fault however, the locus of the  $I_d-I_s$  points on the plane of the differential characteristics (see the figure above, "Trip characteristic of the busbar differential protection.") start moving in the direction of the  $I_s$  axis. If the algorithm recognizes this movement, i.e. the locus is below the line described by the slope "k" then the number of the required check points gets a high value. This extended checking period does not permit trip command generation during the time period, when the iron core of the overloaded current transformer gets saturated, and it cannot deliver proportional secondary current for the measurement.

### 7.3.6 Voltage breakdown condition

In case of current transformer circuit error, the missing current from any of the bays, the measuring element detects current difference. This could result a trip command to the bus section. To prevent this kind of operation error, the trip command is released only if in the affected bus section the voltage collapses.

To perform this supervision, the presence of the voltage is monitored with a quick voltage measuring function. The result of the supervision is considered in every millisecond. If before increasing the current, the voltage is in the range of the normal operating voltage (above approximately  $0.6 \times U_n$ ), and then during a fault any of the voltages is below  $0.6 \times U_n$ , the function enables the operation of the differential protection function. If the currents fulfill the differential criteria, the algorithm generates a trip command.

If the differential protection function started and the bay units received trip command then this voltage condition does not play any role. The trip command resets only if the currents are outside the tripping zone of the characteristics.

A voltage monitoring function can allow trip command only for 0.5 s, then the function is disabled until the measured voltage returns to healthy state again, or a new initializing is performed (caused by disconnecter status change, switching on, parameter changes).

If all voltage monitoring functions assigned to a measuring element detect low voltage then the busbar section is considered to be disconnected, and the operation of the bus-bar differential protection is enabled again (to cover the switch-on-to-fault condition).

If the trip command is disabled by the voltage condition then the "On-line" screen of the connected PC displays the status signal as "U>disable: +". If one or more voltage supervisions detect low voltage then the display changes form "+" to "-". At that moment a 0.5 s timer is started, and when it expires then the operated voltage supervision function is disabled. As a consequence the signal shows "+" again.

The parameters for the voltage breakdown condition are fixed values and the function does not need any parameter setting.

### 7.3.7 The check zone

If any of the status signals received from the bays is wrong then the false operation based on this wrong signal could disconnect the bus section. To avoid this kind of errors the "check zone" is applied. This additional "check zone measuring element" supposes the whole busbar system as a single node. It gets all current samples from the bays (except those sampled from the current transformers connecting bus sections; this is to be selected in the process of the topology configuration by the user with "Master" access rights) and adds them all to get the check zone differential current. The individual measuring elements can generate a trip command only if also the "check zone measuring element" detects an internal busbar fault. The check zone operation must be enabled by parameter setting.

The parameters of the "check zone measuring element" are similar to those of the individual measuring element, but the values can be set independently.

### 7.3.8 Saturated waveform compensation

In case of external fault, with the exception of the faulty bay, all bays deliver currents towards the busbar. The sum of these currents flows through the current transformer of the faulty bay. Consequently this current can be extremely high, which can saturate the iron core of this current transformer. The shape of this secondary current gets distorted, and the “missing” section of the wave-shape is a differential current.

To prevent unwanted operation of the busbar differential protection function for these external faults, there are several remedies. One of them is the “saturated waveform compensation”. The algorithm “keeps” the detected current peak till the end of the half period, decreasing the chance for the false trip decision.

This method does not need any special parameter setting.

### 7.3.9 Directionality check

In case of internal fault all bays deliver currents towards the busbar. In case of external fault however, with the exception of the faulty bay, all bays deliver currents towards the busbar, and the current of the faulty bay flows out of the busbar. When considering this basic difference, the stability of the busbar differential protection can be improved by “directionality check”.

The busbar differential protection algorithm compares the sign of all current samples in a “measuring element”. If during the majority of the samples one of the currents shows opposite sign, indicating opposite direction, then this fact prevents generation of the trip command.

### 7.3.10 Current transformer failure detection

If the current transformers do not deliver correct currents for the evaluation then the correct decision of the busbar differential protection is not possible.

The currents are continuously supervised also during normal operation of the system, when the currents are below the operation level of the differential protection. If in this state any of the currents is missing then a relatively high differential current is measured (which is still not sufficient to operate the differential protection). The algorithm performs the current supervision based on a similar characteristic as the trip characteristic, which has a sensitive base setting and a given slope. (See the figure above, “Trip characteristic of the busbar differential protection.”)

If the measured currents result an  $I_d$ - $I_s$  point above this characteristic, then after a time delay the “measuring element” gets blocked.

### 7.3.11 Checking the disconnector status signals

The actual configuration of the busbar (interconnected or separated bus sections and the connection of the bays to the bus sections) is evaluated using status signals of the disconnectors. The status of each disconnectors is characterized by dual signals: “Disconnector open” and “Disconnector closed”. Only one of them can be true and one of them can be false. This function checks these status signals, and performs the decision based on parameter setting.

In normal operation when receiving faulty status signals from the disconnectors the device keeps the previous state for a time period defined by parameter setting. After this time delay the reaction of the algorithm depends on the setting of the dedicated enumerated parameter. If the setting of the “BadState Tolerate” is true, then the operation neglects the faulty status signal, and the last valid status is kept. In case of setting “false”, the “measuring element” gets blocked.

If the status error is detected after energizing or following parameter changes, the protection remains disabled until the faulty status is corrected, and generates “Differential protection disabled” and “Breaker failure disabled” status signals as well.

### 7.3.12 Measured values

For each voltage inputs the device measures and displays the phase voltages. The following table shows as an example the voltages of a bus section:

Table. 7.3.12 - 19. Measured voltages of the centralized busbar differential protection function (example).

Measured value	Dim.	Explanation
Voltage Ch – U1	(secondary) V	Phase voltage L1, Fourier base component
Voltage Ch – U2	(secondary) V	Phase voltage L2, Fourier base component
Voltage Ch – U3	(secondary) V	Phase voltage L3, Fourier base component

For each bays the device measures and displays the phase currents. The following table shows as an example the currents of a bay.

Table. 7.3.12 - 20. Measured phase currents of the centralized busbar differential protection function (example).

Measured value	Dim.	Explanation
Current Ch – I1	(secondary) V	Phase current L1, Fourier base component
Angle Ch – I1	deg	Phase angle of the current in L1
Current Ch – I2	(secondary) V	Phase current L2, Fourier base component
Angle Ch – I2	deg	Phase angle of the current in L2
Current Ch – I3	(secondary) V	Phase current L3, Fourier base component
Angle Ch – I3	deg	Phase angle of the current in L3

For each bus sections the device measures and displays the differential currents and the bias currents. The following table shows as an example the currents of a bus section. (If the bus sections are interconnected with each other then the displayed values are the same of the interconnected sections.)

Table. 7.3.12 - 21. Measured voltages of the centralized busbar differential protection function (example).

Measured value	Dim.	Explanation
I Diff L1	(primary) A	Differential current L1, Fourier base component
I Diff L2	(primary) A	Differential current L2, Fourier base component
I Diff L3	(primary) A	Differential current L3, Fourier base component
I Bias L1	(primary) A	Bias current L1, Fourier base component
I Bias L2	(primary) A	Bias current L2, Fourier base component
I Bias L3	(primary) A	Bias current L3, Fourier base component



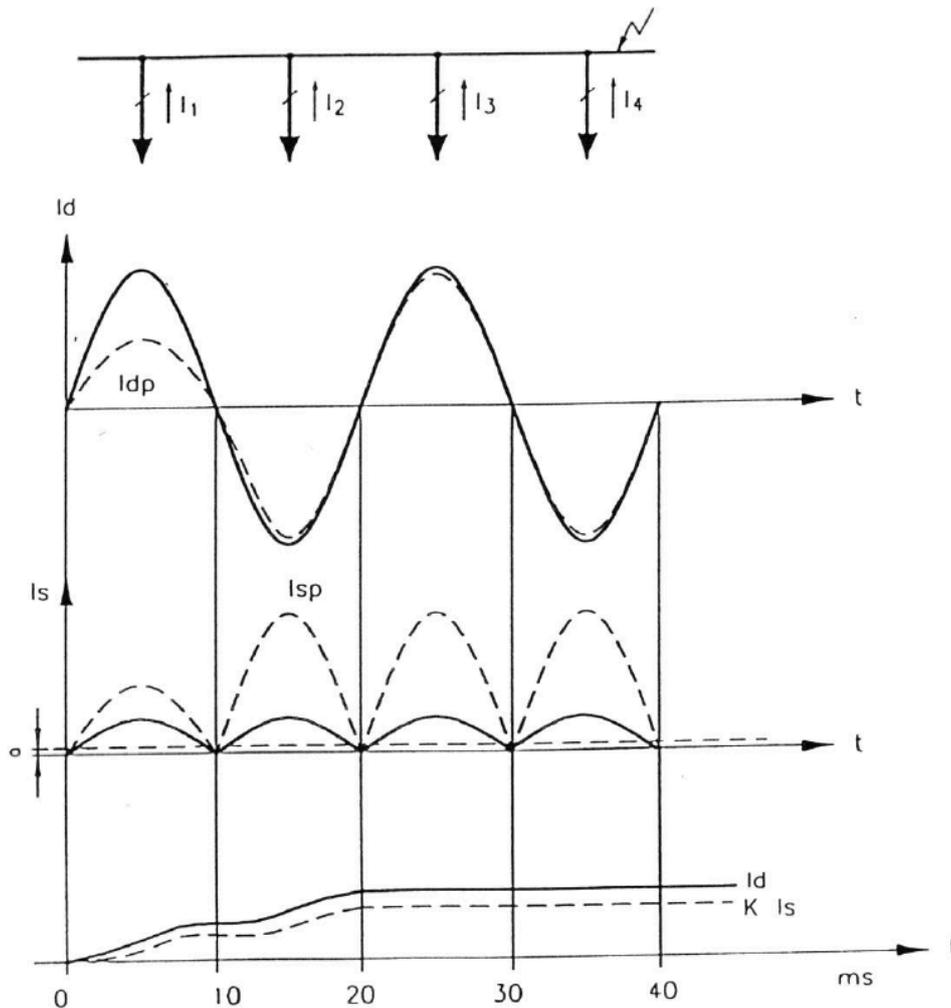
**NOTICE!**

The evaluated basic harmonic values of the measured input phase currents help the commissioning of the busbar differential protection function. The reference quantity of the per unit values is the rated current of the current input.

### 7.3.13 Behavior of the algorithm in internal fault

For an internal bus-bar fault the measuring principle can be seen in the figure below.

Figure. 7.3.13 - 38. Measurement of the internal busbar fault.



The top of the figure above shows a simple busbar section configuration. Supplying the internal fault, all currents flow in the same direction. The “Idp” time function in the second row of the figure (drawn dashed), in the first half period has half value, because of the average calculation:

$$I_{d.p1} = \frac{I_{d.p} - I_{d.p-10ms}}{2}$$

The calculation is based on the sampled value summation (below) and that sampled 10 ms before:

$$I_{d.p} = \sum I_p$$

The “Isp” time function in the third row of the figure (drawn dashed), in the first half period has half value too, because of the average calculation:

$$I_{s.p1} = \frac{I_{s.p} + I_{s.p-10ms}}{2}$$

The average calculation is based on the calculation mentioned before:

$$I_{s.p} = \sum (|I_p| - Max.I\_Load)$$

(if  $|I_p| - Max.I\_Load > 0$ ).

Because in normal operation these values are continuously zero, the “a” loadcurrent value is continuously subtracted.

The bottom curve of the figure shows  $I_d$  and  $K \cdot I_s$ , which is the result of averaging 10 values:

$$I_d = \frac{\sum_{n=1}^{10} |I_{d.pn}|}{10}$$

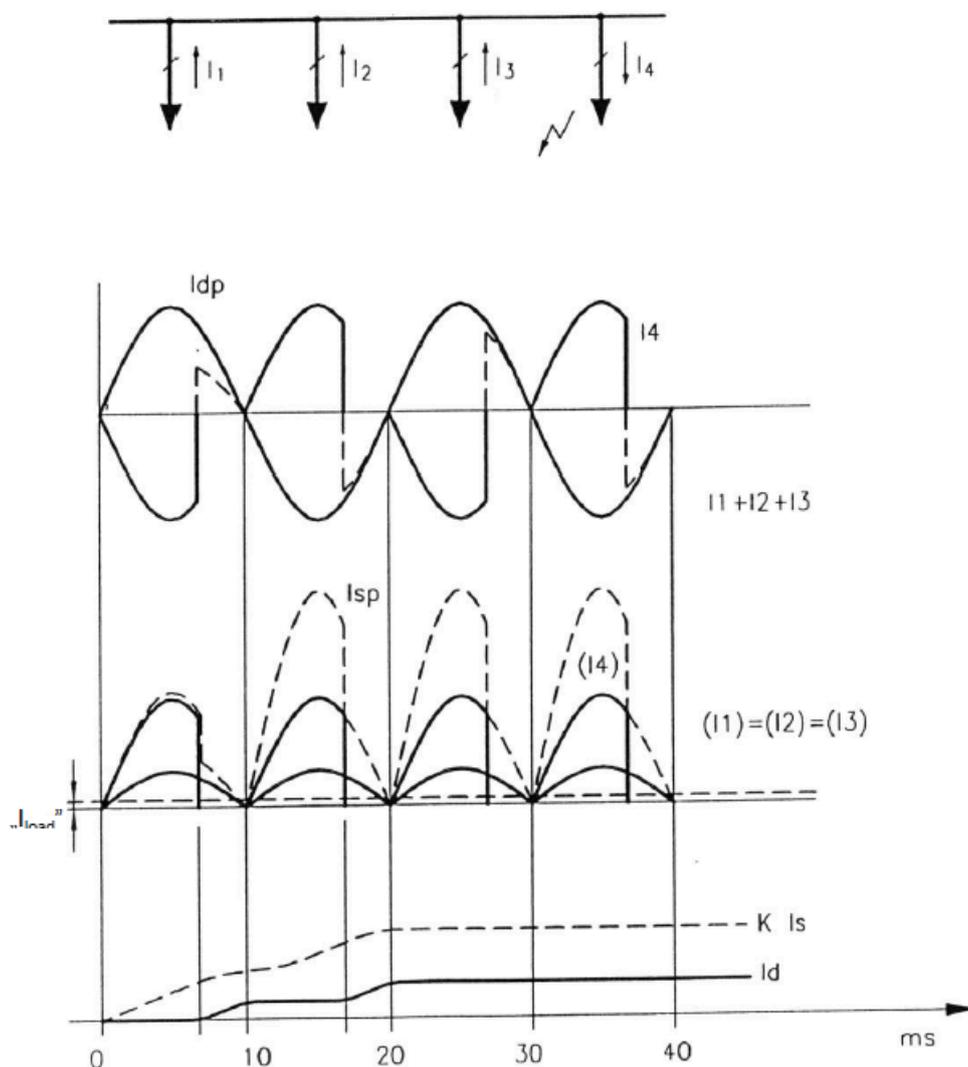
$$K \times I_s = K \times \frac{\sum_{n=1}^{10} |I_{s.pn}|}{10}$$

As before fault both  $I_d$  and  $K \cdot I_s$  are zero the bottom curves in the figure increase step-by-step. In the evaluation there is no intentional time delay or measured value exclusion. Tripping is generated after 8 consecutive starting of the function. In case of internal fault as the figure shows,  $I_d$  is continuously above  $K \cdot I_s$ , and after 8 comparisons the measuring element automatically generates trip command. The command detected on the output relay is somewhat delayed because of the operating time of the relay. The duration of the trip impulse is at least 500 ms, the algorithm resets the command only after this time delay, if the conditions are reset meantime. The drop-off ratio of the trip current is 1.

### 7.3.14 Behavior of the algorithm in external fault

The figure below shows the calculation of the bias and differential currents for an external fault in case of heavy current transformer saturation.

Figure. 7.3.14 - 39. Measurement of the external busbar fault.



The top of the figure above shows a simple busbar section configuration, where Bay 4 has an external fault. The currents in the healthy bays flow in the same direction, the fault current in Bay 4 is the sum of these currents, and flows in inverse direction. Because of concentrated fault current the CT in Bay 4 can be saturated. The first curves of the figure show that opposite to the sum of the healthy bay current ( $I_1+I_2+I_3$ ) the  $I_4$  bay current is not exactly the inverse, some current samples are “missing” as caused by the distortion of the saturation. (The figure shows “ideal” saturation!). In calculation of  $I_{dp}$ , this “missing” current section is detected (dashed line).

The third section of the figure shows the calculated  $I_{sp}$  (dashed line too). It is clearly seen that the biasing current increases immediately, and because of the saturation the increasing is slowed down only at the end of the first half period. Of course in the first half period the values are halved, as in case of internal fault.

As the fourth section of the figure shows the summed  $K \cdot I_s$  biasing current is continuously above  $I_d$ . So in case of  $K=0.8$  the comparison performed in each millisecond never cause operation of the differential protection function.

Based on the figure the limits of the measuring principle of the algorithm can be explained:

Let’s suppose that the current transformer of the faulty bay saturates at  $I_T$  current, and that the current transformer cannot deliver secondary current in saturated state (“ideal saturation”).

If the sum of the currents on healthy bays is  $I_{zm}$  (this is the maximal fault current, when the protection operates correctly), in the faulty bay it is only  $I_T$  (less than the fault current) then the trip current is:

$$I_d = I_{zm} - I_T$$

The biasing current is with similar procedure:

$$K \times I_s = K \times [(I_{zm} + I_T) - n \times \text{Max.}I_{Load}]$$

, where  $n$  is the number of the bays,  $\text{Max.}I_{load}$  is the subtracted load current value.

In the following explanation  $\text{Max.}I_{load} = 0$  setting value is supposed.

The trip equation is:

$$I_d \geq K \times I_s$$

which yields with substitution of the expressions above:

$$I_{zm} = I_T \frac{1 + K}{1 - K}$$

This equation helps when setting the  $K$  biasing factor supposing the maximal  $I_{zm}$  or determination of the maximal  $I_{zm}$  in case of a given  $K$  setting.

Example: if the current transformer with rated current of 250 A primary saturates at  $I_T = 2,500$  A, and the setting is  $K = 0.5$ , then  $I_{zm} = 3 \cdot I_T = 30 \cdot I_n = 7,500$  A, if the setting is  $K = 0.8$ , then  $I_{zm} = 9 \cdot I_T = 90 \cdot I_n = 22,500$  A.

These data show that for stationary state this protection provides a sufficient protection.

If a current transformer is at the saturation limit in stationary state, (the fault current is equal with the saturation value) then the flux reaches the saturation level, and the "time to saturation" of the current transformer is 10 ms, and the current peak value is  $I_{Tcs} = 1.42 \cdot I_T$ . If the current exceeds this value, then the current transformer saturates in shorter time than 10 ms. Based on the principle of equality of areas the "time to saturation" can be calculated as shown below (supposing "ideal" saturation):

$$t_T = \frac{1}{\omega} \arccos \left( 1 - \frac{2}{I_{zm}/I_T} \right)$$

The maximal current, at which the current transmission of the current transformer is distortionless, which means that the current value at the moment of  $t_T$ , related to the  $I_{Tcs} = \sqrt{2} I_T$ .

$$\frac{I_{cs}}{I_{Tcs}} = \frac{I_{zm}}{I_T} \sin \omega t_T$$

The relations of these last two equations are shown in the figure above.

In case of a busbar with high short-circuit power the current transformer in the faulty bay can be extremely saturated. The figure above shows two cases supposing "ideal" saturation". In one case the time to saturation is 2 ms, in the other one it is 3 ms.

Based on the equations above the data are:

for

$$\frac{I_{zm}}{I_T} = 5$$

$t_T = 3$  ms and

$$\frac{I_{cs}}{I_{Tcs}} = 4$$

for

$$\frac{I_{zm}}{I_T} = 10$$

$t_T = 2$  ms and

$$\frac{I_{cs}}{I_{Tcs}} = 6$$

Figure. 7.3.14 - 40. Time to saturation and the maximal transmitted current as the function of the fault current.

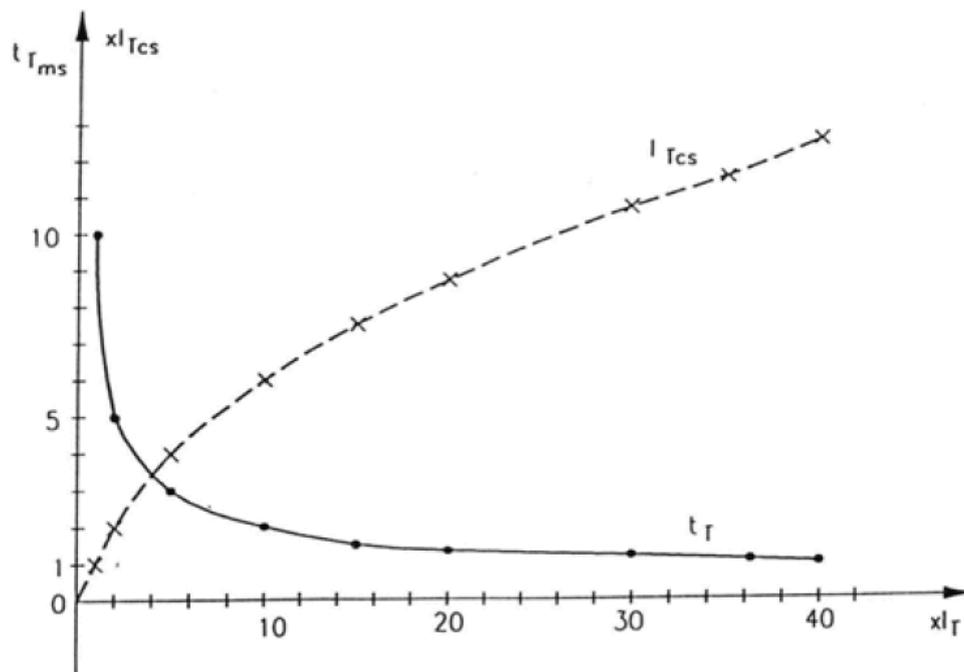
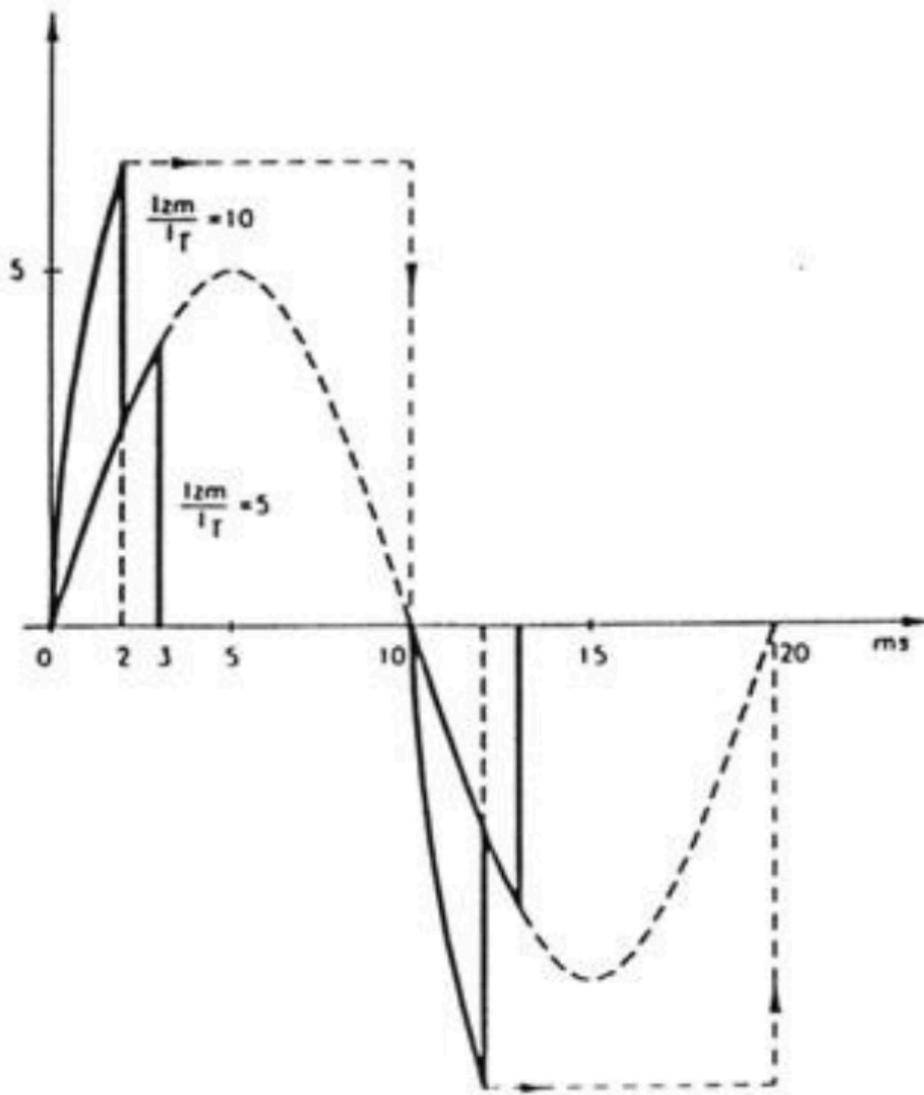
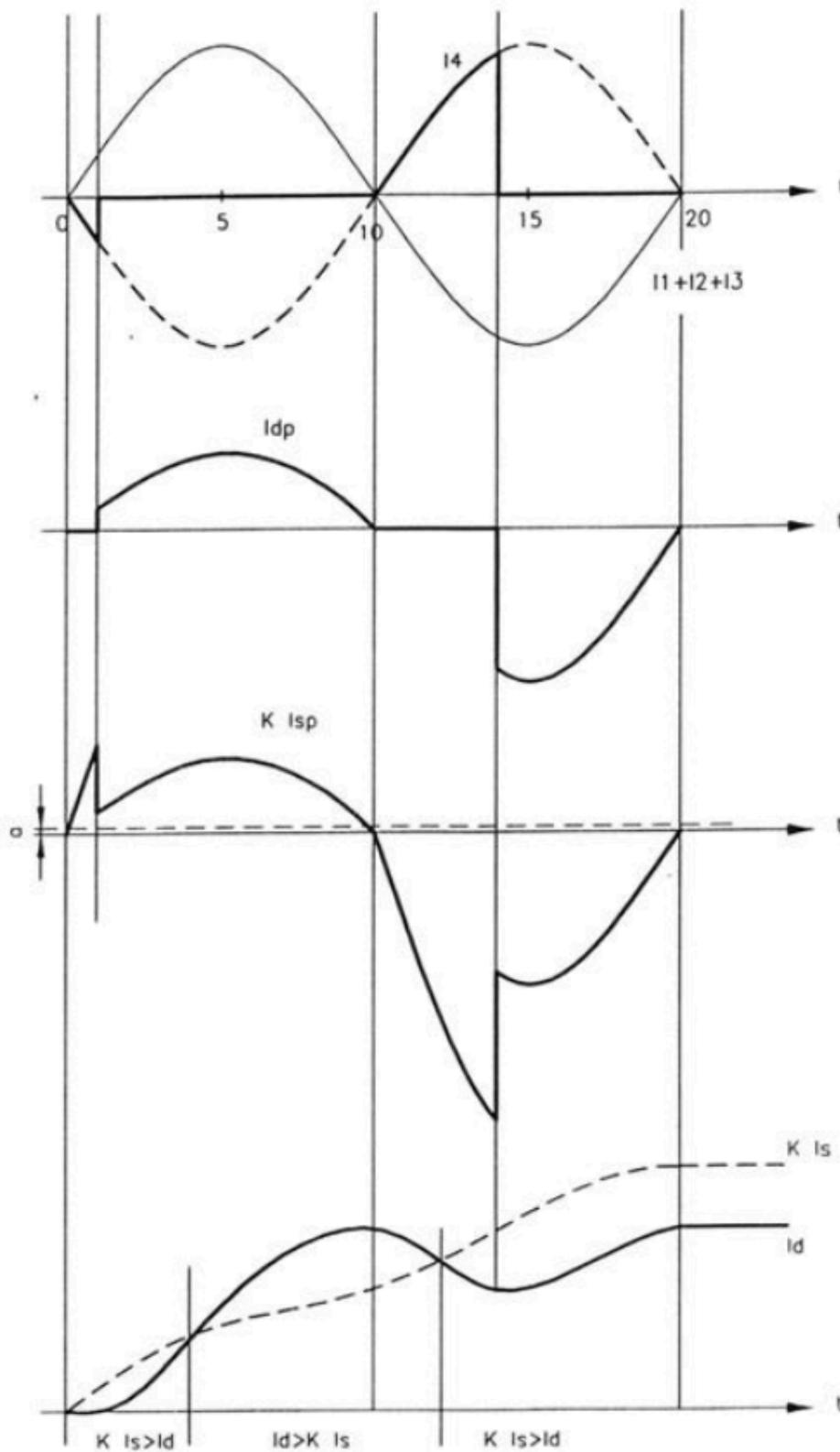


Figure. 7.3.14 - 41. External fault causing extreme saturation (supposing "ideal saturation").



In case of external fault, even if the time to saturation is below 2 ms, there can be a considerable time span, when  $I_d > K \cdot I_s$  (see the Figure titled "Measurement of the external busbar fault" in the previous subchapter). If this time is more than 8 ms, then the measuring element generates a false trip command for external fault. This can occur in case of high grade of transient saturation.

Figure. 7.3.14 - 42. External fault with 1 ms time to saturation.



To avoid false trip command in case of external fault the algorithm uses the following method. As it can be seen in the figure titled "Measurement of internal bus-bar fault" in the previous subchapter, at the beginning the biasing current is always above the trip current, and in this time the measuring element blocks the trip command. This blocking can never occur in case of internal fault, so in case of initial blocking it can be always supposed that the fault is an external fault. So if the biasing current is above the tripping current even in one step, then the measuring element switches over from 8 to 25 for the count limit of tripping conditions (the duration is in this case 25 ms). This method assures correct operation in case of extreme saturation as well.

The application of the method above does not result increasing operating time in case of internal fault, because the 25 times checking can occur only for external faults. The only exception is the "transition" of the fault location, when a close external fault evolves to internal fault. In this special case the operation can be expected only after a 25 ms time delay, but this method increases stability for external faults.

To avoid false tripping the algorithm applies an additional safety method. All bay units of the busbar differential protection system monitor in all three phases the increasing and decreasing periods of the bay currents. If in a bay the current increases, subsequently decreases within 3 ms, then the protection algorithm keeps the last high value up to the end of the half period. This method supplies at least partly the missing current samples, and at the same time no excess in biasing current can occur, because this curve shape results the same current value as the unsaturated one if the time span is 2 ms, and about the half value if the time span is 1 ms. (See the figure titled "Measurement of internal bus-bar fault" in the previous subchapter).

This method results suitable biasing and a small  $I_d$  value, which assures stability for stationary external faults even in case of 40 times saturation current (e.g. for  $n=10$  this means  $10 \cdot 40 = 400$  times rated current).

This explanation proves the use of the method keeping the last high value up to the end of the half period.

It has to be mentioned that even in extreme cases the method of changing the number of checking from 8 to 25 can prevent false tripping with high reliability. As the result of the application of the methods explained above the operation of the protection is reliable in case of extreme stationary saturation and for high residual flux value as well. The only requirement of the protection is  $t_T \geq 1$  ms minimal time to saturation (the time span, when the current transition is distortionless).

The busbar differential protection measures in all three phases, but the trip command is generated common for all three phases of the circuit breaker.

### 7.3.15 Setting parameters

Table. 7.3.15 - 22. Setting parameters of busbar differential protection function.

Parameter name	Setting value range	Setting step	Description
Operation	Off On	-	The operating mode selection of the differential function. The default setting is "Off".
CheckZone Operation	Off On	-	The check zone operation parameter. The default setting is "Off".
BFP Operation	Off On	-	The parameter to enable the trip command distribution of the breaker failure protection function. The default setting is "Off".
BadState Tolerate	Off On	-	The toleration of the disconnecter status signal errors. The default setting is "Off".

Parameter name	Setting value range	Setting step	Description
Base Sensitivity	100...10,000 A	1 A	The percentage characteristic for base sensitivity. The default setting is "1,000 A".
k zone	40...90 %	1 %	The percentage characteristic for slope. The default setting is "80 %".
CheckZone Sens	100...10,000 A	1 A	The check zone percentage characteristic for base sensitivity. The default setting is "1,000 A".
k checkzone	40...80 %	1 %	The check zone percentage characteristic for slope. The default setting is "50 %".
CT failure Sens	50...5,000 A	1 A	The CT error detection for base sensitivity. The default setting is "500 A".
k CT failure	40...80 %	1 %	The CT error detection for slope. The default setting is "40 %".
Max.I_load	0...10,000 A	1 A	The maximum load current (offset). The default setting is "1,000 A".
BadState Delay	100...60,000 ms	1 ms	The time delay for signaling a bad state. The default setting is "1,000 ms".
CT failure Delay	100...60,000 ms	1 ms	The time delay for signaling a CT error. The default setting is "1,000 ms".

Table. 7.3.15 - 23. Bay related setting parameters.

Parameter name	Setting value range	Setting step	Description
Bay disable	0: Enabled 1: Disabled	-	Disables and enables the bay (for example, during maintenance). The default setting is "0".
Rated secondary	1 A 5 A	-	The CT secondary rated current. The default setting is "1 A".
Star point I1-3	Line Bus	-	The location of the CT star point. The default setting is "Line".
CT nominal	100...10,000 A	1 A	The CT primary rated current. The default setting is "1,000 A".
BFP operation	Off On	-	Enables and disables the bay to be a part of a breaker failure protection scheme. The default setting is "Off".

Table. 7.3.15 - 24. Breaker failure protection related setting parameters.

Parameter name	Setting value range	Setting step	Description
Start Ph Current	20...200 %	1 %	The current condition for the breaker failure protection function. The default setting is "30 %".
Backup Time Delay	60...1,000 ms	1 ms	The breaker failure time delay setting. The default setting is "200 ms".

Parameter name	Setting value range	Setting step	Description
Pulse Duration	0...60,000 ms	1 ms	The breaker failure pulse duration setting. The default setting is "100 ms".
Intertrip operation (NB! only in distributed version)	Off On	-	The parameter to enable the trip command distribution of the breaker failure protection function.

Table. 7.3.15 - 25. Voltage breakdown parameters.

Parameter name	Setting value	Description
Voltage check	Fixed setting value of $0.6 \times U_n$	The voltage breakdown criterion. It has a fixed setting of $0.6 \times U_n$ .

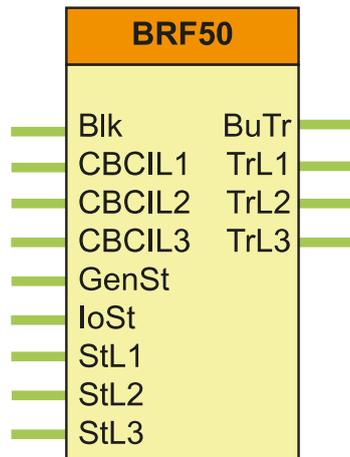
## 7.4 Breaker failure protection function

The breaker failure protection utilizes the processed status information of the busbar protection to disconnect only the section of the busbar to which the faulty circuit breaker is connected. So the other zones can remain in continuous service, fulfilling the same requirement as the busbar differential protection does. The starting of the breaker failure protection is received on dedicated binary input channels. For operation the current of the bay must be above the level, as set by an integer parameter value. Also the time delay of the function is a parameter value. The duration of the pulse can be set based on the status signals of the disconnectors, the algorithm selects all bays, which are interconnected with the bay announcing breaker failure. Accordingly only the minimum number of the bays gets the trip command, the other bus-sections remain in continuous operation.

Figure. 7.4 - 43. Function block of the breaker failure protection in centralized busbar protection version.



Figure. 7.4 - 44. Function block of the breaker failure protection in distributed busbar protection bay units.



This function block is identical to bay unit device circuit breaker failure protection block, for details of its function refer to related bay unit device instruction manual.

## 8 Busbar differential protection variants

The AQ-398 unit comes in two alternative configurations, either as centralized busbar protection or as distributed (de-centralized) busbar protection. In both configurations of the AQ-B398 unit provide three phase biased low impedance type of bus-bar differential protection and circuit breaker failure protection functions. The protection algorithm is identical in both configurations. The difference between the configurations is that in distributed system the bay related information is transferred to the AQ-B398 unit from bay units via fiber optic links whereas in centralized system the bay information is wired directly to AQ-B398 unit.

### 8.1 Distributed busbar protection

When the AQ-B398 unit is configured as a master unit of a distributed busbar protection system the busbar protection system operation is based on high-speed optical fibre cable communication between the AQ-B398 master unit and bay units. AQ 300 series protection IEDs can be utilized as bay units. The central unit performs bus section selective protection based on the information received from the bay units. The circuit breaker failure protection is activated by AQ B398 unit in case of failure in opening of the circuit breaker.

The distributed busbar protection system consists of one central unit, AQ B398 and one bay unit for each bay. The bay unit can be an AQ 300 series distance protection, transformer protection or an overcurrent protection IED with incorporated busbar protection bay unit feature. All bay units are interconnected with the central unit via high-speed serial fibre optic cable pairs.

The bay units send to the central unit the following information:

- the current values of each phase sampled with 1 ms time intervals
- presence or absence of the three phase voltages
- the status of bus disconnecting switches of the bay using two bit status signals
- starting command for the bay breaker failure protection
- trip signals.

The central unit sends to the bay units the following information:

- synchronizing signal with 1 ms time intervals
- trip command, when protection activates.

The central unit determines the busbar configuration based on the signals received via fibre optic communication links and assigns measuring elements to the bus sections. The measuring elements are used to determine the sum of the currents (current difference) and to calculate the biasing current based on the current magnitudes. The differential protection is based on the characteristics with a single knee point. The AQ B398 decision logic guarantees the correct operation even in case of high CT saturation. In order to issue the trip command the voltage breakdown condition must be fulfilled as well (voltage drop in faulty busbar and affected phase).

The breaker failure protection has two steps. The first step generates a repeat trip command to the selected bay unit's circuit breakers both trip coils and the second step issues a general trip command to all circuit breakers.

## 8.2 Centralized busbar differential protection

In centralized configurations all the bay current transformer inputs, bus section voltage transformer inputs and switching status inputs are wired directly to AQ 398 unit. The selected hardware configuration depends on the number of bays connected to the system (for more details refer to section 4.2.1). The AQ 398 performs bus section selective protection based on the information wired directly to the unit. The circuit breaker failure protection is activated by AQ B398 unit in case of failure in opening of the circuit breaker.

The centralized busbar protection unit determines the busbar configuration based on the wired status signals. The measuring elements are used to determine the sum of the currents (current difference) and to calculate the biasing current based on the current magnitudes. The differential protection is based on the characteristics with a single knee point. The AQ B398 decision logic guarantees the correct operation even in case of high CT saturation. In order to issue the trip command the voltage breakdown condition must be fulfilled as well (voltage drop in faulty busbar and affected phase).

The breaker failure protection has two steps. The first step generates a repeat trip command to the selected bay unit's circuit breakers both trip coils and the second step issues a general trip command to all circuit breakers.

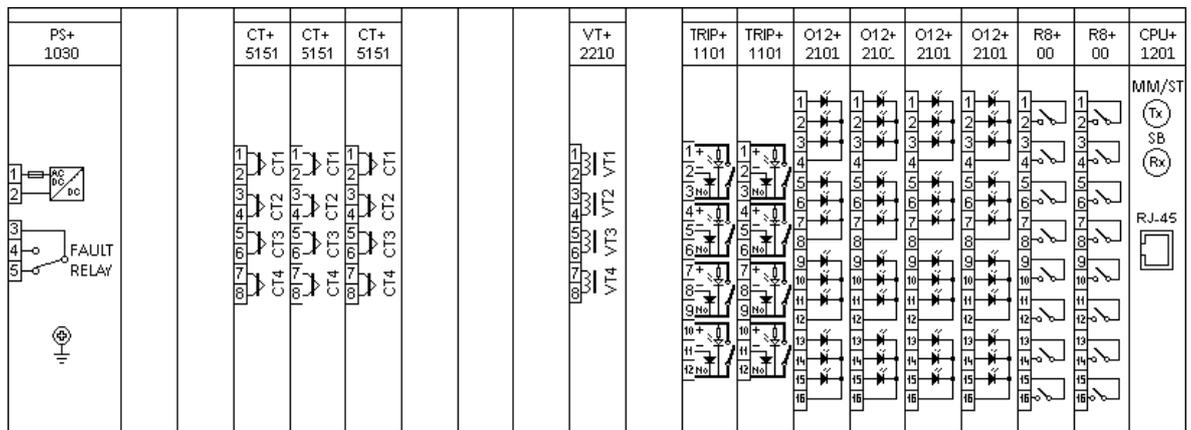
There are different variants for centralized busbar differential protection configurations. The maximum configuration in one AQ B398 unit contains six current transformer input cards and two voltage transformer input cards. This means that maximum 3-phase protection configuration is for six bays and two busbar sections. If more than six bays and/or two busbar sections are to be protected three AQ B398 units are needed, each in a single-phase configuration.

All configurations contain eight high speed trip outputs, 48 digital status inputs and 16 digital outputs. Communication options are in the CPU card. Optionally a redundant power supply may be utilized.

### Centralized busbar hardware configuration with three CT cards and one VT card

The hardware variant in the figure below contains three current transformer input cards and one voltage transformer input card. This variant can be utilized for 3-phase busbar differential protection of maximum three bays and one busbar section. Alternatively this unit can be used for 12 single phase bays and four single phase bus sections.

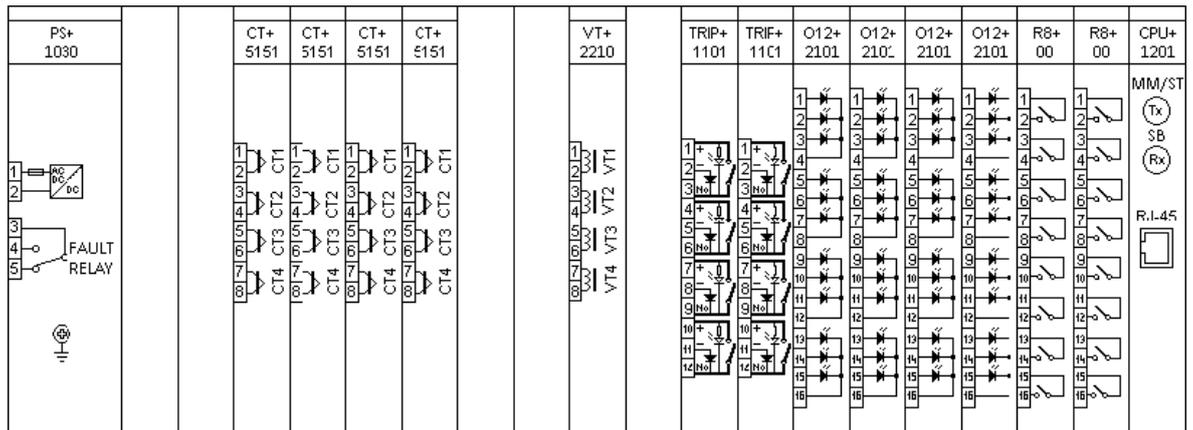
Figure. 8.2 - 45. Hardware variant of three CT cards and one VT card.



### Centralized busbar hardware configuration with four CT cards and one VT card

The hardware variant in the figure below contains four current transformer input cards and one voltage transformer input card. This variant can be utilized for 3-phase busbar differential protection of maximum four bays and one busbar section. Alternatively this unit can be used for 16 single phase bays and four single phase bus sections.

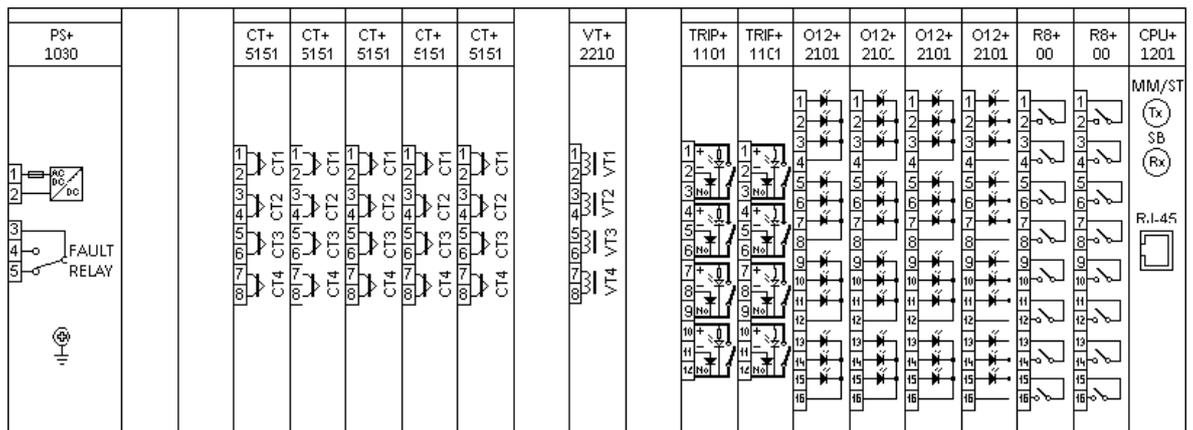
Figure. 8.2 - 46. Hardware variant of four CT cards and one VT card.



### Centralized busbar hardware configuration with five CT cards and one VT card

The hardware variant in the figure below contains five current transformer input cards and one voltage transformer input card. This variant can be utilized for 3-phase busbar differential protection of maximum five bays and one busbar section. Alternatively this unit can be used for 20 single phase bays and four single phase bus sections.

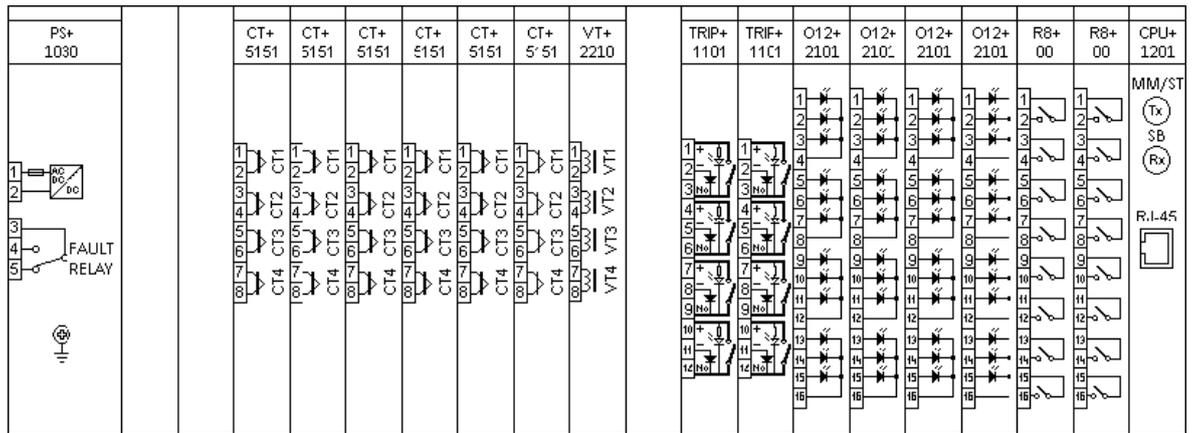
Figure. 8.2 - 47. Hardware variant of five CT cards and one VT card.



### Centralized busbar hardware configuration with six CT cards and one VT card

The hardware variant in the figure below contains six current transformer input cards and one voltage transformer input card. This variant can be utilized for 3-phase busbar differential protection of maximum six bays and one busbar section. Alternatively this unit can be used for 24 single phase bays and four single phase bus sections.

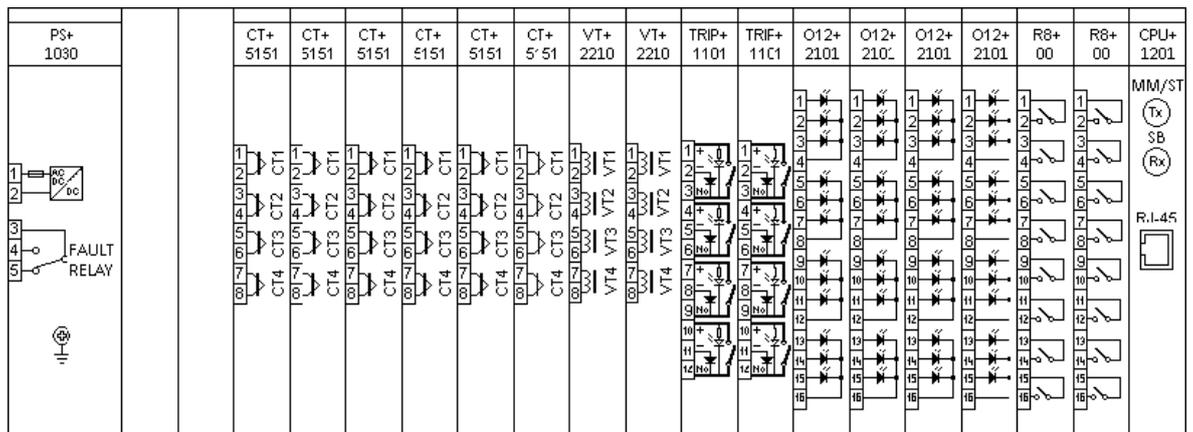
Figure. 8.2 - 48. Hardware variant of six CT cards and one VT card.



### Centralized busbar hardware configuration with six CT cards and two VT cards

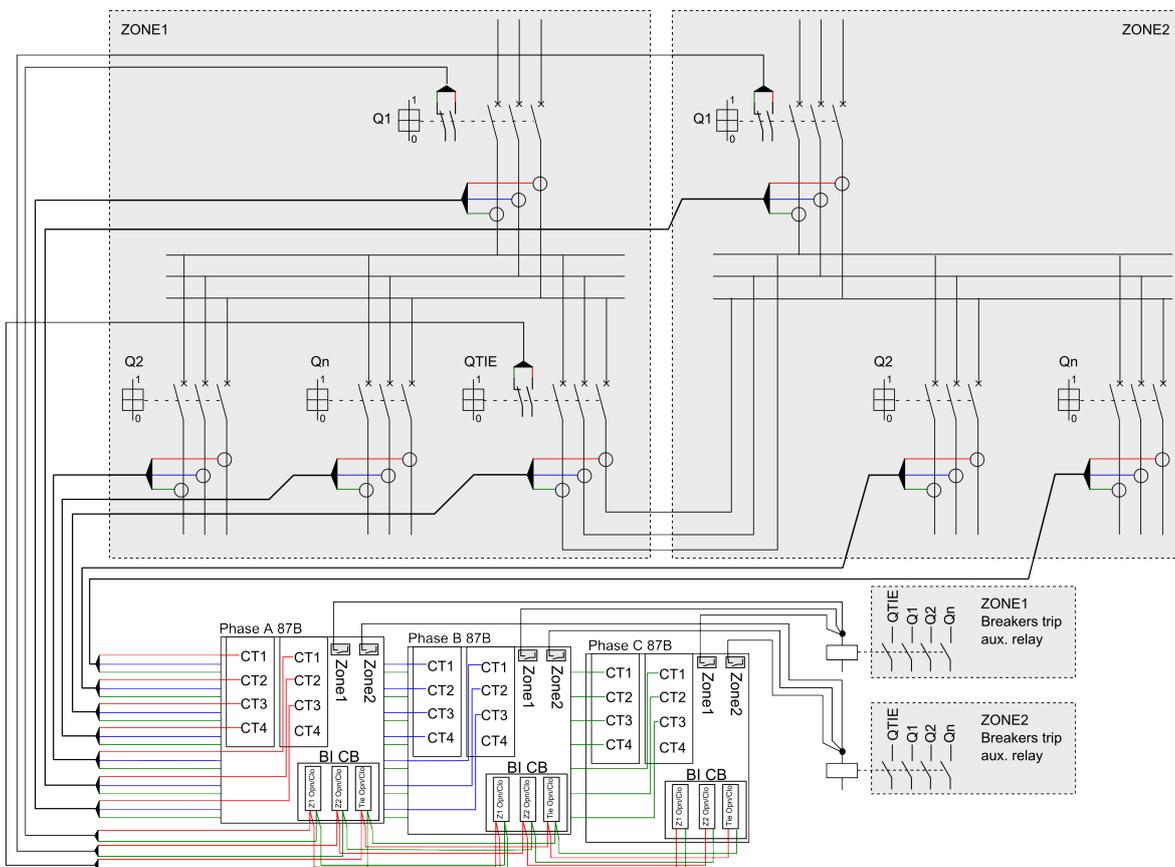
The hardware variant in the figure below contains six current transformer input cards and two voltage transformer input cards. This variant can be utilized for 3-phase busbar differential protection of maximum six bays and two busbar sections. Alternatively this unit can be used for 24 single phase bays and eight single phase bus sections.

Figure. 8.2 - 49. Hardware variant of six CT cards and two VT card.



## 8.3 Generic busbar protection application example

Figure. 8.3 - 50. Generic busbar protection application example.



## 8.4 Software configuration

The behavior of the busbar differential protection is determined by the configuration and the algorithm and related parameter setting.

### 8.4.1 Function blocks

The busbar protection related functions blocks are as described in following chapters. Both centralized and distributed busbar protection function blocks are explained.

#### Busbar function block

The busbar function block performs the organization of the busbar protection system, and also the numerical calculations and decisions are performed in this module. Based on the disconnector status information received from the bus sections “Measuring elements” are composed. A “Measuring element” processes all currents, which are flowing into or out of the interconnected bus sections. Accordingly the number of the processed “Measuring elements” can be the number of the individual bus sections, as a maximum; or there can be less “Measuring elements”, if some bus sections are interconnected with each other.

The busbar protection function always contains one “Busbar” function block. Its task is also to process the parameters of the busbar protection function. The symbol of the “Busbar” function block, as it appears in the AQtivate 300 software, is as follows.

Figure. 8.4.1 - 51. Bus function block in centralized busbar protection version.

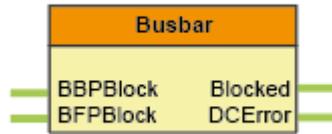


Figure. 8.4.1 - 52. Bus function block in distributed busbar protection version.

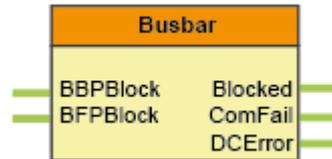


Table. 8.4.1 - 26. The binary input status signals of the centralized busbar differential protection function, central SW module.

Binary input signals	Signal title	Explanation
Busbar_BBPBlock_GrO_	BBP Block	Blocking the busbar differential protection function
Busbar_BFPBlock_GrO_	BFP Block	Blocking the breaker failure protection function

Table. 8.4.1 - 27. The binary output status signals of the centralized busbar differential protection function, central SW module.

Binary output signals	Signal title	Explanation
Busbar_Blocked_GrI_	Blocked	The busbar protection is in blocked state
Busbar_DCErrr_GrI_	DC Error	Disconnecter status error



**NOTICE!**

Please note that the COM fail signal in a distributed busbar protection version indicates a communication failure to bay unit(s)!

### Bus section function block

The number of these blocks coincides with the number of the bus sections. Up to 12 sections can be included. The task of this function block is to process the status signals, and to send them to the “Busbar” block to form the “Measuring elements”. The symbol of the “Bus section” function block, as it appears in the AQtivate 300 software, is as follows.

Figure. 8.4.1 - 53. Bus section function block in centralized busbar and distributed differential protection function, bus section SW modules.

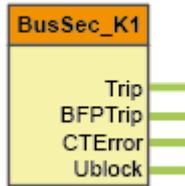


Table. 8.4.1 - 28. The binary output status signals of the centralized busbar differential protection function, bus section SW modules.

Binary output signals	Signal title	Explanation
BusSec_TripL1_Grl_M01	Trip L1	L1 trip signal for the bus section
BusSec_TripL2_Grl_M01	Trip L2	L2 trip signal for the bus section
BusSec_TripL3_Grl_M01	Trip L3	L3 trip signal for the bus section
BusSec_Trip_Grl_M01	Trip	General trip command for the bus section
BusSec_BFPTrip_Grl_M01	BFP Trip	Trip command generated by the breaker failure protection function
BusSec_CTError_Grl_M01	CT Error	Error in current measurement
BusSec_Ublock_Grl_M01	U block	The differential protection is blocked by voltage condition



**NOTICE!**

Please note that the parameters "Trip L1", "Trip L2", and "Trip L3" are valid only in the three-pole version!

### Bay unit function block

The number of these blocks coincides with the number of the bays in the substation. The task of this block is to receive and process all information from the primary devices of the bay:

- Currents (Three phase currents or one phase current, depending of the selected option)
- Voltages (Three phase voltages or one phase voltage, depending of the selected option)
- Status signals of the disconnectors: these signals are received with dual signals (disconnector open and disconnector closed). Up to 4 disconnectors can be configured to a physical bay.

This block passes the trip command to the circuit breaker of the bay.

This block also inputs the breaker failure signal from the bay protection units, and information related to the “stub” protection. The blocking input signal received by this bay unit disables the operation of the “Measuring element”, to which this bay is dynamically assigned.

Figure. 8.4.1 - 54. Bay unit function block in centralized busbar protection version.

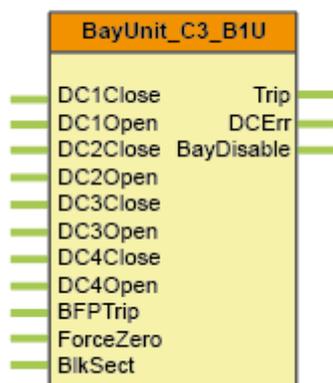


Figure. 8.4.1 - 55. Bay unit function block in distributed busbar protection mater unit.



Table. 8.4.1 - 29. The binary input status signals of the centralized busbar differential protection function, bay unit SW modules.

Binary input signals	Signal title	Explanation
BayUnit_BFPTrip_GrO_	BFP Trip	Breaker failure signal from the protection of the bay. The breaker failure protection passes this signal to all bays of the interconnected bus sections, related to this particular bay.
BayUnit_DC1Close_GrO_	DC1 Close	Disconnecter 1 in closed state
BayUnit_DC1Open_GrO_	DC1 Open	Disconnecter 1 in open state
BayUnit_DC2Close_GrO_	DC2 Close	Disconnecter 2 in closed state
BayUnit_DC2Open_GrO_	DC2 Open	Disconnecter 2 in open state
BayUnit_DC3Close_GrO_	DC3 Close	Disconnecter 3 in closed state
BayUnit_DC3Open_GrO_	DC3 Open	Disconnecter 3 in open state
BayUnit_DC4Close_GrO_	DC4 Close	Disconnecter 4 in closed state
BayUnit_DC4Open_GrO_	DC4 Open	Disconnecter 4 in open state
BayUnit_ForceZero_GrO_ (See the note below!)	Force Zero	In TRUE state of this input signal the bay unit sends zero value as the sampled current.
BayUnit_BlkJsect_GrO_	BlkJ Sect	In TRUE state of this input signal the measuring element related to this bay gets in blocked state.



**NOTICE!**

In bay units without CT the parameter "Force Zero" is missing!

Table. 8.4.1 - 30. The binary output status signals of the centralized busbar differential protection function, bay unit SW modules.

Binary output signals	Signal title	Explanation
BayUnit1f_DCErr_Grl_T1	DC Error	Disconnecter error
BayUnit1f_Trip_Grl_T1	Trip	Trip command to the circuit breaker of the bay
BayUnit_BayDisable_Grl_B1U	Bay disabled	Bay disabled

### Sectionalizer function block

These blocks serve mapping the sectionalizer bays, the bays which interconnect bus sections with disconnectors. These blocks receive up to two disconnector status signals.

Figure. 8.4.1 - 56. Sectionalizer function block in centralized busbar and distributed busbar protection version.

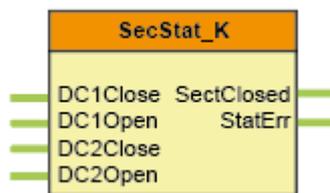


Table. 8.4.1 - 31. The binary input status signals of the centralized busbar differential protection function, sectionalizer SW modules.

Binary input signals	Signal title	Explanation
SecStat_DC1Close_GrO_	DC1 Close	Disconnecter 1 in closed state
SecStat_DC1Open_GrO_	DC1 Open	Disconnecter 1 in open state
SecStat_DC2Close_GrO_	DC2 Close	Disconnecter 2 in closed state
SecStat_DC2Open_GrO_	DC2 Open	Disconnecter 2 in open state

Table. 8.4.1 - 32. The binary output status signals of the centralized busbar differential protection function, sectionalizer SW modules.

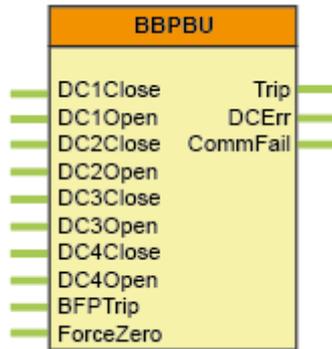
Binary output signals	Signal title	Explanation
SecStat_StatErr_Grl_K	Status Error	Status signal error
SecStat_SectClosed_Grl_K	Sect. Closed	Closed state of the sectionalizer

### Busbar bay unit function block

This block is applied only in the distributed busbar protection system and it is the “interface” between the power technology (measuring transformers, disconnector status signals, and circuit breaker trip commands) and the busbar protection function in the central device. In the bay device it receives the disconnector status information, the breaker failure signal from the protection function (according to the graphic assignment), and a special signal to exclude the measurements from the evaluation.

If the bay protection is to be involved in the busbar protection scheme, this function block is mandatory. The busbar protection function always contains one “Busbar” function block. Its task is also to process the parameters of the busbar protection configuration. The symbol of the “Busbar bay unit” function block, as it appears in the AQtivate 300, is as follows.

Figure. 8.4.1 - 57. Busbar bay unit function block in distributed busbar system.



In the “background” this block samples the assigned phase currents and voltages, and sends them, together with the status information to the central device via fiber optic network.

### Function block symbols

The function blocks of the centralized busbar differential protection function are shown in figures below. These blocks show all binary input and output status signals that are described in previous chapters.

Figure. 8.4.1 - 58. Function blocks of the centralized busbar differential protection function, single-pole version.

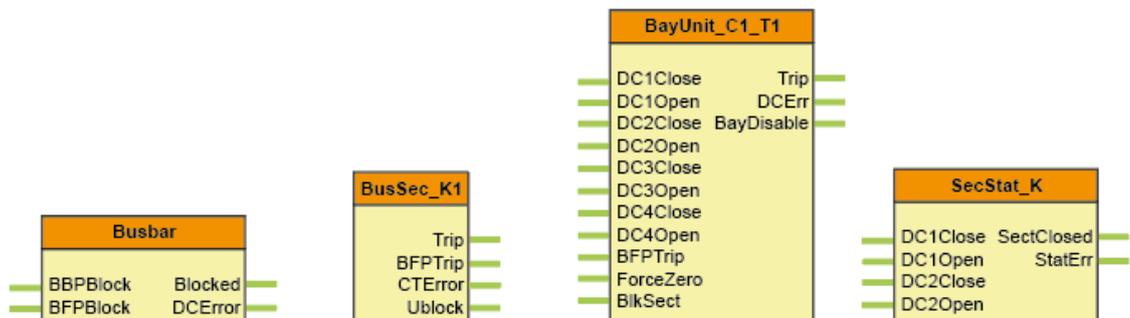
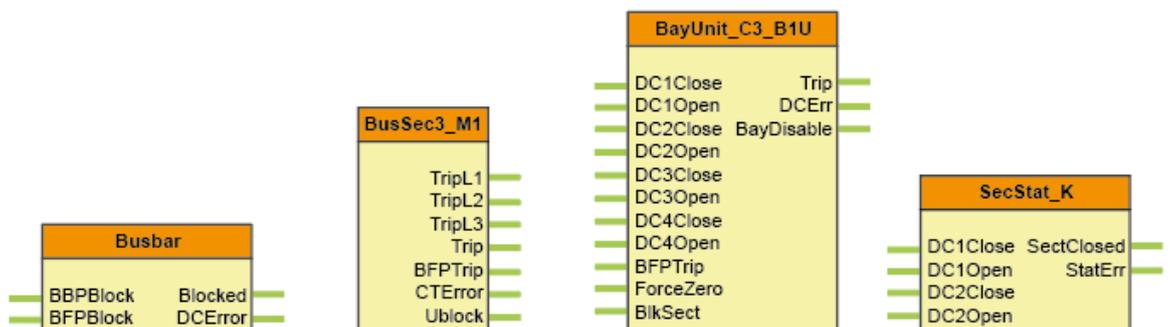


Figure. 8.4.1 - 59. Function blocks of the centralized busbar differential protection function, three-pole version.



## 8.4.2 Configuration procedure

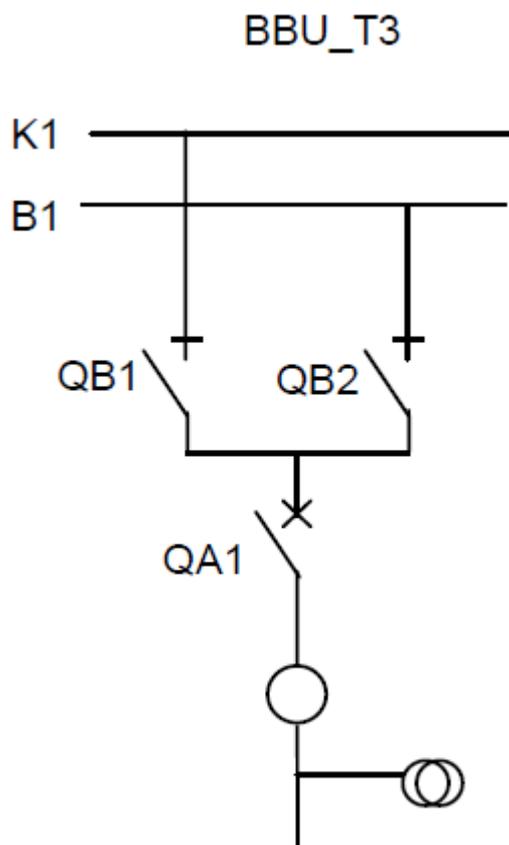
### Configuration in the factory

The factory configuration assembles the needed number of hardware elements and the related software elements. In the factory configuration each bay unit gets the assigned hardware elements, e.g. analog current inputs, analog voltage inputs if any, available disconnector status signal inputs, and the assigned trip contacts.

### Defining the bay topology

User can define the bay topology. The definition of a topology is illustrated with the example of a bay connected to a double busbar below:

Figure. 8.4.2 - 60. Example bay topology.



The user describes the topology, stating to which busbar sections the given bay is connected. This is performed using the AQtivate 300 software with the application of dialog window of the "Topology element" as in the Figure below. In the topology element related to this window the bay "BBU-T3" is connected via "Disconnector 1" (QB1) to the busbar section "K1" and via "Disconnector 2" (QB2) to the busbar section "B1".

In this application disconnectors 3 and 4 are not applied. The information "Include to check zone" states that the information of this bay is applied also for check zone calculation. (As an example the current of a bus couple bay generally may not be involved in the check zone calculation.)

The subsequent parameter in the Figure below (CT dir inverted) states that the positive direction of the current is not inverted. (As an example the current transformer direction in a bus coupler bay must be inverted for one of the bus sections.)

The “Connection ref. No.” setting is usually 0, indicating that the bay is not interconnected with any of other bays. The code number deviating from zero means that the bay is interconnected with bays having the same value for this parameter.

Figure. 8.4.2 - 61. Topology element view in AQtivate 300 software.

Assigned bay []:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnecter section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnecter section [h]:	(nothing)
4. disconnecter section [h]:	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	101

### Defining the sectionalizers

The user describes the topology, stating how the sectionalizers connect the busbar sections. This is performed using the AQtivate 300 software with the application of dialog window as in the Figures below.

Figure. 8.4.2 - 62. Example sectionalizer topology.



Topology element view of sectionalizer in AQtivate 300 software is shown in below figure.

Figure. 8.4.2 - 63. Defining sectionalizers in AQtivate 300.

1. disconnecter on [u]:	0213 Graphed input Status
	SecStat_SectClosed_GrI_B ()
Sect.disconnecter status error [u]:	0213 Graphed input Status
	SecStat_StatErr_GrI_B (Status Error)
1. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
2. disconnecter section [h]:	0197 Sections
	BusSection_B2 (BusSection)

In this example the sectionalizer interconnects the bus sections B1 and B2. The closed status is the result of closed states QB11 AND QB12. This is the task of the user to compose a graphic equation for the binary variable “SecStat\_SectClosed\_GrI\_B()”.

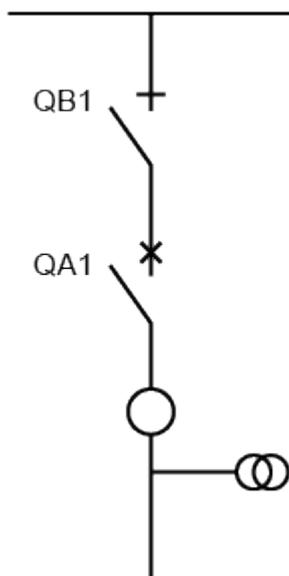
Similarly the disconnecter status error is composed in AQtivate 300 software for the binary variable “SecStat\_StatErr\_GrI\_B(Status Error)”.

### 8.4.3 Application examples

These application examples show typical solutions for defining the busbar topology. Based on these examples, also the details of here not discussed busbar configurations can be defined. The individual examples show the graphic connections of the bay units and the parameter setting of the topology objects.

#### Example 1: Bay connected to a single busbar

Figure. 8.4.3 - 64. Example bay topology of single busbar.

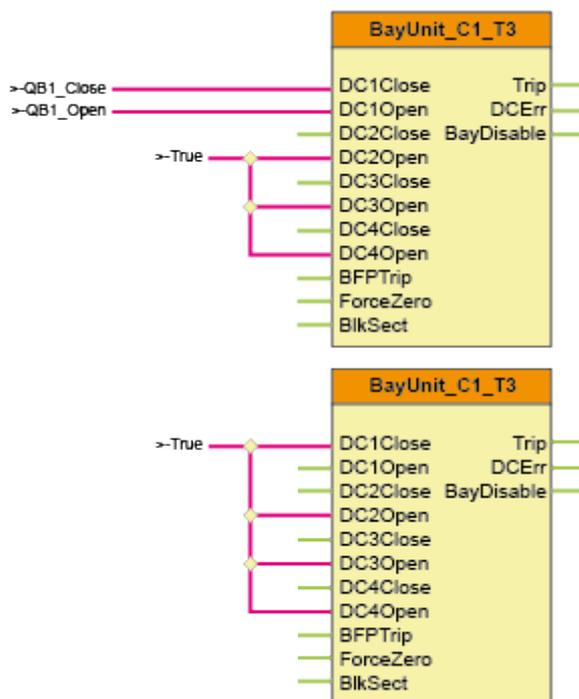


In this simple bay configuration the status signals indicating the closed and open state of the disconnecter are connected to “DC1Close” and “DC1Open inputs”. All other “DCOpen” inputs are connected to logic “True”.

In the second indicated solution the connection of the bay is fixed to “DC1Close” of the function block. All other “DCOpen” inputs are connected to logic “True”.

Figure below shows function block connection examples for single busbar system.

Figure. 8.4.3 - 65. "Function block connection examples for single busbar system.



The parameters describing the topology are shown in Figure below.

Figure. 8.4.3 - 66. Topology element view in AQtivate 300 software of single busbar setting.

Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU_T3 (Bay Unit)
1. disconnector section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnector section [h]:	
	(nothing)
3. disconnector section [h]:	
	(nothing)
4. disconnector section [h]:	
	(nothing)
Include to check zone [0,1]:	1
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	0

## Example 2: Bay connected to a double busbar

Example bay topology of double busbar system can be seen in the picture below.

Figure. 8.4.3 - 67. Example bay topology of double busbar.

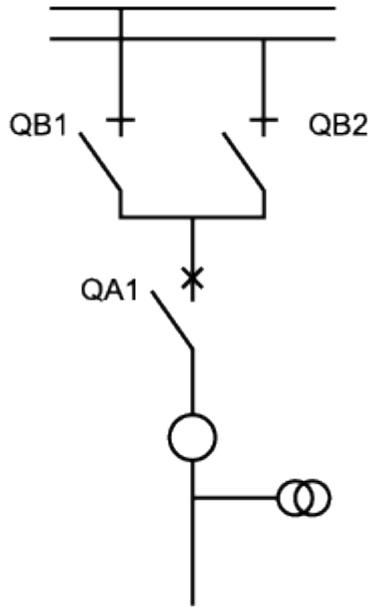
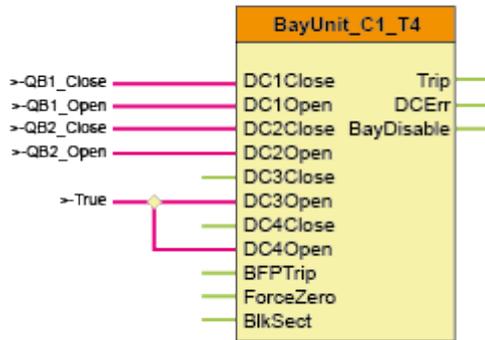


Figure below shows a function block connection example for double busbar system.

Figure. 8.4.3 - 68. Function block connection example for double busbar bay.



The parameters describing the topology are shown in Figure below.

Figure. 8.4.3 - 69. Topology element view in AQtivate 300 software of double busbar setting.

Assigned bay []:	0198 Bay units
	BayUnit1f_BU_BBU_T3 (Bay Unit)
1. disconnecter section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnecter section [h]:	(nothing)
4. disconnecter section [h]:	(nothing)
Include to check zone [0,1]:	1
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	0

### Example 3: Bus coupler bay with one current transformer

Example bay topology of bus coupler is shown in figure below.

Figure. 8.4.3 - 70. Example bay topology of bus coupler.

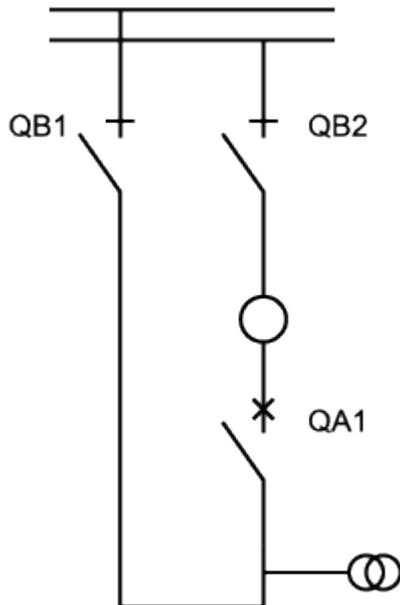
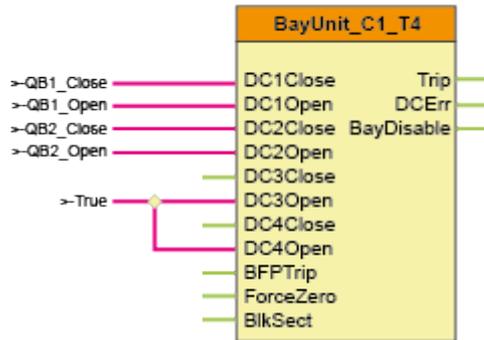


Figure below shows a function block connection example for bus coupler.

Figure. 8.4.3 - 71. Function block connection example of bus coupler.



There are two topology elements assigned to this bus coupler bay: one for the side of QB1 and one for the side of QB2, the current positive direction for the second one must be inverted.

Both topology elements refer to the same bay unit.

In this application also the state of the circuit breaker is to be considered: in its open state the measured current must be disclosed to correctly clear the dead zone faults between the circuit breaker and the current transformer.

The algorithm automatically discloses the current measured by this current transformer if the connected busbar sections are interconnected also by any other element of the busbar system. This bypass is identified if two topology elements refer to the same bay unit.

The topology element related to QB1 is as follows:

Figure. 8.4.3 - 72. Topology element view of QB1 in AQtivate 300 software of bus coupler setting.

Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnector section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnector section [h]:	(nothing)
3. disconnector section [h]:	(nothing)
4. disconnector section [h]:	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	1
Connection ref.No. [0,255]:	0

The topology element related to QB2 is as follows:

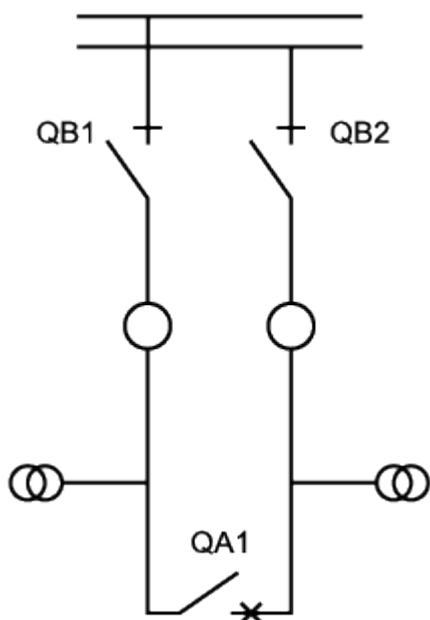
Figure. 8.4.3 - 73. Topology element view of QB2 in AQtivate 300 software of bus coupler setting.

Assigned bay []:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnecter section [h]:	(nothing)
2. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnecter section [h]:	(nothing)
4. disconnecter section [h]:	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	0

#### Example 4: Bus coupler bay with two current transformers

Example bay topology of bus coupler with two current transformers is shown in figure below.

Figure. 8.4.3 - 74. Example bay topology of bus coupler with two current transformers.



To describe this configuration two “Bay unit” function blocks are applied. The current transformers must be connected in overlapping arrangement. Because of overlapping, the “Open” state of the circuit breaker need not disclose the current.

When however the bus sections are interconnected also by any other element of the busbar system, then the automatic disclosing the current is also needed. For this purpose the algorithm must be informed about the bypass of the bus coupler bay. For this purpose the parameter "Connection ref.No" is applied. If the identifiers of these two bay units have identical (but not 0) identifier then these bays are considered to be interconnected.

Figure. 8.4.3 - 75. "Function block connection example of bus coupler with two CTs.

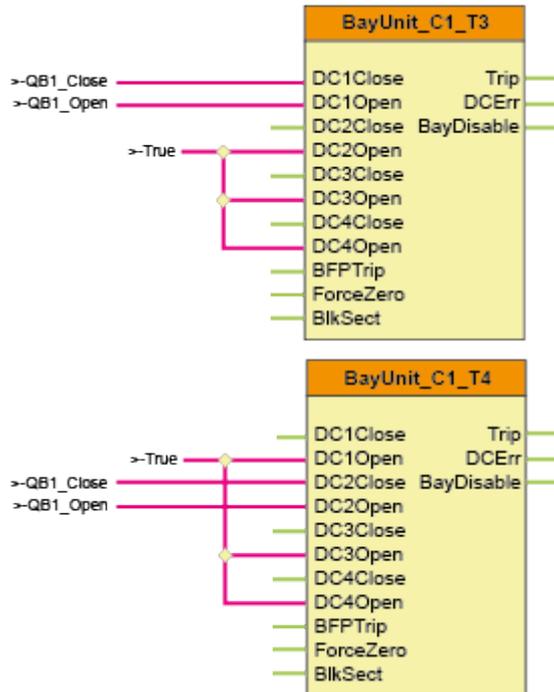


Figure. 8.4.3 - 76. Topology element views of QB1 and QB2 in AQtivate 300 software of bus coupler setting with two CTs.

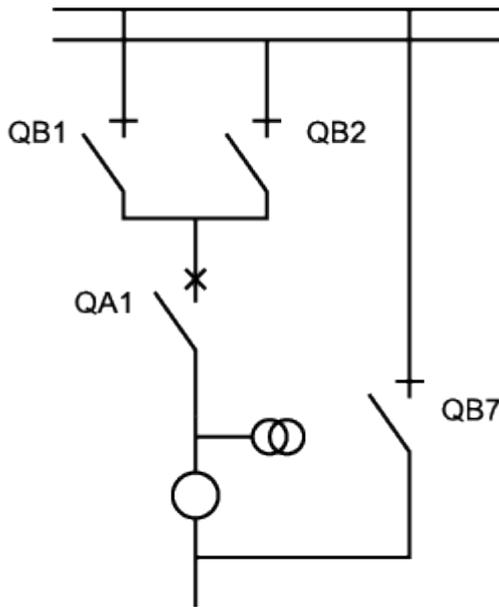
Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnecter section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnecter section [h]:	
	(nothing)
3. disconnecter section [h]:	
	(nothing)
4. disconnecter section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	100

Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU__T4 (Bay Unit)
1. disconnecter section [h]:	
	(nothing)
2. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnecter section [h]:	
	(nothing)
4. disconnecter section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	100

### Example 5: Double bus connection with bypass.

Example bay topology of bus with bypass is shown in the figure below.

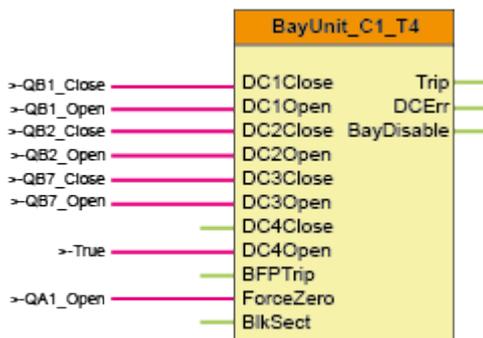
Figure. 8.4.3 - 77. Example bay topology of double bus connection with bypass.



This bay can serve as bus coupler and as a feeder bay at the same time.

The connections of the applied bay unit are as follows.

Figure. 8.4.3 - 78. Function block connection example of bus with bypass.



The related topology element is as follows.

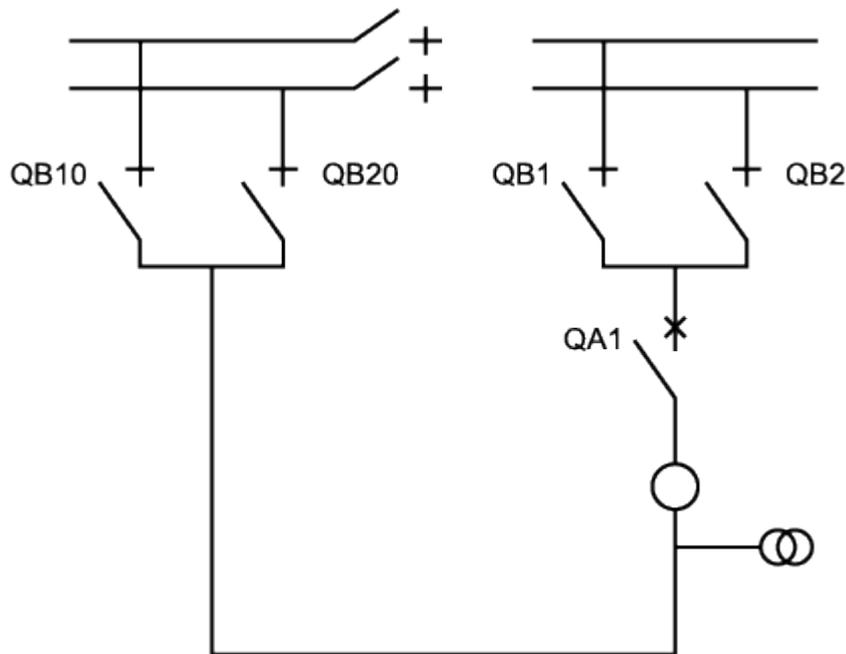
Figure. 8.4.3 - 79. Topology element view in AQtivate 300 software of bus with bypass.

Assigned bay []:	0198 Bay units
	BayUnit1f_BU_BBU__T4 (Bay Unit)
1. disconnector section [h]:	(nothing)
2. disconnector section [h]:	(nothing)
3. disconnector section [h]:	0197 Sections
	BusSection_K1 (BusSection)
4. disconnector section [h]:	(nothing)
Include to check zone [0,1]:	1
CT Dir.Inverted [0,1]:	1
Connection ref.No. [0,255]:	0

### Example 6: Bus coupler in a double busbar system

Example bay topology of bus coupler in a double busbar system can be seen in the figure below.

Figure. 8.4.3 - 80. Example bay topology of a bus coupler in a double busbar system.



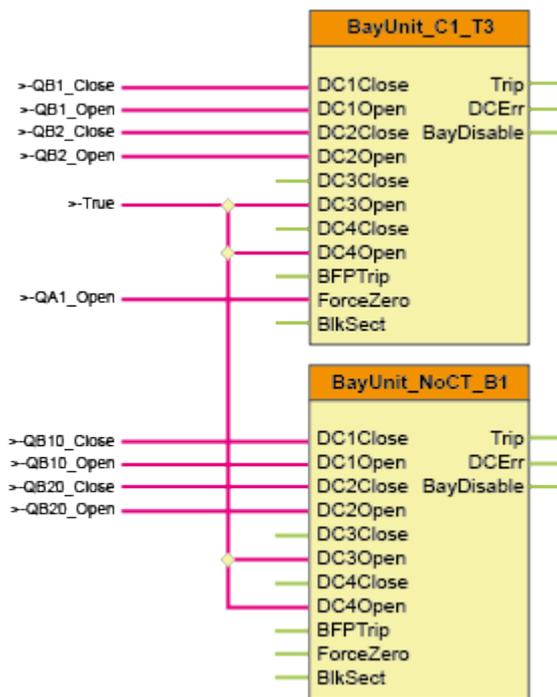
This configuration can be describes in two ways:

If the description is realized with a single bay unit, then the method is the same as a bay single bay coupler with a single current transformer. The only difference is that two disconnectors are applied in both sides. One of them is connected to the inputs DC1-DC2, the other side applies the inputs DC3-DC4.

If the description applies two bay units, or if the number of busbars is more than two (e.g. triple bay system) then the solution is as follows:

Here a function block is to be applied which operates without current transformer. With this solution a quadruple system (consisting of four busbars) can be described.

Figure. 8.4.3 - 81. Function block connection example of bus coupler in a double busbar system.



The setting of the topology elements is as follows.

Figure. 8.4.3 - 82. Topology element view in AQtivate 300 software of bus coupler in a double busbar system.

Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnecter section [h]:	0197 Sections
	BusSection_K1 (BusSection)
2. disconnecter section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnecter section [h]:	
	(nothing)
4. disconnecter section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	101

Assigned bay [I]:	0198 Bay units
	BayUnitNoCT_BU_BBU__B1 (Bay Unit)
1. disconnecter section [h]:	0197 Sections
	BusSection_K2 (BusSection)
2. disconnecter section [h]:	0197 Sections
	BusSection_B2 (BusSection)
3. disconnecter section [h]:	
	(nothing)
4. disconnecter section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	101

## 9 Construction and installation

### 9.1 Construction

The Arcteq AQ-B398 busbar protection IED consists of hardware modules. Due to modular structure optional positions for the slots can be user defined in the ordering of the IED to include I/O modules and other types of additional modules. An example module arrangement configuration of the AQ-B398 is shown in the figure below. Visit <https://configurator.arcteq.fi/> to see all of the available options.

Figure. 9.1 - 83. An example module arrangement configuration of the AQ-B398 IED.

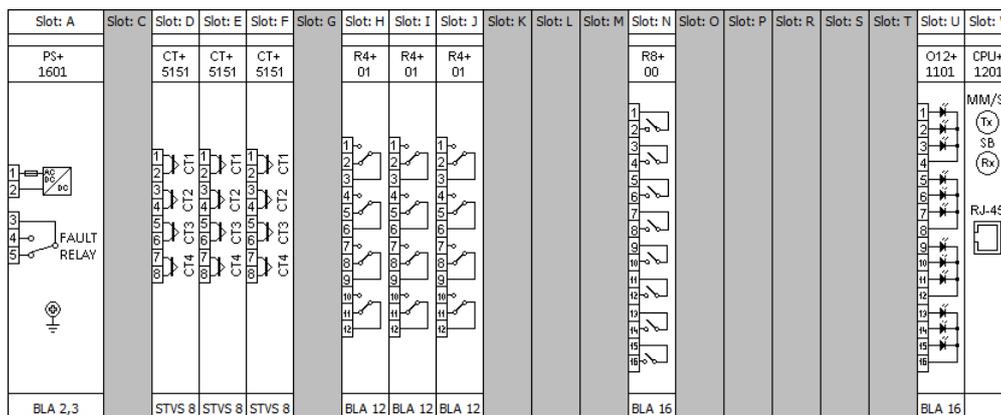


Table. 9.1 - 33. Descriptions of the hardware modules for AQ-B398.

Position	Module identifier	Explanation
A–B	PS+ 1601	Power supply unit, 85...265 V AC, 88...300 V DC
D, E, F	CT+ 5151	Analog current input module
H, I, J	R4+ 01	Signaling output module, 4 output contacts (switchover type)
U	O12+ 1101	Binary input module, 12 inputs, threshold 110 V DC
N	R8+ 00	Signaling output module, 8 output contacts
V	CPU+ 1201	Processor and communication module
Others	Spare	—

### 9.2 CPU module

The CPU module contains all the protection, control and communication functions of the AQ-x3xx device. Dual 500 MHz high-performance Analog Devices Blackfin processors separates relay functions (RDSP) from communication and HMI functions (CDSP). Reliable communication between processors is performed via high-speed synchronous serial internal bus (SPORT).

Each processor has its own operative memory such as SDRAM and flash memories for configuration, parameter and firmware storage. CDSP's operating system (uClinux) utilizes a robust JFFS flash file system, which enables fail-safe operation and the storage of disturbance record files, configuration and parameters.

After power-up the RDSP processor starts up with the previously saved configuration and parameters. Generally, the power-up procedure for the RDSP and relay functions takes approx. 1 sec. That is to say, it is ready to trip within this time. CDSP's start-up procedure is longer, because its operating system needs time to build its file system, initializing user applications such as HMI functions and the IEC 61850 software stack.

The built-in 5- port Ethernet switch allows the AQ-x3xx device to connect to IP/Ethernet- based networks. The following Ethernet ports are available:

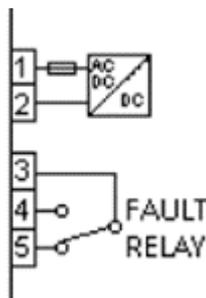
- Station bus (100Base-FX Ethernet).
- Redundant Station bus (100Base-FX Ethernet).
- Process bus (100Base-FX Ethernet).
- EOB (Ethernet over Board) user interface.
- Optional 100Base-TX port via RJ-45 connector.

Other communication:

- R422/RS485/RS232 interfaces.
- Plastic or glass fiber interfaces to support legacy protocols.
- Process-bus communication controller on COM+ card.

## 9.3 Power supply module

Figure. 9.3 - 84. Connector allocation of the 30 W power supply unit.



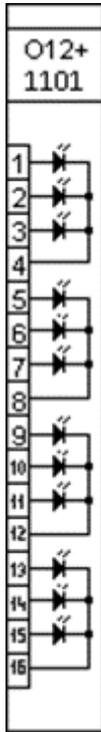
The power supply module converts primary AC and/or DC voltage to required system voltages. Redundant power supply cards extend system availability in case of the outage of any power source and can be ordered separately if required.

Main features of the power supply module:

- 30 W input.
- Maximum 100 ms power interruption time: measured at nominal input voltage with nominal power consumption.
- IED system fault contacts (NC and NO): device fault contact and also assignable to user functions. All the three relay contact points (NO, NC, COM) are accessible to users 80...300 V DC input range, AC power is also supported.
- Redundant applications which require two independent power supply modules can be ordered optionally.
- On-board self-supervisory circuits: temperature and voltage monitors.
- Short-circuit-protected outputs.
- Efficiency: >70 %.
- Passive heat sink cooling.
- Early power failure indication signals to the CPU the possibility of power outage, thus the CPU has enough time to save the necessary data to non-volatile memory.

## 9.4 Binary input module(s)

Figure. 9.4 - 85. The binary input module O12+ 1101.



The inputs are galvanic isolated and the module converts high-voltage signals to the voltage level and format of the internal circuits. This module is also used as an external IRIG-B synchronization input. Dedicated synchronization input (input channel 1) is used for this purpose.

The binary input modules are:

- Rated input voltage: 110/220 V DC.
- Clamp voltage: falling 0.75  $U_n$ , rising 0.78  $U_n$ .
- Digitally filtered per channel.
- Current drain approx.: 2 mA per channel.
- 12 inputs.
- IRIG-B timing and synchronization input.

## 9.5 Binary output module(s)

Figure. 9.5 - 86. The binary output module R8+ 80.



The signaling output modules can be ordered as 8 relay outputs with dry contacts.

The binary output modules are:

- Rated voltage: 250 V AC/DC.
- Continuous carry: 8 A.
- Breaking capacity, (L/R = 40 ms) at 220 V DC: 0.2 A
- 8 contacts: 7 NO and 1 NC

## 9.6 Tripping module

Figure. 9.6 - 87. The tripping module TRIP+ 2101.



The tripping module applies direct control of a circuit breaker. The module provides fast operation and is rated for heavy duty controlling.

The main characteristics of the trip module:

- 4 independent tripping circuits.
- High-speed operation.
- Rated voltage: 110 V, 220 V DC.
- Continuous carry: 8 A.
- Making capacity: 0.5 s, 30 A.
- Breaking capacity (L/R = 40 ms) at 220 V DC: 4A.
- Trip circuit supervision for each trip contact.

## 9.7 Voltage measurement module

Figure. 9.7 - 88. The voltage measurement module VT+ 2211.



For voltage related functions (over- /under -voltage, directional functions, distance function, power functions) or disturbance recorder functionality this module is needed. This module also has capability for frequency measurement.

For capacitive voltage measurement of the synchrocheck reference, the voltage measurement module can be ordered with reduced burden in channel VT4. In this module the burden is < 50 mVA.

The main characteristics of the voltage measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Selectable rated voltage ( $U_n$ ):  $100/\sqrt{3}$ , 100 V,  $200/\sqrt{3}$ , 200 V by parameter.
- Voltage measuring range:  $0.05 U_n - 1.2 U_n$ .
- Continuous voltage withstand: 250 V.
- Power consumption of voltage input:  $\leq 1$  VA at 200 V (with special CVT module the burden is < 50 mVA for VT4 channel).
- Relative accuracy:  $\pm 0.5$  %.
- Frequency measurement range:  $\pm 0.01$  % at  $U_x 25$  % of rated voltage.
- Measurement of phase angle:  $0.5^\circ U_x 25$  % of rated voltage.

## 9.8 Current measurement module

Figure. 9.8 - 89. Connector allocation of the current measurement module.



Current measurement module is used for measuring current transformer output current. Module includes three phase current inputs and one zero sequence current input. The nominal rated current of the input can be selected with a software parameter either 1 A or 5 A.

The main characteristics of the current measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Electronic iron-core flux compensation.
- Low consumption:  $\leq 0.1$  VA at rated current.
- Current measuring range:  $35 \times I_n$ .
- Selectable rated current 1 A/5 A by parameter.
- Thermal withstand:
  - 20 A (continuously)
  - 500 A (for 1 s)
  - 1200 A (for 10 ms)
- Relative accuracy:  $\pm 0.5$  %.
- Measurement of phase angle:  $0.5^\circ$ ,  $I_x 10$  % rated current.

## 9.9 Installation and dimensions

Figure. 9.9 - 90. Dimensions of AQ-x39x IED.

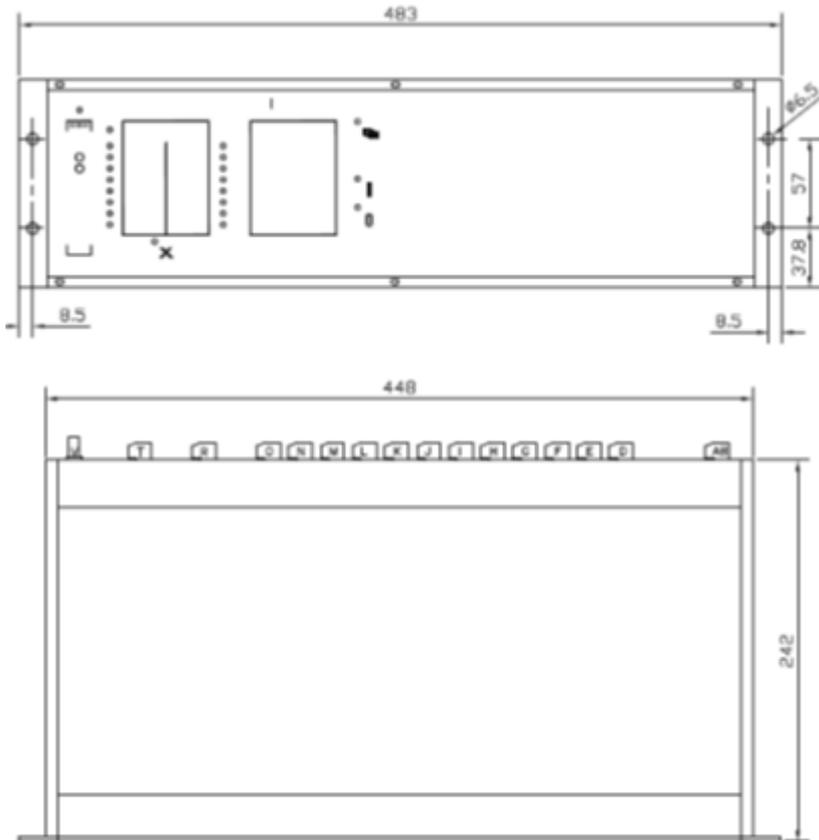
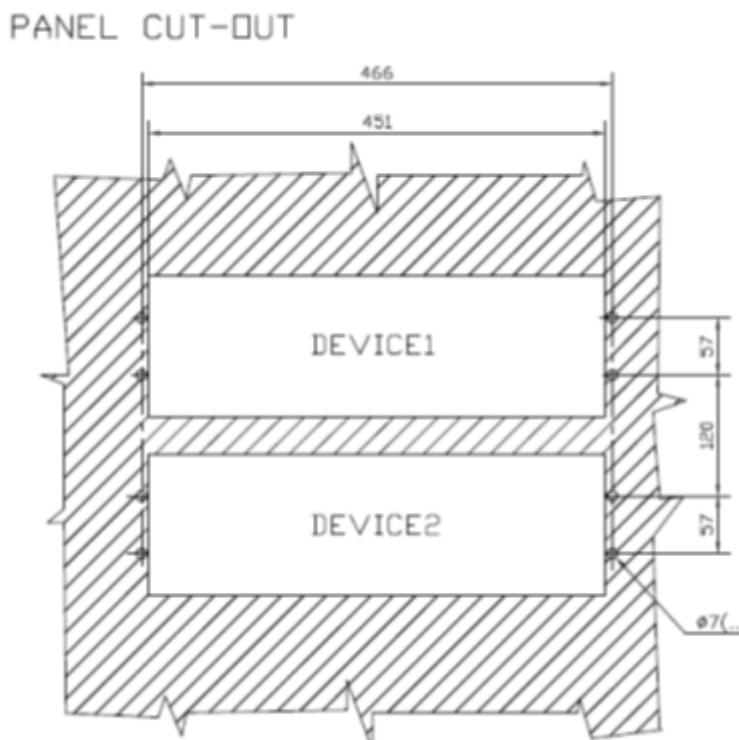


Figure. 9.9 - 91. Panel cut-out and spacing of AQ-x39x IED.



## 10 Technical data

### 10.1 Busbar differential protection

Table. 10.1 - 34. Technical data for centralized busbar protection.

Operation time: <ul style="list-style-type: none"> <li>• <math>I_{diff} &gt; 2xI_n</math></li> <li>• <math>I_{diff} &gt; 5xI_n</math></li> </ul>	typically <20 ms typically <15 ms
Reset ratio	0.7
Reset time	60 ms
Measurement inaccuracy	2 %

Table. 10.1 - 35. Technical data for distributed busbar protection.

Operation time: <ul style="list-style-type: none"> <li>• <math>I_{diff} &gt; 2xI_n</math></li> <li>• <math>I_{diff} &gt; 5xI_n</math></li> </ul>	typically <30 ms typically <20 ms
Reset ratio	0.7
Reset time	60 ms
Measurement inaccuracy	2 %

### 10.2 Hardware

#### Power supply module

Input voltage	80-255VAC 90-300VDC
Nominal voltage	110VDC/220VDC
Maximum interruption	100ms
Maximum power consumption	30W

#### Current measurement module

Nominal current	1/5A (parameter settable) 0.2A (ordering option)
Number of channels per module	4
Rated frequency	50Hz 60Hz (ordering option)
Burden	<0.1VA at rated current

Thermal withstand	20A (continuous) 500A (for 1s) 1200A (for 10ms)
Current measurement range	0-50xIn
Power consumption at rated current	0.01 VA with 1A rated current 0.25 VA with 5A rated current
Phase angle accuracy at $I_x \geq 10\% \pm 1$ digit	$\leq 0.5^\circ$
Relative accuracy [%] $\pm 1$ digit	$\pm 1$ ( $> 0.5I_n$ ) with 1A rated current $\pm 1$ ( $> 0.4I_n$ ) with 5A rated current

### Voltage measurement module

Rated voltage $U_n$	100/ $\sqrt{3}$ , 100V, 200/ $\sqrt{3}$ , 200V (parameter settable)
Number of channels per module	4
Rated frequency	50Hz 60Hz (ordering option)
Burden	<1VA at 200V
Voltage withstand	250V (continuous) 275VAC/350VDC (1s)
Voltage measurement range	0.05-1.2x $U_n$
Power consumption	0.61VA at 200V 0.2 VA at 100V
Relative accuracy	$\pm 0.5\%$ ( $> 0.6U_n$ )
Frequency measurement range	$\pm 0.01\%$ at $U_x \geq 25\%$ of rated voltage
Phase angle accuracy	$\leq 0.5^\circ$ at $U_x \geq 25\%$ of rated voltage

### Binary input module

Rated voltage $U_n$	110 or 220Vdc (ordering option)
Number of inputs per module	12 (in groups of 3)
Current drain	approx. 2mA per channel
Breaking capacity	0.2A (L/R=40ms, 220Vdc)

### Binary output module

Rated voltage $U_n$	250Vac/dc
Number of outputs per module	7 (NO) + 1 (NC)
Continuous carry	8A
Breaking capacity	0.2A (L/R=40ms, 220Vdc)

## High speed trip module

Rated voltage Un	110/220VDC
Max. withstand voltage	242V DC
Number of outputs per module	4
Continuous carry	8A
Making capacity	30A (0.5s)
Breaking capacity	4A (L/R=40ms, 220Vdc)

## 10.3 Tests and environmental conditions

### Disturbance tests

EMC test	CE approved and tested according to EN 50081-2, EN 50082-2
Emission - Conducted (EN 55011 class A) - Emitted (EN 55011 class A)	0.15 - 30MHz 30 - 1 000MHz
Immunity	
- Static discharge (ESD) (According to IEC244-22-2 and EN61000-4-2, class III)	Air discharge 8kV Contact discharge 6kV
- Fast transients (EFT) (According to EN61000-4-4, class III and IEC801-4, level 4)	Power supply input 4kV, 5/50ns other inputs and outputs 4kV, 5/50ns
- Surge (According to EN61000-4-5 [09/96], level 4)	Between wires 2 kV / 1.2/50µs Between wire and earth 4 kV / 1.2/50µs
- RF electromagnetic field test (According. to EN 61000-4-3, class III)	f = 80....1000 MHz 10V /m
- Conducted RF field (According. to EN 61000-4-6, class III)	f = 150 kHz....80 MHz 10V

### Voltage tests

Insulation test voltage acc- to IEC 60255-5	2 kV, 50Hz, 1min
Impulse test voltage acc- to IEC 60255-5	5 kV, 1.2/50µs, 0.5J

### Mechanical tests

Vibration test	2 ... 13.2 Hz ±3.5mm 13.2 ... 100Hz, ±1.0g
Shock/Bump test acc. to IEC 60255-21-2	20g, 1000 bumps/dir.

## Casing and package

Protection degree (front)	IP 54 (with optional cover)
Weight	5kg net (AQ-x35x devices) 6kg net (AQ-x39x devices) 6kg with package (AQ-x35x devices) 7kg with package (AQ-x39x devices)

## Environmental conditions

Specified ambient service temp. range	-10...+55°C
Transport and storage temp. range	-40...+70°C

## 11 Ordering information

Visit <https://configurator.arcteq.fi/> to build a hardware configuration, define an ordering code and get a module layout image.

## 12 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.fi">arcteq.fi</a>
Technical support:	<a href="mailto:support.arcteq.fi">support.arcteq.fi</a> +358 10 3221 388 (EET 9:00 – 17.00)
E-mail (sales):	<a href="mailto:sales@arcteq.fi">sales@arcteq.fi</a>