ARCTEQ
PART OF ENSTO GROUP

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.

You are advised to notify the manufacturer in case you become aware of any errors in this document or of defects in the equipment.

The manufacturer reserves the right to update or amend this document at any time.

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1 Document information

Table. 1 - 1. History of Revision 1.

Revision	1.00
Date	January 2012
Changes	• The first revision of the manual.
Revision	1.01
Date	February 2015
Changes	• Current and voltage measurement descriptions were revised.
Revision	1.02
Date	December 2019
Changes	• The "Construction and installation" chapter was updated.

Table. 1 - 2. History of Revision 2.

Revision	2.00
Date	February 2023
Changes	• Updated the Arcteq logo on the cover. • An overall visual update for the manual's layout and design. • Added the "Safety information" chapter. • Added the "Abbreviations" chapter. • Added the previously separate documents "AQ 300 Operator's manual" and "AQ 300 Web server description" into the "IED user interface" chapter. • Various images updated. • Updated contact and reference information.
Revision	2.01
Date	August 2026
Changes	• Busbar differential protection description revision.

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 may contain 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 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

AC
: alternating current

AVR
: automatic voltage regulator

CB
: circuit breaker

CBFP
: circuit breaker failure protection

CPU
: central processing unit

CT
: current transformer

CTS
: current transformer supervision

CVT
: capacitive voltage transformer

DC
: direct current

DI
: digital input(s)

DLD
: dead line detection

DO
: digital output(s)

EFT
: electronic fast transients

EMC
: electromagnetic compatibility

EOB
: Ethernet Overboard

ESD
: electrostatic discharge

HMI
: human—machine interface

IDMT
: inverse definite minimum time

IED
: intelligent electronic device

IO
: inputs and outputs

LCD
: liquid-crystal display

LED
: light-emitting diode

NC
: normally closed

NO
: normally open

NTP
: Network Time Protocol

RF
: radio frequency

RCA
: relay characteristic angle

RMS
: root mean square

SCADA
: supervisory control and data acquisition

SDRAM
: synchronous dynamic random access memory

SLD
: single-line diagram

SOTF
: switch-on-to-fault

TMS
: time multiplier setting

VT
: voltage transformer

VTS
: 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.

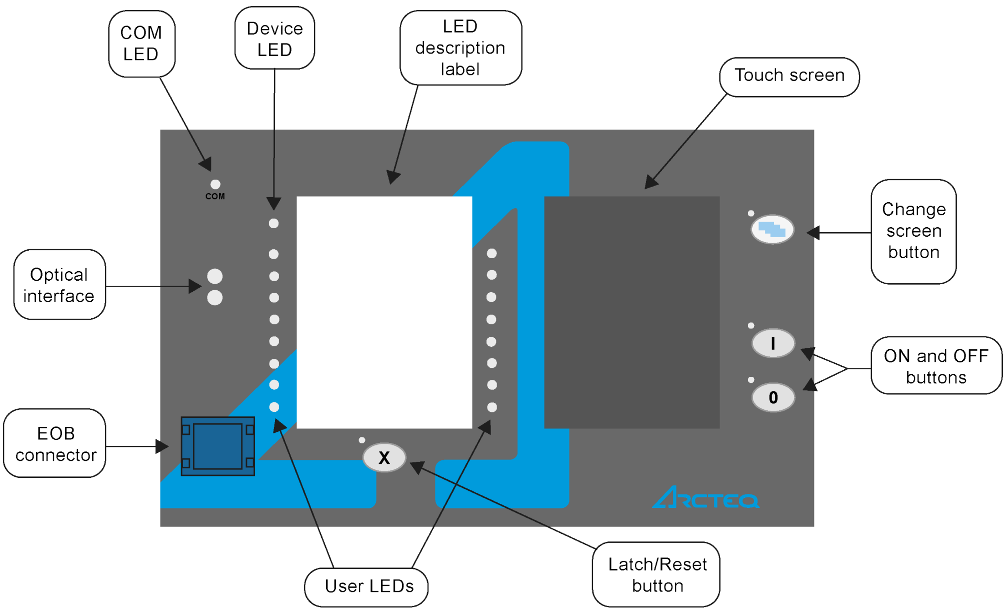


Table. 5.1 - 3. Elements of the front panel.

Function	Description
Device LED	One (1) three-colored circular LED. • Green = normal operation • Yellow = warning state • Red = alarm state
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	The device has four (4) capacitive operational buttons: • "X" (below the LED label) latches and resets the LEDs. • The button with a blue icon (top right) changes the touch screen menus. • "ON" and "OFF" (bottom right). 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.

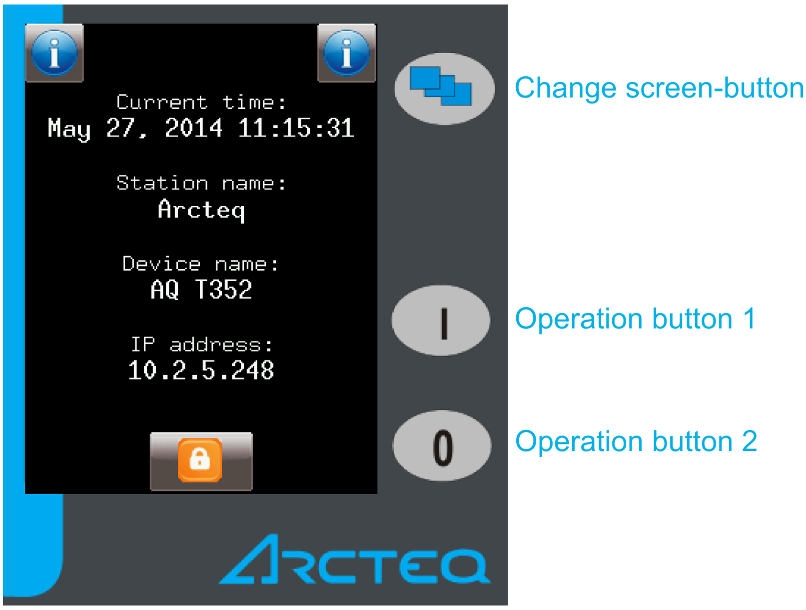
5.2 LED assignment

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, is 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

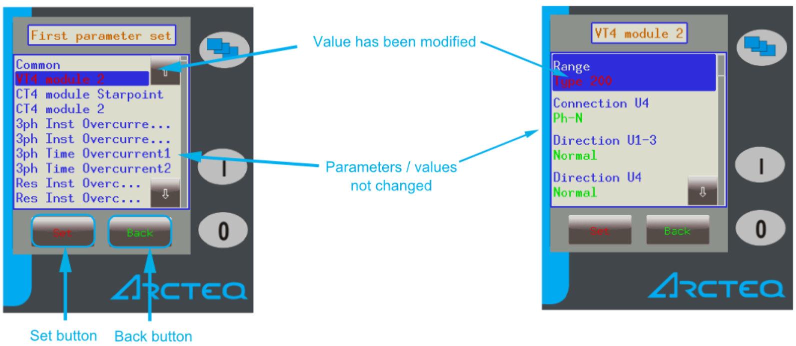
In the parameters menu (below) you can view, set and edit certain parameters within the device. You can also choose which of the parameter sets the device uses.

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.

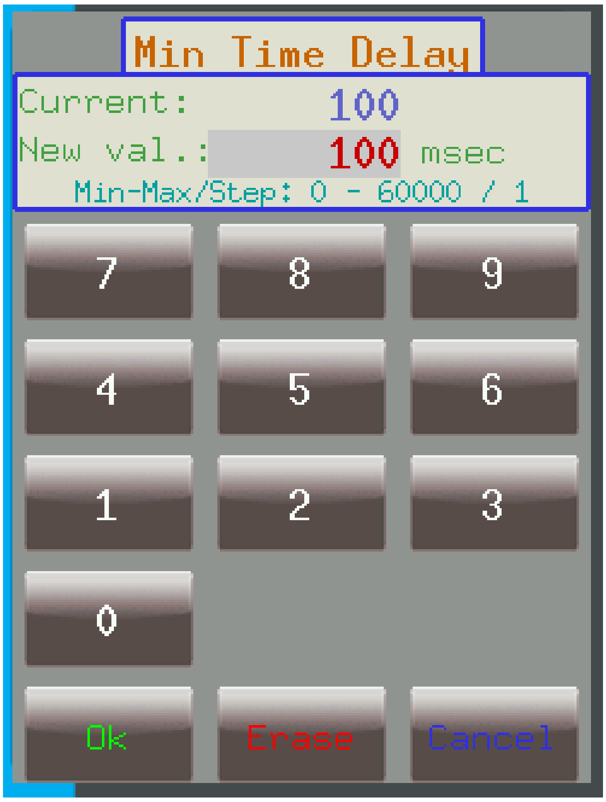
The Set button brings up a screen where you can modify a value. If there is a lock icon instead of the "Set" button, the device must first be unlocked. The Back button returns you to the previous screen.

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 thr 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 0000. If the step value were 5, the field would only accept values such as 1 005, 1 010, 1 015, and so on.

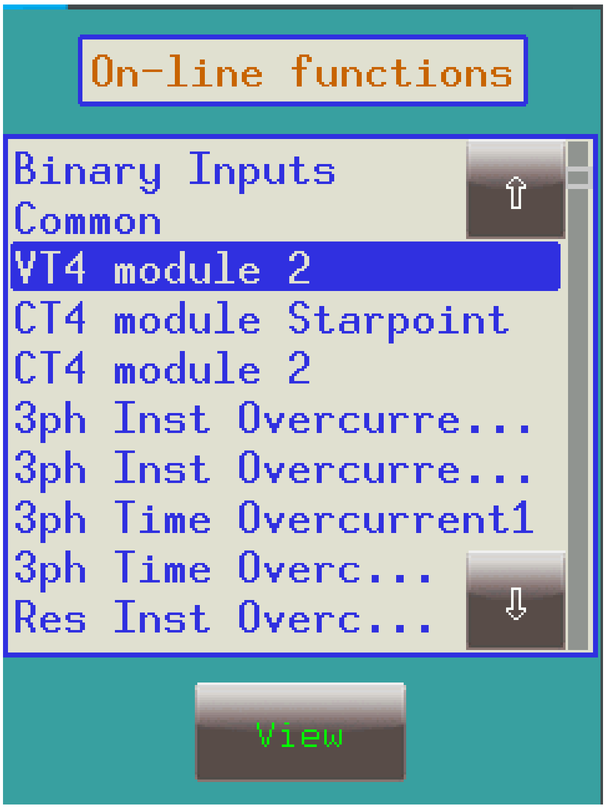
The OK button confirms the value in the "New value" field and returns the user to the previous screen. The Cancel button deletes a single digit from the "New value" field. The Erase button discards any changes to the current parameter and returns the user to the previous menu item.

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.

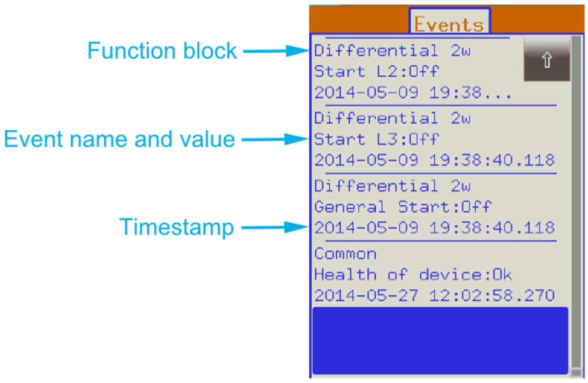


Events menu

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.

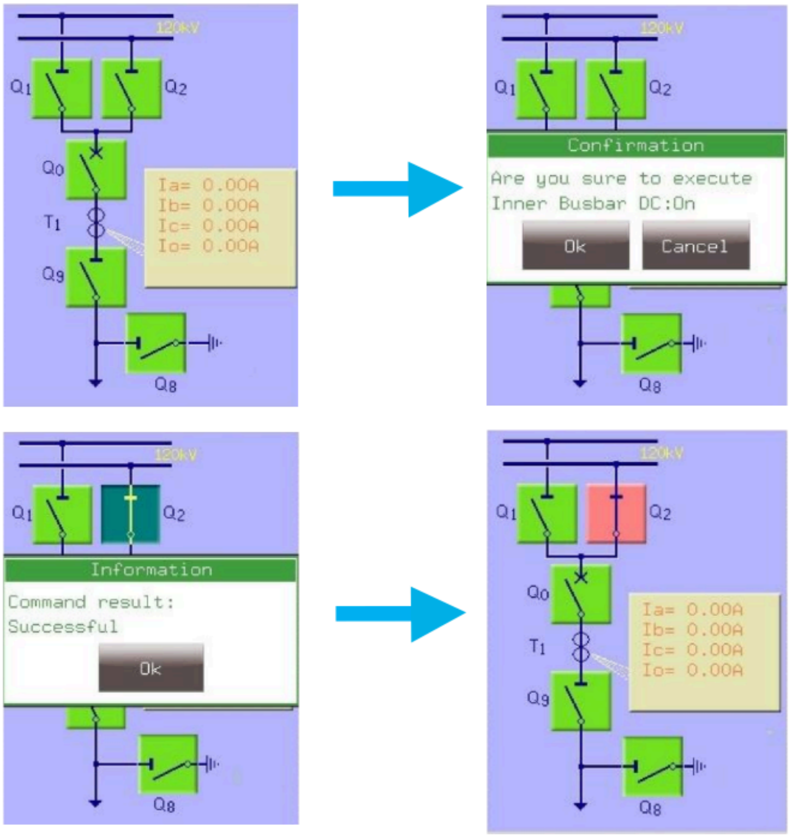
Setting	Description
System parameters and station bus settings (IP address, netmask, default gateway, DNS servers)	Please contact your local network administrator for further information about these settings.
Ethernet communication (IEC 61850 enabled, IEC 104 enabled)	Enables or disables the IEC 61850 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 "0" 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 shirt 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 priviledges 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 updgrades
- 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.

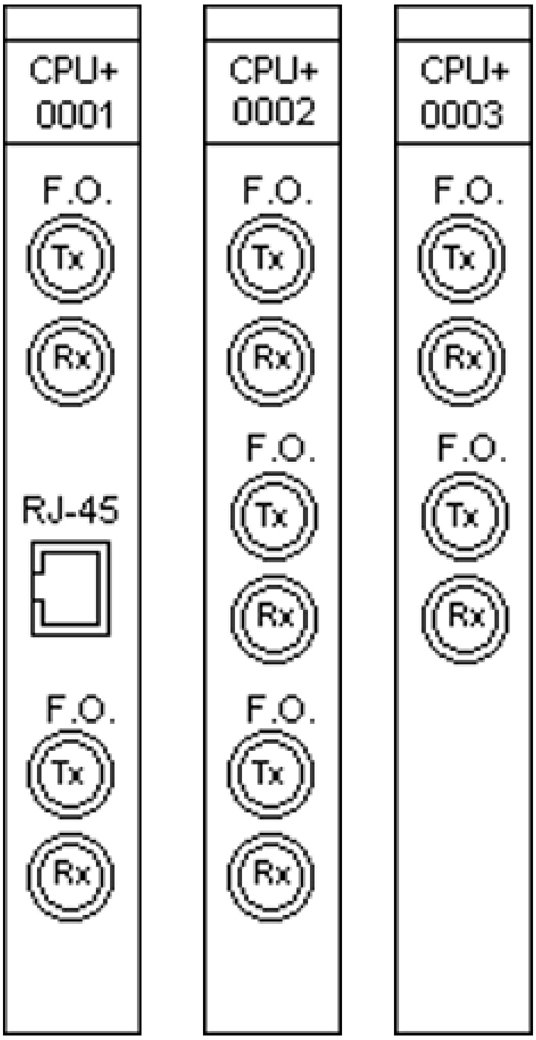
Table. 5.4.1 - 5. The available Ethernet communication in different CPU versions.

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 version	EOB	Station Bus	Redundant Station Bus	Process Bus	RJ45	Legacy port/protocol
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.

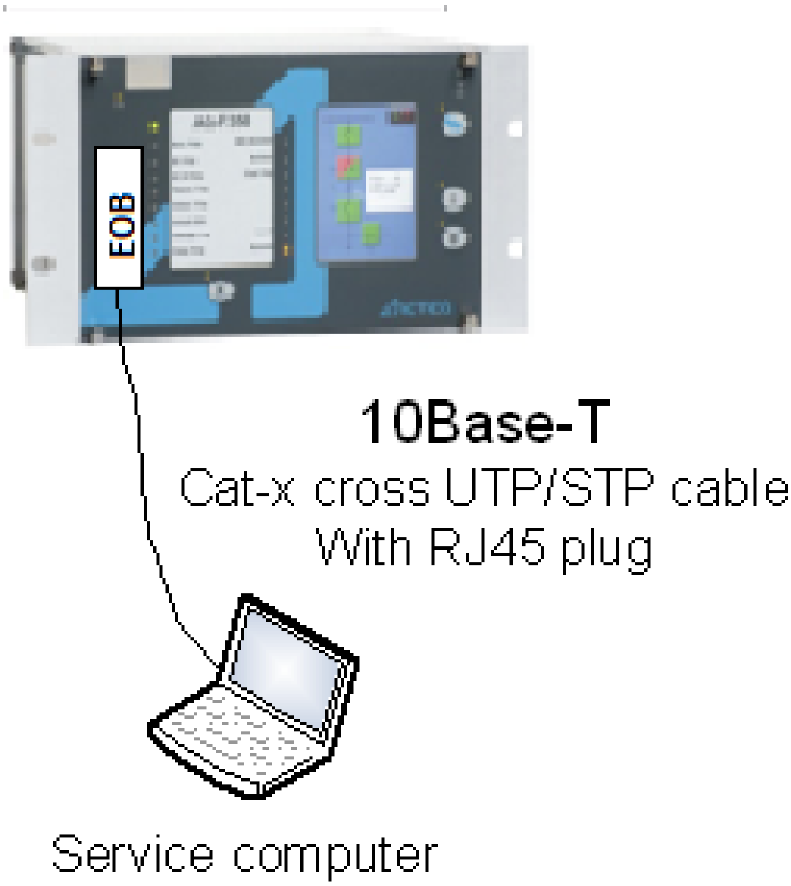
Web browser settings

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.

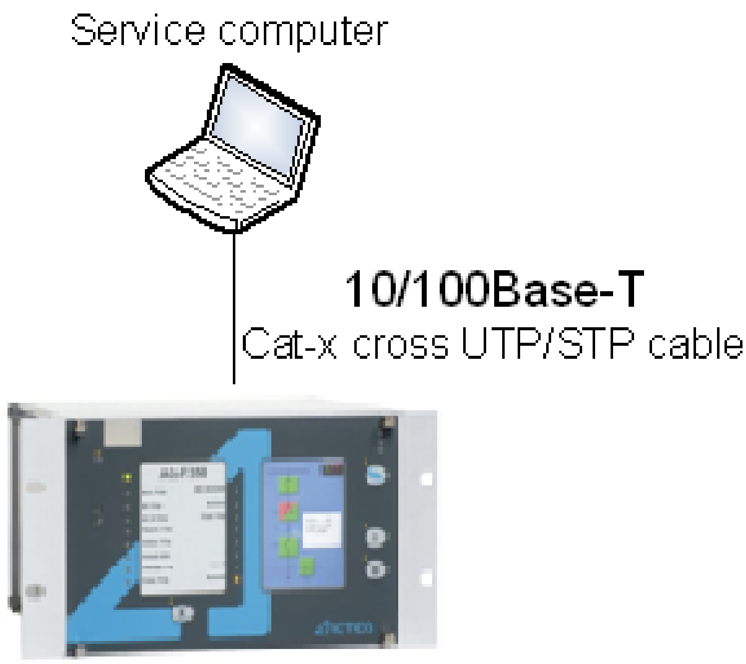


Please note that the RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

RJ45 connection

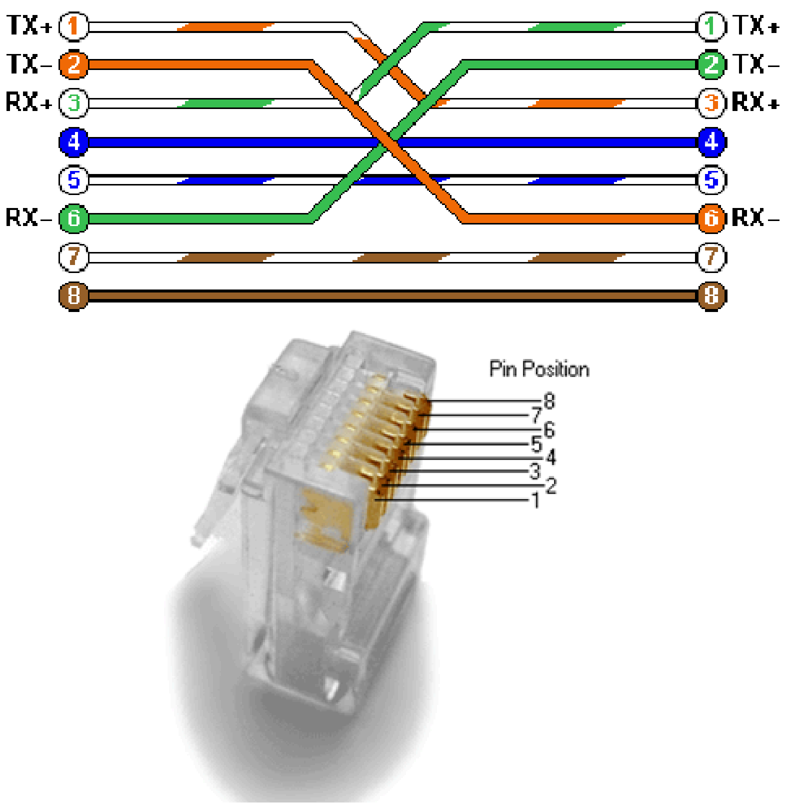
As seen in the beginning of this chapter, the CPU version "+0001" also has an integrated RJ4 port. When using a UTP crossover cable with RJ45 connectors at both ends, you can connect the device directly to a computer (see the figure below).

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.

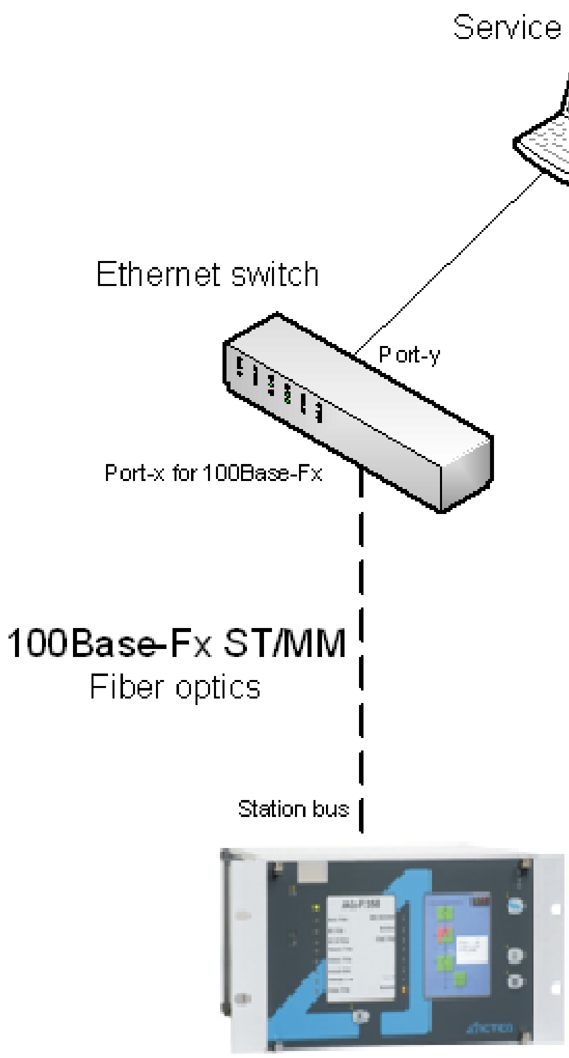


Please note that the cable's RJ45 connector can also be connected to an Ethernet switch. When this is the case, all the network's IEDs with client functionalities (e.g. a computer) have access to the device.

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).

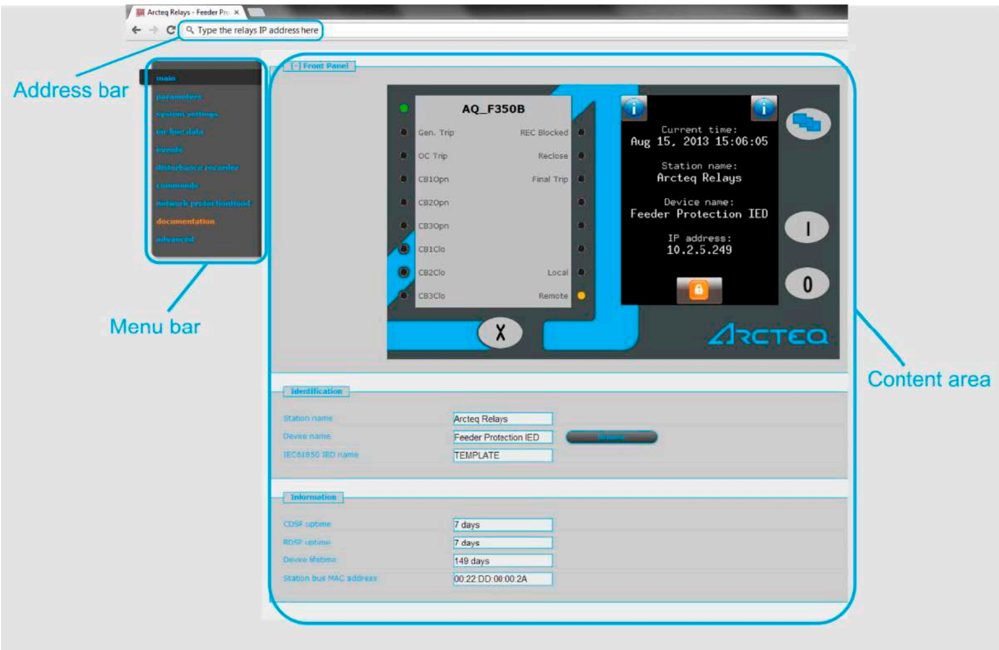
Figure. 5.4.1 - 16. Using the ST-type fiber optic connection to connect computers via an optical Ethernet switch.



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.



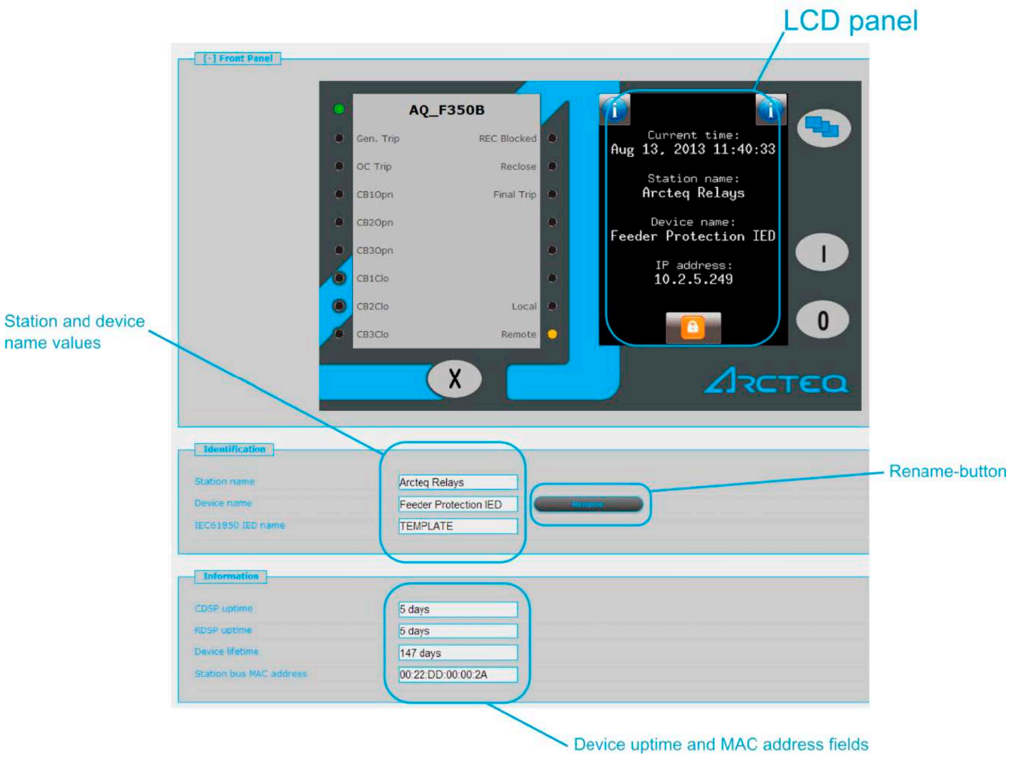
The menu that is currently selected is highlighted in black (in the image above, the main menu is selected). If the content area is too long to fit the browser window, you can scroll down; the menu bar will always be visible as it follows the user.

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.



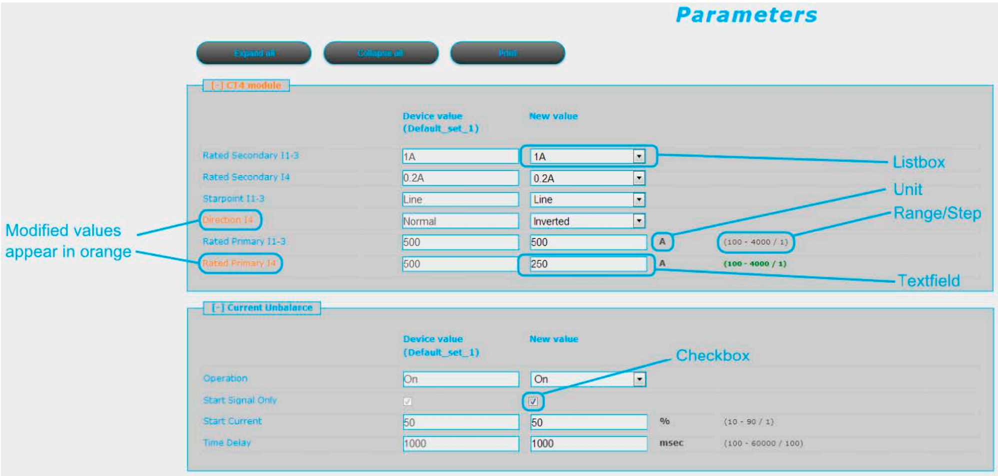
In the main menu you can control the device's front panel. The image of a touch screen (located on the right) behaves the same way as the actual touch screen. For more information on the touch screen, please refer to the "Touch screen" subchapter in the "IED user interface" main chapter.

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 uniwue 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.

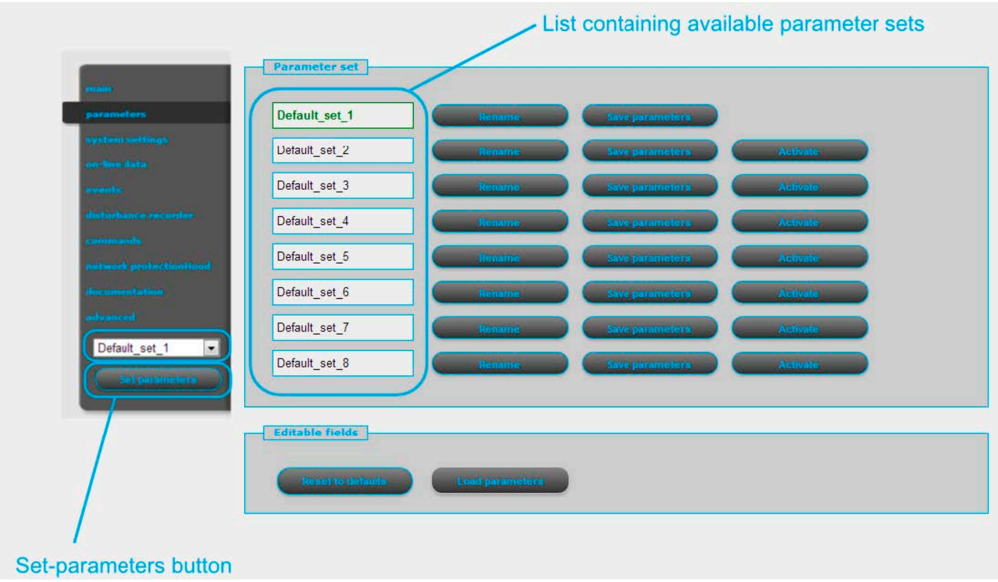
The parameter values are displayed in text fields, checkboxes, or listboxes. All of these can be modified; the name of the parameter whose value has been modifed appears in orange, as does the name of the function block (see the image above). When modifying *text fields*, please be mindful of the parameter 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.

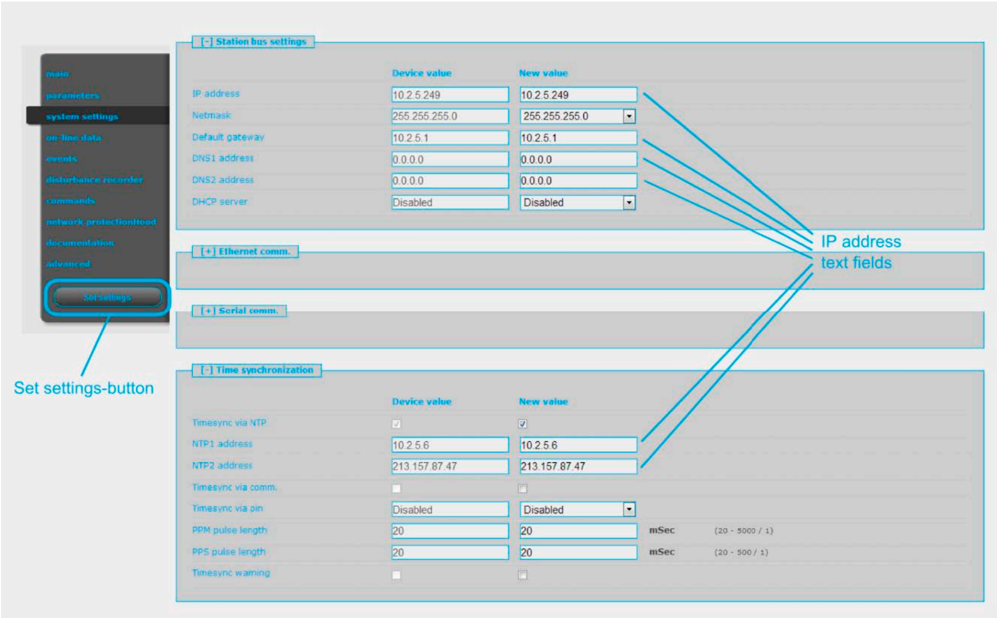


Table. 5.4.3 - 6. The system setting sections and their content.

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 "0" (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. CAUTION! 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. CAUTION! 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 synchronzation 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.

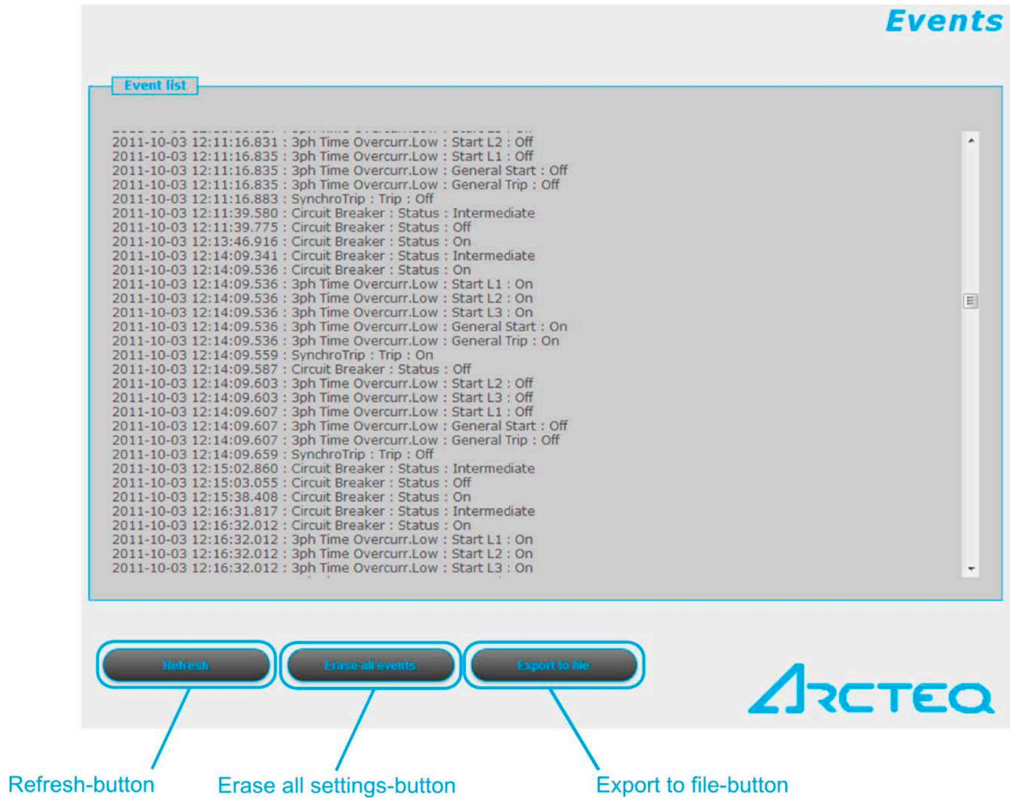
This menu displays the data measured by the device. Each block has their own section, and these sections can be expanded and collapsed individually as needed with the [+] and [–] signs in front of their names. The values on screen are updated every second, which may cause older systems to slow down or 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 occured in the device. The events are listed in the following format: [local time] : [function block] : [channel] : [new value].

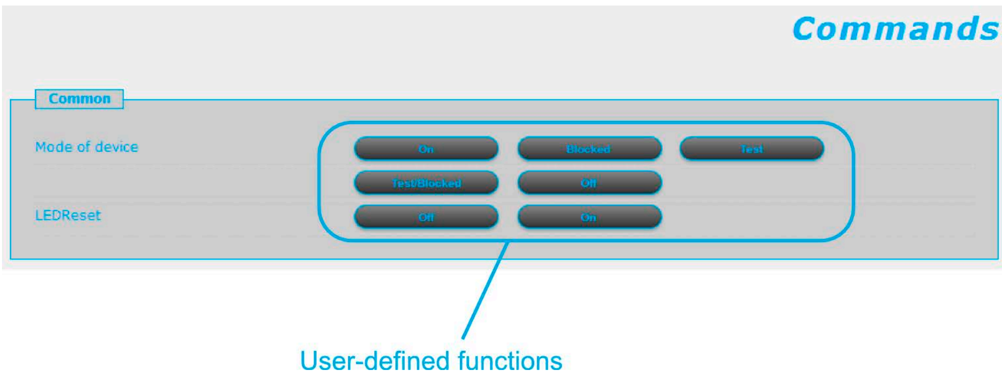
Figure. 5.4.3 - 23. Elements of the events menu.



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.

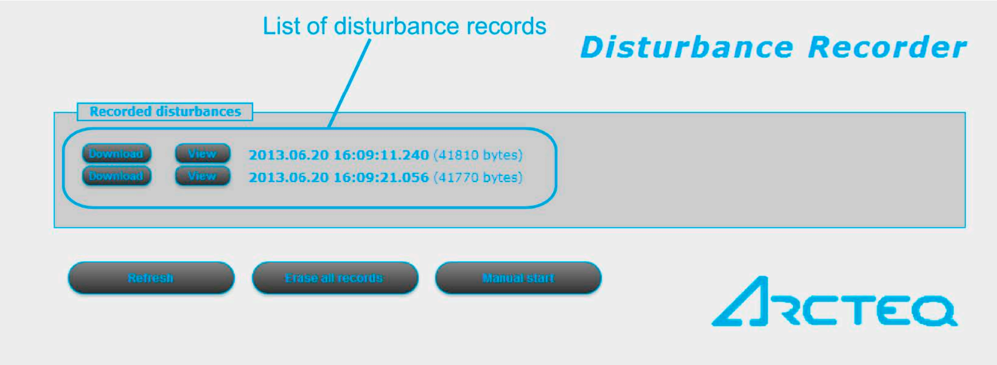


In the commands menu you can instruct the processor to carry out customized, user-defined commands. You can use the various mode buttons (**On**, **Blocked**, **Test**, **Test/Blocked**, **Off**) and LED buttons (**On**, **Off**) to define functions. A status update is always generated with a command, 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.

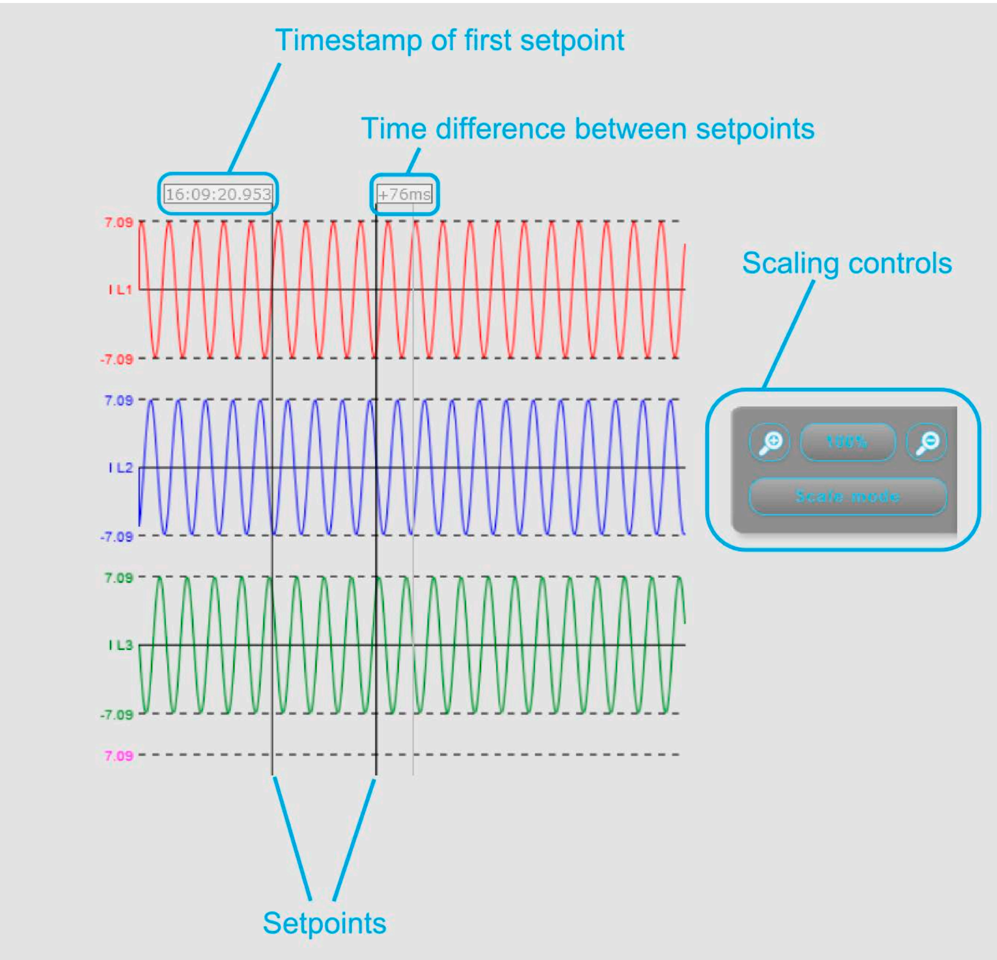
Figure. 5.4.3 - 25. Disturbance recorder.



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 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).

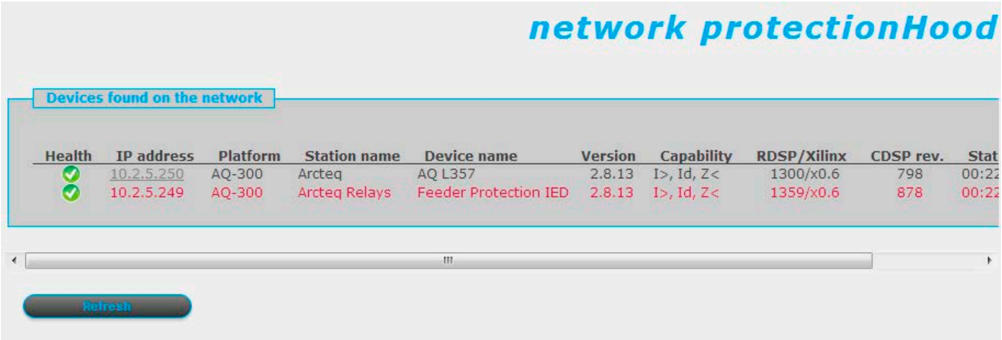
Figure. 5.4.3 - 26. Example of a disturbance record preview.



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

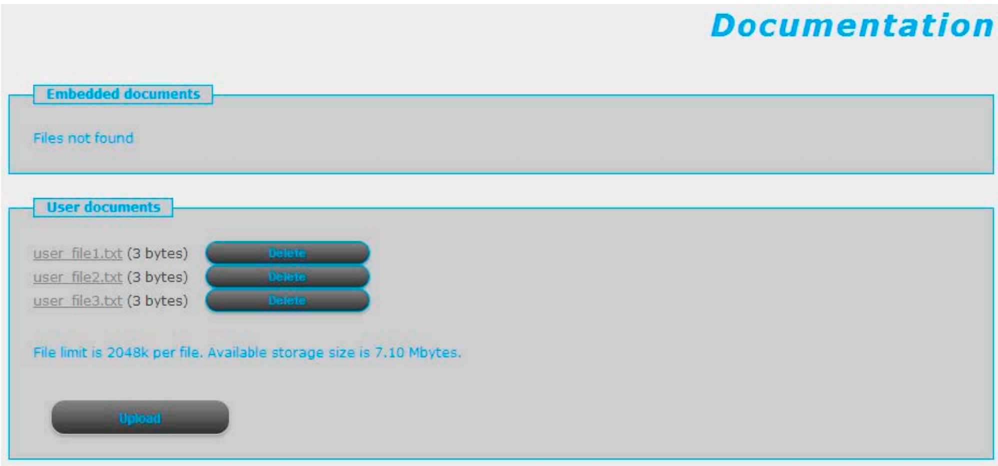
Figure. 5.4.3 - 27. The network protectionHood menu.



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.

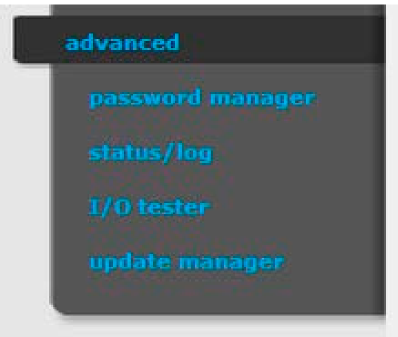


This page displays the documentation files on the device. You can upload other documents and files on the device, which are then saved and can be accessed later. One file can be up to 2048K , and there is storage for up to 8 MB of documentation.

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.

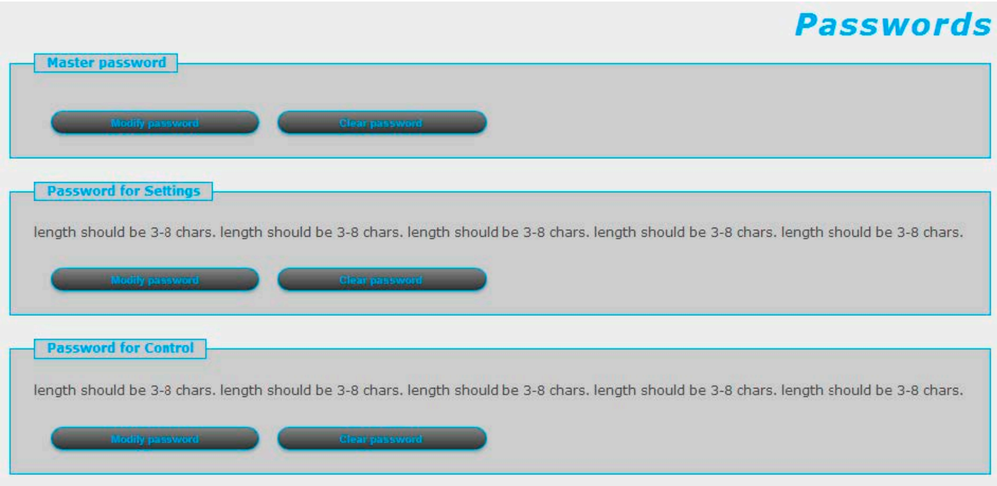


This menu displays the additional, more advanced options. You can set a password request before a user is allowed access to these options.

<u>Password manager</u>

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.



<u>Status/log</u>

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.

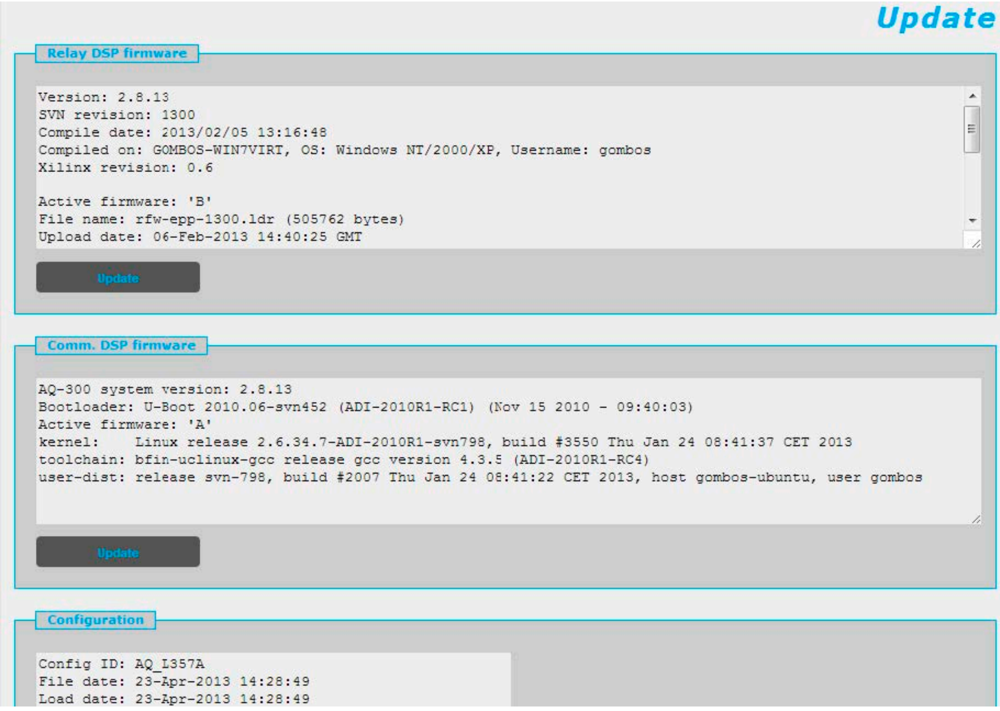
NOTICE!
All log files are in English, regardless of your language selection!

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 disconnector 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	$3I_dB>$	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.

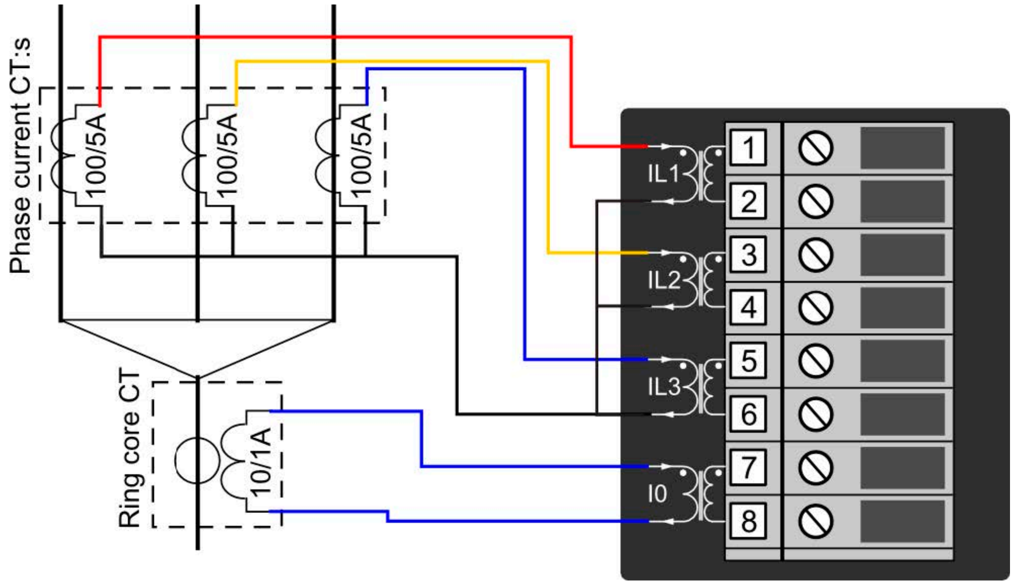


Table. 7.2.1 - 9. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: I0CT primary 10A I0CT 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.

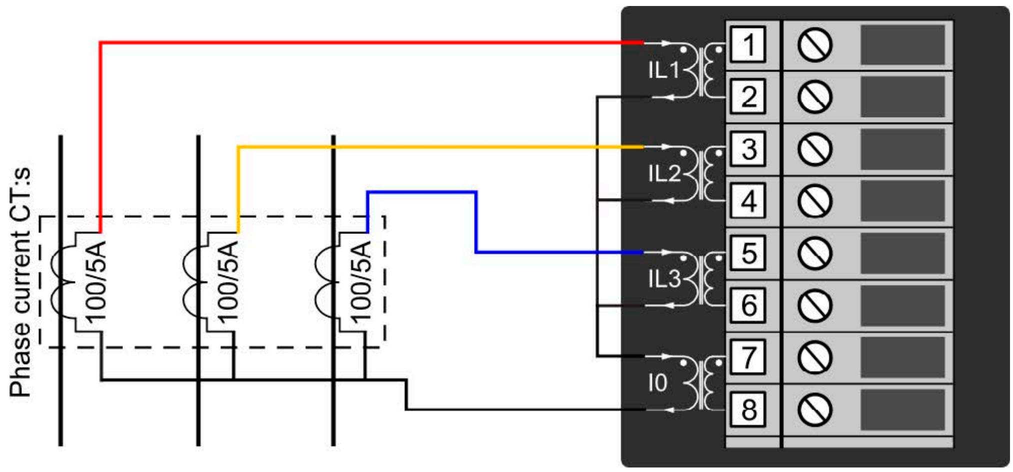


Table. 7.2.1 - 10. Values for the example above.

Phase current CT: CT primary 100A CT secondary 5A	Ring core CT in Input I0: I0CT primary 100A I0CT 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_PriI13_FPar_	Rated Primary I1-3	A	100	4000	1000
Rated primary current of channel4					
CT4_PriI4_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.

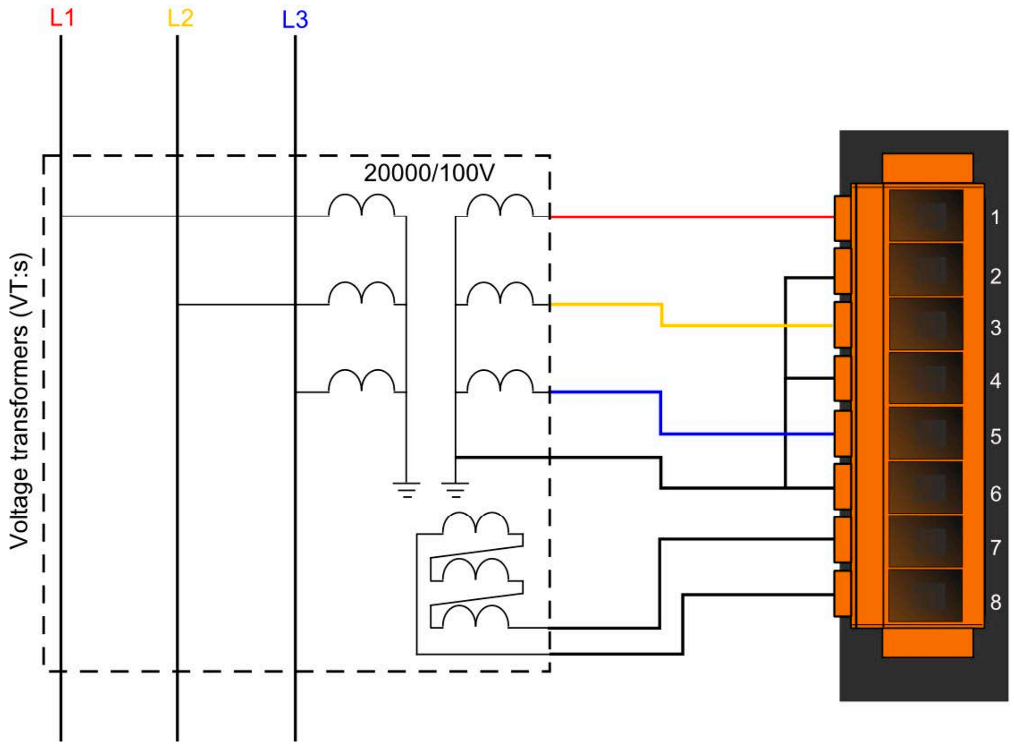
The voltage input function block receives the sampled voltage values from the internal operating system. The scaling (even hardware scaling) depends on a common parameter “Range” for type selection. The options to choose from are 100V or 200V, no hardware modification is needed. A small voltage is processed 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-Un. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

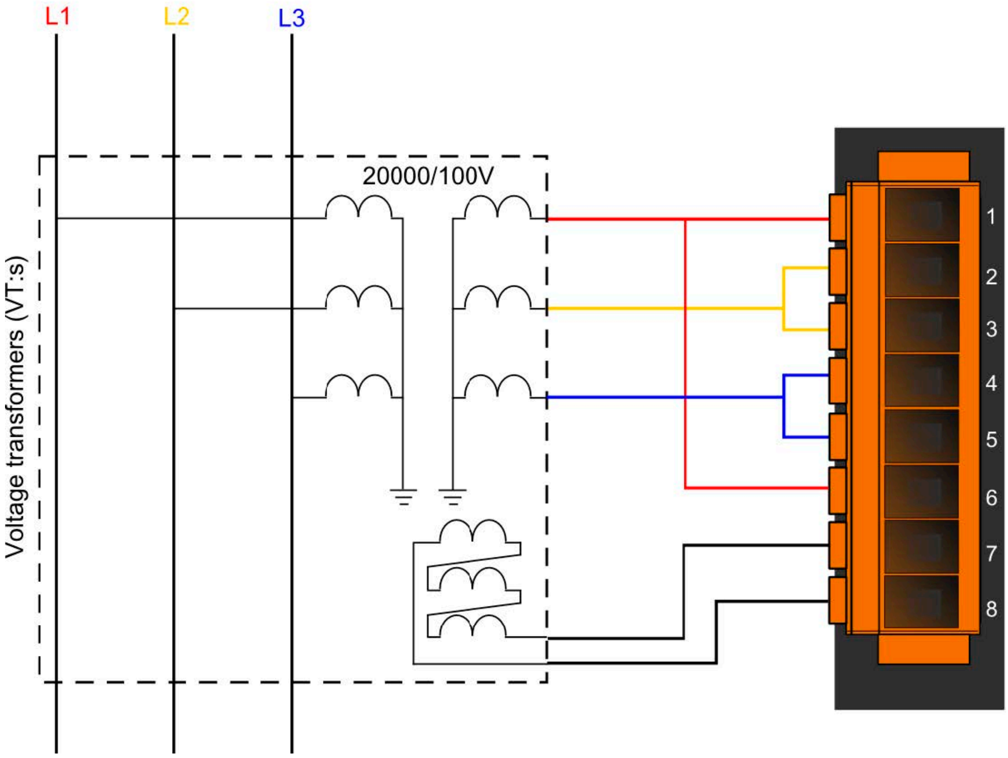
Figure. 7.2.2 - 35. Phase to neutral connection. Connection U1-3.



Ph-N Voltage: Rated Primary U1-3: 11.55kV (=20kV/√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/√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

Measured value	Dim.	Explanation
Voltage Ch - U2	V(secondary)	Fourier basic component of the voltage in channel UL2
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 Protection functions

8 Busbar differential protection

The busbar differential protection function provides main protection for busbar systems of the substations or power plants.

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.

Two different types of busbar protection are available. Both of them perform basically the well-known principle: the sum of the currents flowing into and out of the busbar results zero, if there are no internal faults. If the sum is not zero then there is an internal fault, and a fast trip command is generated. The scheme in both versions is the low impedance, biased differential scheme, the application of Kirchhoff`s node law.

The difference between the two types is the structure of the differential protection system:

- Centralized version:
    - If the number of bays connected to the busbar is limited (there are not more bays than 6) the tasks related to the three-phase busbar differential protection function are performed within one device.
    - With the increasing number of the bays, the tasks are divided among three independent devices. Each of them is responsible for the differential protection of one phase (L1, L2 or L3) of the busbar. This version can be considered also as a centralized version.
- Distributed (Decentralized) version:
    - In this version other individual protective devices of the bays (e.g. distance protection, overcurrent protection, etc.) are involved in the busbar protection scheme. They are located in the substation according to the bay structure of the primary system. These devices perform the sampling of the currents and have access to all information needed for the busbar protection system. This information is sent by fiber optic link to the central unit. The calculation and decision is performed by the central unit, and the dedicated trip commands are sent back to the devices also via fiber optic links.

This document contains all parameters, inputs, and outputs of the three versions, but it hints the differences of the versions.

The numerical protection integrates two independent protection functions:

- numerical differential protection
- breaker failure protection

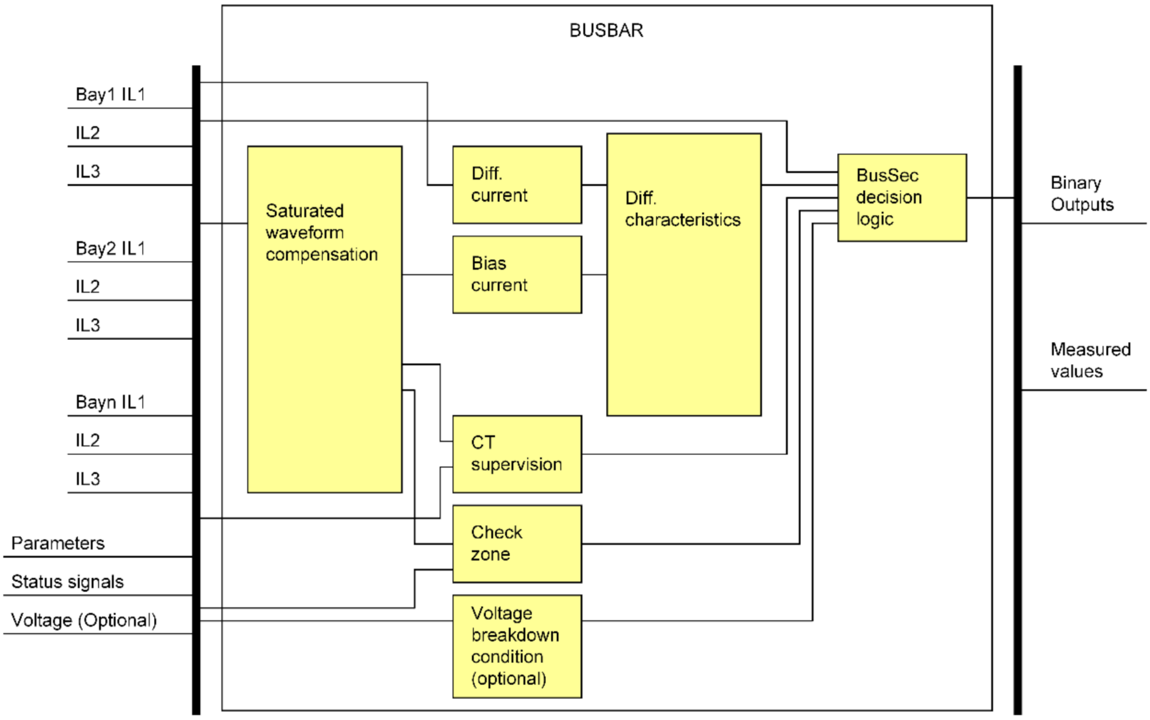
The joint discussion of these functions is based on the fact that the breaker failure protection utilizes the processed status information of the busbar protection to disconnect only the section of the busbar to which the faulty circuit breaker is connected. So, the other zones can remain in continuous service.

8.1 Operation principle

The behavior of the busbar differential protection is determined by:

- The configuration,
- The algorithm and the related parameter setting.

Figure. 8.1 - 37. Structure of the busbar differential protection algorithm



The main features of busbar differential protection function can be summarized as follows:

- The function is performed within one central device, but the analog currents and status signals from all bays of the busbar are accessed by protection devices dedicated to the bay;
- The bay units can perform any other protection functions, but they communicate binary information and sampled values with the central device via fiber optic links;
- Dynamic busbar replica, based on disconnector status signals;
- High stability in case of external faults in spite of current transformer saturation;
- Short tripping time;
- Selectivity for internal fault, only the bays connected to the faulty busbar section are disconnected, all other bays remain in continuous operation;
- Easily to extend according to the busbar configuration;
- Easy adaptation of the function for different primary bus systems:
    - Single busbar
    - Up to quadruple busbar
    - Ring bus,
    - 1 ½ circuit breaker arrangement,
    - Bus couplers,
    - Bus sectionalizers with one or two current transformers,
    - Transfer bus;
- Individual numerical calculation and decision for all three phases;
- Stabilized differential current characteristics;
- The security and stability are increased with special software methods;
- Voltage breakdown condition,
- Check zone application,
- Saturated waveform compensation,
- Directionality check,
- Current transformer failure detection,
- Checking the disconnector status signals,
- Included breaker failure protection.

8.1.1 Blocking

Busbar function blocking

BBP blocking input blocks the algorithm of the busbar protection function when Operation parameter is "On". This blocking means the algorithm stops working and only the Busbar function has active blocked signal, neither BusSec nor BayUnit functions. BBPBlocked output is also active when CT error (See Busbar replica evaluation chapter), disconnector status (See Checking the disconnector status signal chapter) occurs or Operation parameter is Off. BFP functionality is not affected. If "On-Meas" is selected in Operation parameter, it means the calculation of differential and bias current is active and Online measurement as well. Before FW version 3015, the BBP block input also blocked the BFP functionality.(See The breaker failure protection function chapter)

Bus section and Bay unit blocking

BayUnit function has BBPSecBlk input. Bus section can be blocked using its own blocking input "BBPSecBlk" or blocking input of BayUnit function block "BBPSecBlk".It was "BlkSect" in the previous versions. Activating any inputs means the Bus section is blocked, measurement is up to the operation parameter of Busbar function and all connected bays to this section are also blocked. Usually there are spare or future bays in the busbar system. BayUnit function has "Bay Disable" parameter to eliminate these bays from the algorithm but keep them in the topology to activate whether it is necessary.

8.1.2 The busbar replica evaluation

The algorithm continuously evaluates the status signals of the disconnectors and if there are changes in the status signals then based on the input 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.

In the distributed version, the algorithm is processed in the central device. The algorithm continuously evaluates the status signals of the disconnectors and if there are changes in the status signals then based on the received signals from the bay units via the fiber optic cable 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. Disconnector statuses of Sectionalizer have to wiring into the central unit.

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 inactive measuring elements of interconnected bus sections. It means that the on-line displayed values will be the same for these bus sections

8.1.3 The protection algorithm

The current transformer cards perform synchronous sampling of all analog signals These values are used by the assigned "Measuring elements" of the central unit. The "Measuring elements" perform the following tasks:

In the distributed version of the function, the bay units perform synchronous sampling of all analog signals and send them to the central device via the fiber optic cable. These values are used by the assigned "Measuring elements" of the central unit. The "Measuring elements" perform the following tasks:

The differential current calculation

Summation of the sampled Ip momentary current values for the bays connected to the “Measuring element”. The result is the calculated momentary value of the differential current:

Figure. 8.1.3 - 38. 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.

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

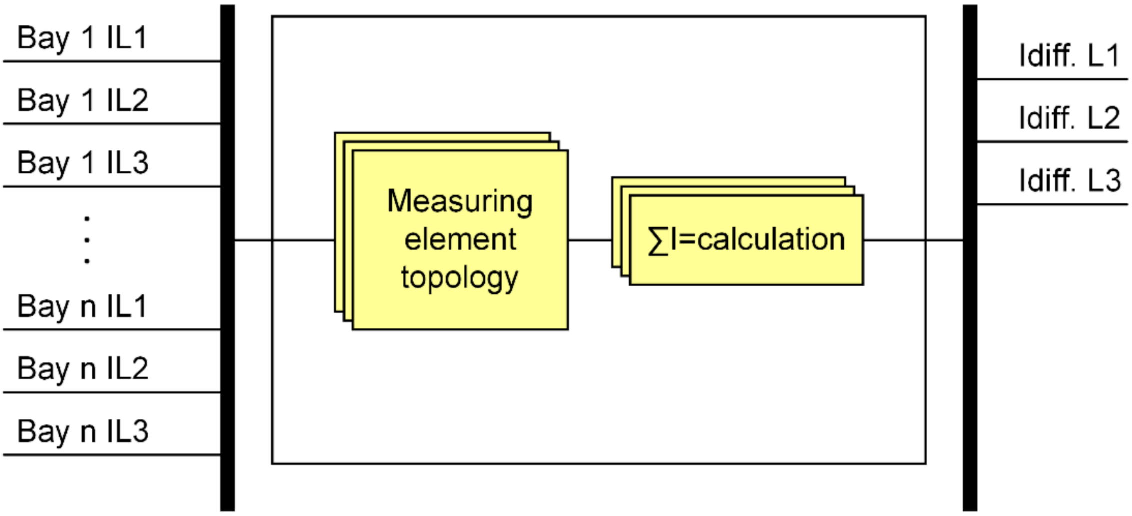
Figure. 8.1.3 - 39. Filtering the current DC component by subtracting the value sampled 10 ms before from the actual value, and the difference is divided by two. The result is the calculated momentary value of the differential current without the DC component.

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

Figure. 8.1.3 - 40. The magnitudes of the ten last calculated values are averaged, receiving the Id 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.)

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

Figure. 8.1.3 - 41. Logic scheme of the differential current calculation



The biasing current calculation

The method of the biasing current calculation is as follows:

Figure. 8.1.3 - 42. From the absolute value of the sampled Ip momentary current values a predetermined "I max. load" value, determined with parameter setting is subtracted. Here I max. 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.

$$|I_p| - \mathrm{I\ max\ load}$$

Figure. 8.1.3 - 43. Out of these differences only the values above 0 (if (|��| –I max load) > 0) are summed. 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).

$$I_{s.p} = \sum (|I_p| - \mathrm{I\ max\ load})$$

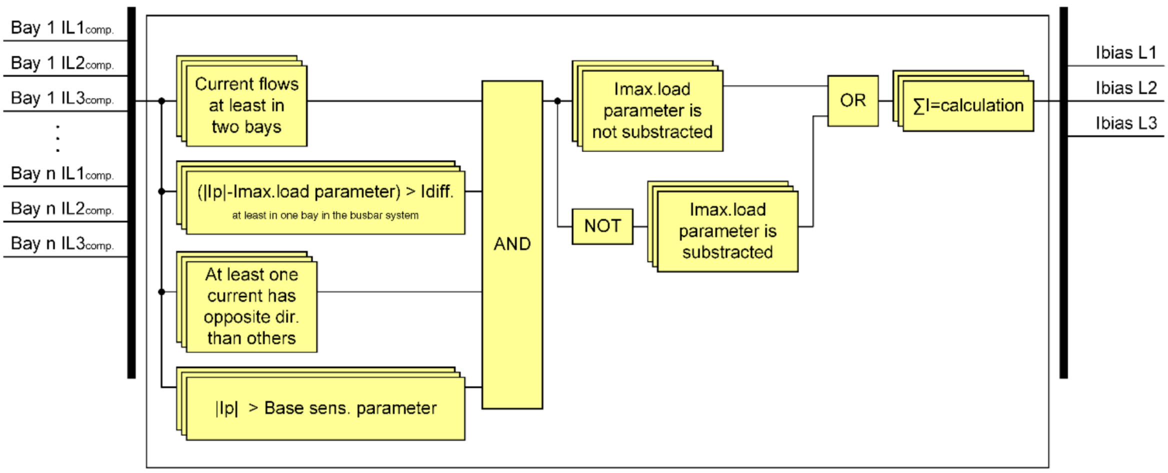
Figure. 8.1.3 - 44. Then the average of this value and that received 10 ms before is calculated:

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

Figure. 8.1.3 - 45. The last ten calculated values stored in the memory are averaged, receiving the Is biasing current:

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

Figure. 8.1.3 - 46. Logic scheme of the bias current calculation



8.1.4 Role of the maximum current setting for normal operation

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 “I max. 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 negative, but shows zero.

If in this state an internal fault occurs, then the current samples get very fast above “I max. load” value. Consequently the locus of the Id-Is points on the plane of the differential characteristics (see The differential characteristics chapter) is at once above the broken line described by the slope “k” (parameter setting “k zone”) and the base sensitivity (parameter setting “Base sensitivity”).

This helps the algorithm to recognize the internal fault and leads to faster operation.

In case of external fault however, the locus of the Id-Is points on the plane of the differential characteristics (see The differential characteristics chapter) start moving in the direction of the Is axis.

If the algorithm recognizes this movement, i.e. the locus is below the line described by the slope “k”, then it is detected as an external fault. This way the algorithm 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.

The algorithm decides there is an external or internal fault and subtracts the “I max. load” value or not. There conditions are shown on "Logic scheme of the bias current calculation" figure in The protection algorithm chapter.

(Additionally to this method, the “saturated waveform compensation” is another means to avoid unwanted trip generation; See Saturated waveform compensation chapter).

Table. 8.1.4 - 18. Integer parameter for maximum load current

Name	Title	Unit	Min	Max	Step	Default
Maximum load current for normal operation:						
Busbar_Offset_IPar_	Max. load current *	A	100	10000	1	1000

* This parameter value should not be higher than the “Base sensitivity” of the differential characteristics. In case of wrong setting the top left LED on the front panel of the device gets yellow, indicating a warning

8.1.5 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.

8.1.6 Voltage breakdown condition

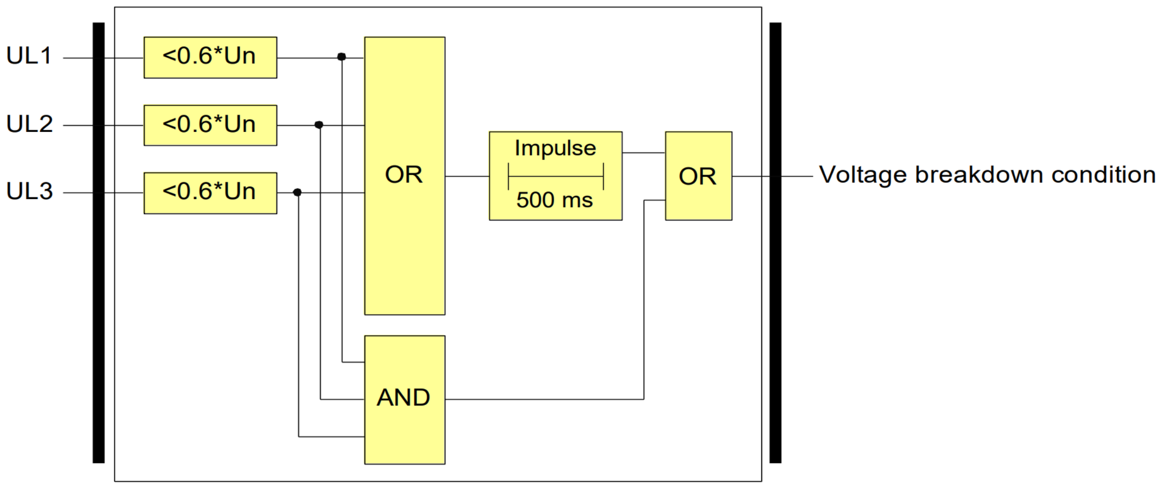
VT module is necessary in the IED to detect the voltage breakdown. Voltage input channels must be assigned as inputs of a Bay Unit function block.

In the distributed version of the function, VT module is necessary in the bay unit IED to detect the voltage breakdown. Voltage input channels must be assigned as inputs of Bay Unit function block in bay unit IED. The central unit gets this information via the fiber optic cable from the bay unit IED.

Latest version of the function block can handle two different 3ph voltage inputs as Bus1 and Bus2 voltages. There is a selector input, Ubus2Sel_GrO_ to select the second 3ph voltage as input of the voltage breakdown condition function. If this input is inactive, the first 3ph voltage is used for voltage breakdown.

The voltage breakdown function follows the logic below:

Figure. 8.1.6 - 47. Logic scheme of the voltage breakdown function



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 at least in one of the bus sections, 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 0.6Un), and then during a fault any of the phase voltages is below 0.6Un, 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 any of 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 for all bus sections, then the function is disabled until the measured voltage returns to healthy state again, or a new initializing is performed (caused by disconnector status change, switching on or off, parameter changes).

If all voltage monitoring functions assigned to a measuring element detect low voltage, then the bus-bar 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 on the webpage displays the status signal as “U Block: +“. If one or more voltage supervisions detect low voltage, then the display changes form “+“ to “-”. At that moment a 0.5s 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 fix values, the function does not need any parameter setting.

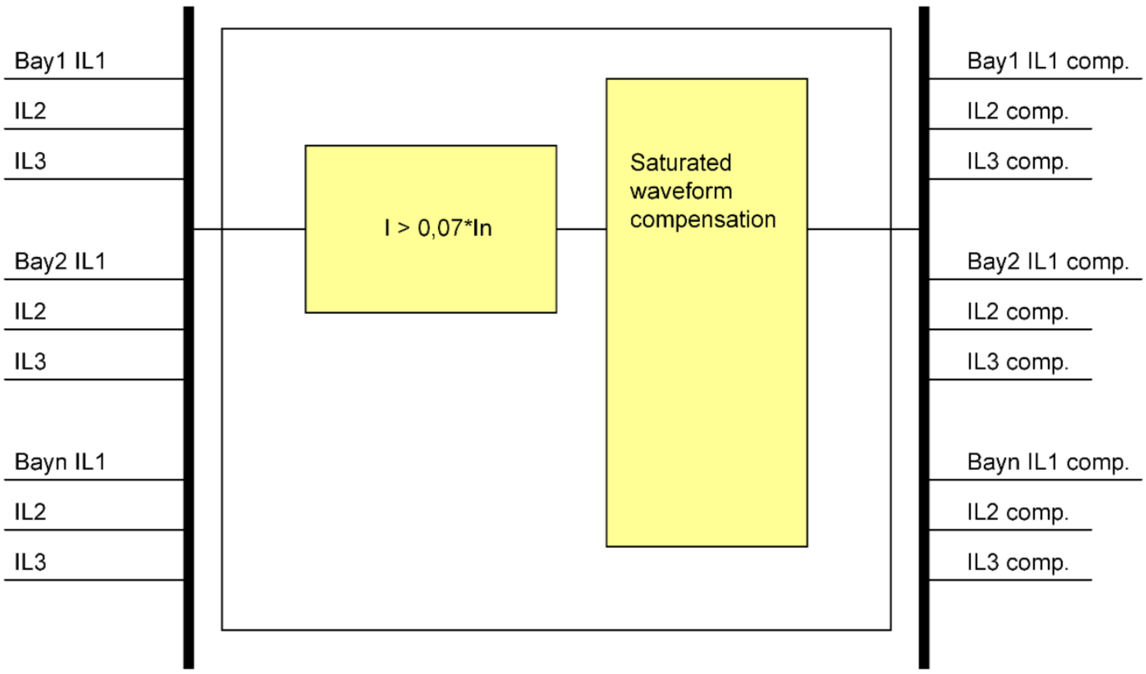
8.1.7 Saturated waveform compensation

In case of external faults, 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.

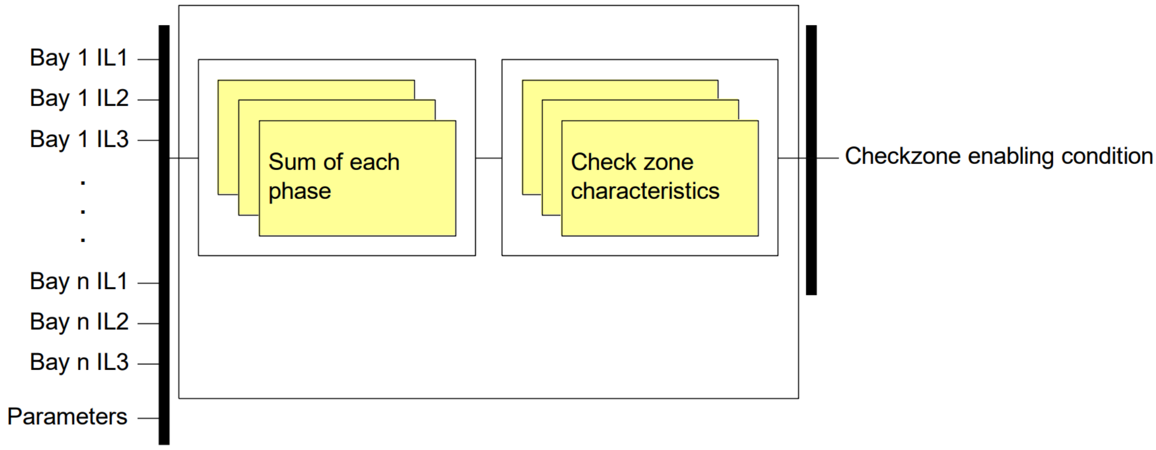
Figure. 8.1.7 - 48. Logic scheme of the saturated waveform compensation



8.1.8 The checkzone

The checkzone function follows the logic below:

Figure. 8.1.8 - 49. Logic scheme of the checkzone



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) 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.

Currents of different bays which are in the check zone calculation have to set in the bay topology menu of AQtivate 300 tool.

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

Table. 8.1.8 - 19. The integer parameters of the check zone differential characteristics

Parameter name	Title	Unit	Min	Max	Step	Default
Check zone characteristics base sensitivity:						
Busbar_CheckSens_IPar_	Base Sensitivity - CheckZone	A	100	10000	1	1000
Slope of the check zone characteristics:						
Busbar_CheckK_IPar_	Slope of Char - CheckZone	%	40	80	1	50

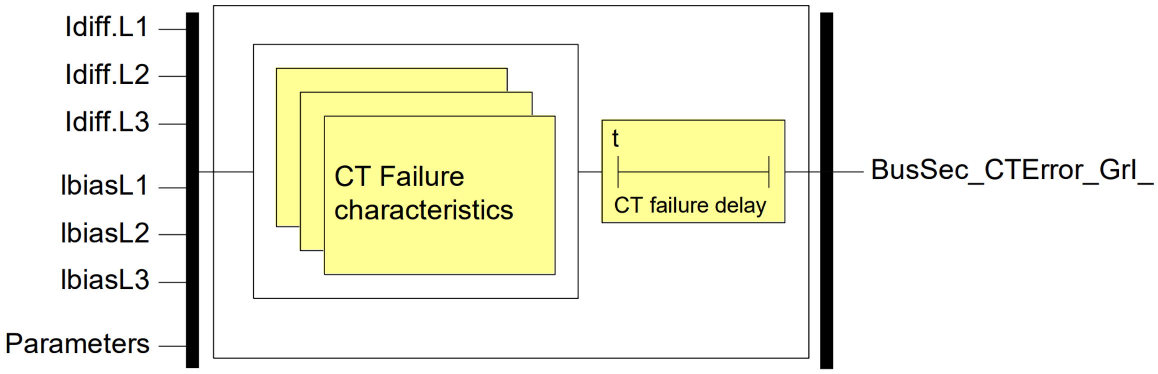
Table. 8.1.8 - 20. Enumerated parameter of the check zone differential characteristics

Parameter name	Title	Selection range	Default
Parameter to enable the supervision by the check zone:			
Busbar_CheckOper_EPar_	CheckZone	Off, On	Off

8.1.9 Current transformer failure detection

The current transformer failure function follows the logic below:

Figure. 8.1.9 - 50. Logic scheme of the current transformer failure



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 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 differential characteristics chapter)

If the measured currents result an Id–Is point above this characteristic, then after a time delay the "measuring element" gets blocked, or, from firmware versions 3022 and up, the user can define this to provide an alarm signal only instead of blocking. Slope parameter is discontinued from this version.

Table. 8.1.9 - 21. Enumerated parameter of the current transformer failure detection

Parameter name	Title	Selection range	Default
Parameter to set the effect of the CT error detection			
Busbar_CTSMode_EPar_	CT supervision	Only Alarm, Operation Blocked	Operation Blocked

Table. 8.1.9 - 22. The integer parameters of the current transformer failure detection characteristics

Parameter name	Title	Unit	Min	Max	Step	Default
CT error detection characteristics base sensitivity:						
Busbar_CTErrSens_IPar_	Base Sensitivity – CT failure	A	50	5000	1	500

Slope of the CT failure detection characteristics: discontinued from FW version 3022.

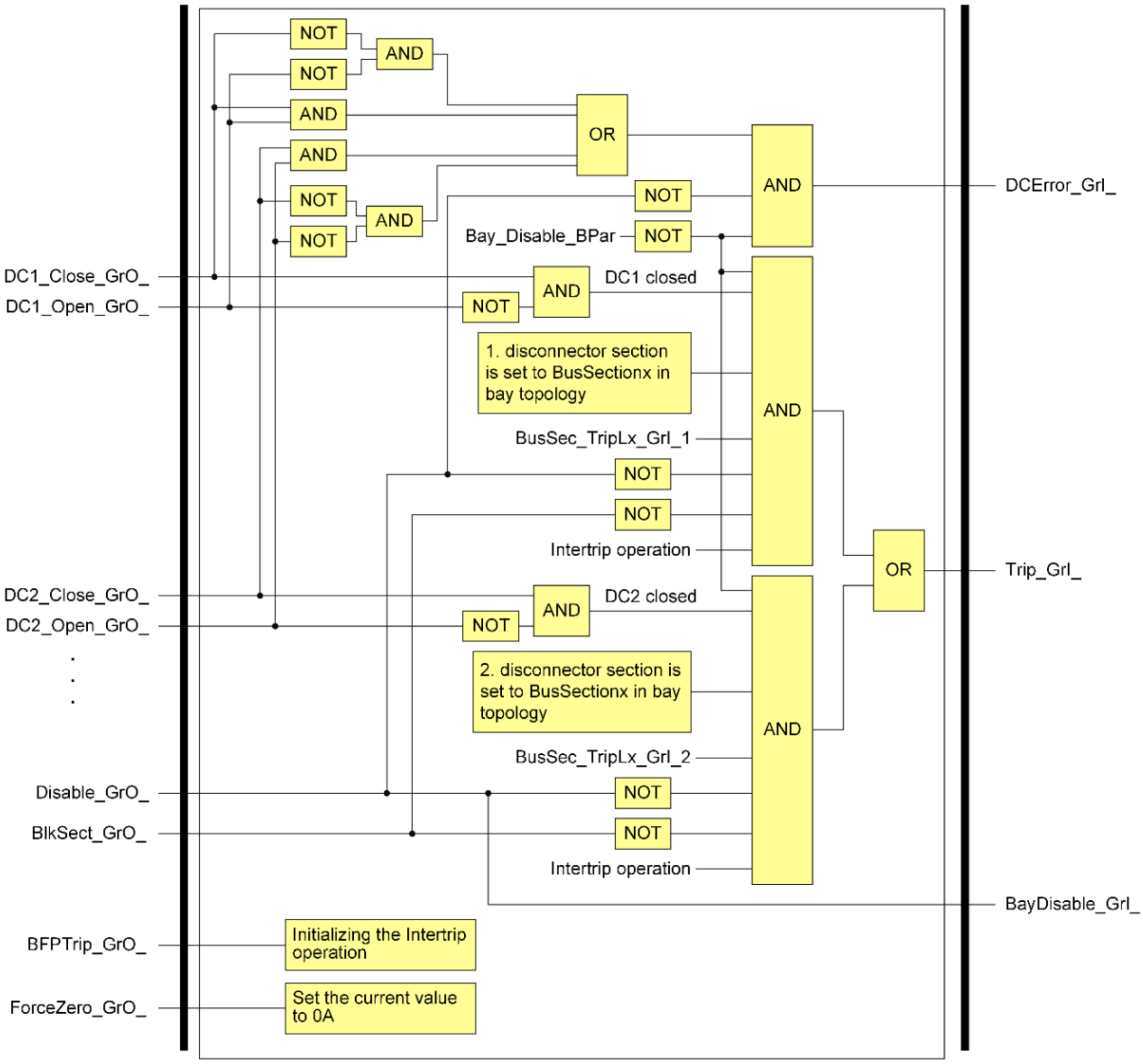
Table. 8.1.9 - 23. Timer parameter of the current transformer failure detection characteristics

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for signaling CT error :						
Busbar_CTErrDelay_TPar_	CT Failure Delay	ms	100	60000	1	1000

8.1.10 The bay unit function block

The bay unit function follows the logic below:

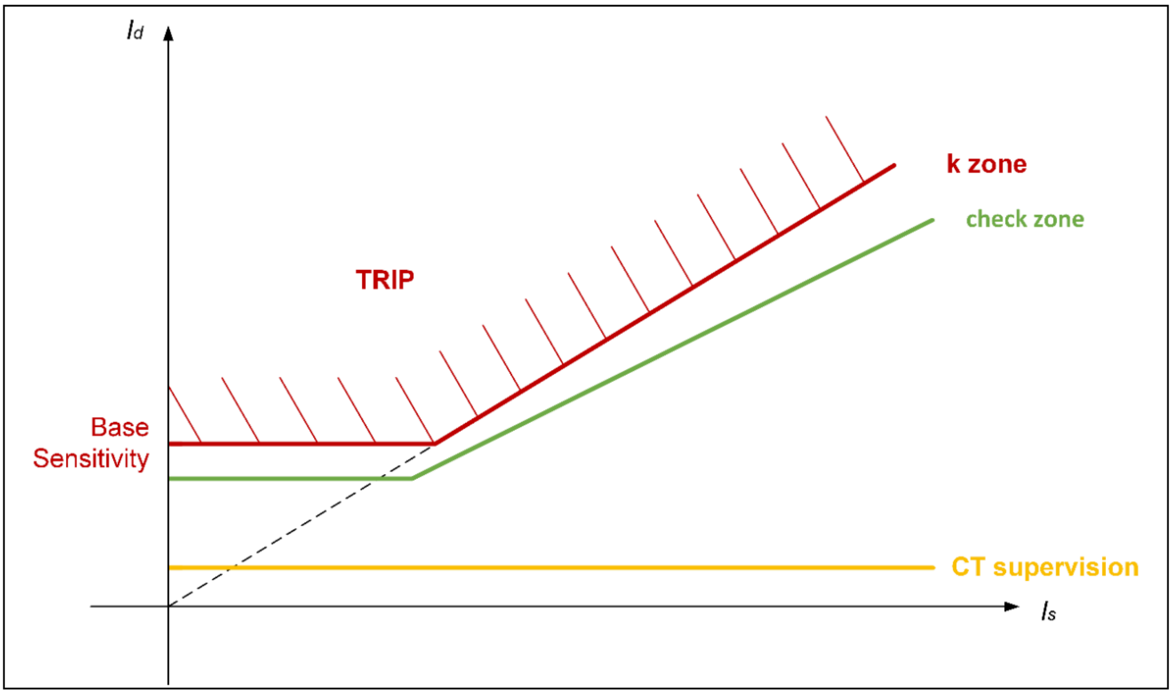
Figure. 8.1.10 - 51. Logic scheme of the bay unit function



The bay unit function transfers the currents to the bus section according to the disconnector status inputs (DC1-4 open/close). Gets the trip signal from the bus section function block according to the topology. Disable input has the same functionality as “Bay disable” parameter, see parameters in The parameters of the busbar differential protection function chapter input is an optional blocking of the connected bus section via the bay unit function with proper logic. BFPTrip input initializes the braker failure intertrip operation (trip command distribution) without any delay if the “Intertrip” parameter of Busbar function is set to enable. ForceZero input is used for setting current value to zero. It is necessary in bus coupler bays to handle the dead-zone faults.

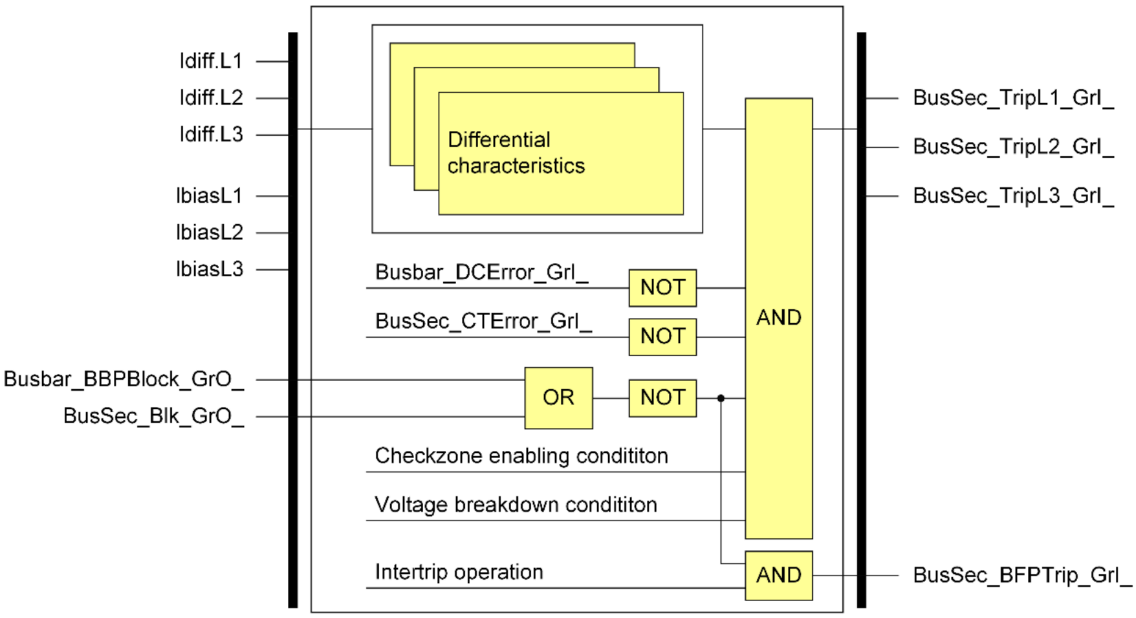
8.1.11 The differential characteristics

Figure. 8.1.11 - 52. The trip characteristic of the busbar differential protection



The bus section trip decision follows the logic below:

Figure. 8.1.11 - 53. Logic scheme of the bus section



Integer parameters of the differential characteristics:

Table. 8.1.11 - 24. The integer parameters of the differential protection characteristics

Parameter name	Title	Unit	Min	Max	Step	Default
Differential characteristics base sensitivity:						
Busbar_ZoneSens_IPar_	Base sensitivity	A	100	10000	1	1000
Slope of the characteristics:						
Busbar_ZoneK_IPar_	Slope of Characteristic *	%	60	90	1	80

Enumerated parameter of the differential characteristics:

Table. 8.1.11 - 25. Enumerated parameter of the differential protection characteristics

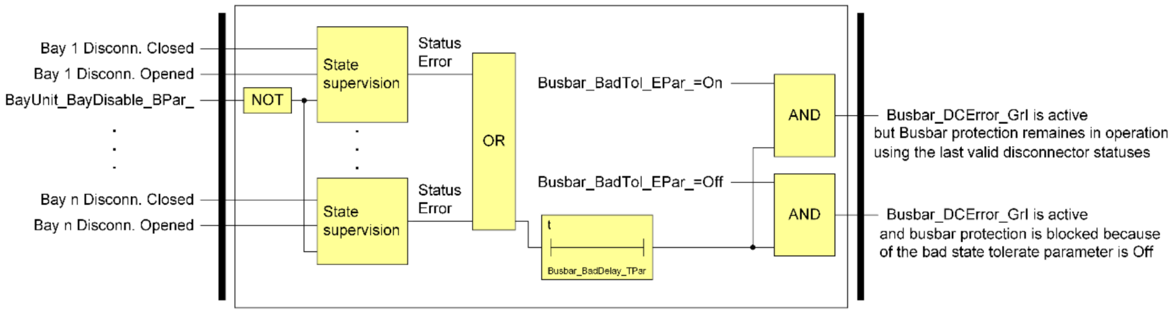
Parameter name	Title	Selection range	Default
Parameter to enable the operation of differential characteristics:			
Busbar_BBPOper_EPar_	Operation	Off, On, On-Meas	Off

NOTICE!
On-Meas is available from FW version 3022 and above.

8.1.12 Checking the disconnector status signals

The disconnector status supervision function follows the logic below:

Figure. 8.1.12 - 54. Logic scheme of the disconnector status supervision



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 disconnector 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 of bay unit. 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.

Table. 8.1.12 - 26. Enumerated parameter for checking the disconnector status signals.

Parameter name	Title	Selection range	Default
Parameter to tolerate the disconnector status signals error:			
Busbar_BadTol_EPar_	Bad State Tolerate	Off, On	Off

Table. 8.1.12 - 27. Timer parameter for checking the disconnector status signals

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for signaling disconnector bad state :						
BayUnit_BadDelay_TPar_	Bad State Delay	ms	100	60000	1	1000

8.2 The measurements

The measurement and displayed values of the busbar differential protection function are listed below.

For each voltage input module, the device measures and displays the phase voltages. Table below shows as an example the voltages of a bus section.

Table. 8.2 - 28. The measured analogue voltages of the busbar differential protection (example)

Measured value	Explanation
Voltage Ch – U1	Phase voltage L1
Voltage Ch – U2	Phase voltage L2
Voltage Ch – U3	Phase voltage L3

For each bays the device measures and displays the phase currents. Table below shows as an example the currents of a bay.

Table. 8.2 - 29. The measured analogue currents of a bay of the busbar differential protection (example)

Measured value	Explanation
Current Ch – I1	Phase current L1
Angle Ch – I1	Phase angle of the current L1
Current Ch – I2	Phase current L2
Angle Ch – I2	Phase angle of the current L2
Current Ch – I3	Phase current L3
Angle Ch – I3	Phase angle of the current L3

NOTICE!
The reference vector selection depends on the configuration.

For each bus section the device measures and displays the differential currents and the bias currents. Table below shows as an example the currents of a bus section.

If the bus section is interconnected with another bus section, then the displayed values are the same of the interconnected sections.

Table. 8.2 - 30. The measured differential and bias currents of the busbar differential protection (example)

Measured value	Explanation
I Diff L1	Differential current L1, primary A
I Diff L2	Differential current L2, primary A
I Diff L3	Differential current L3, primary A
I Bias L1	Bias current L1, primary A
I Bias L2	Bias current L2, primary A
I Bias L3	Bias current L3, primary A

8.3 The breaker failure protection function

The busbar protection integrates two protection functions:

- numerical differential protection,
- breaker failure protection.

The joint discussion of these functions is based on the fact that 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.

NOTICE!
3015-H7, 3020 firmware version and above use the BBP_Block_GrO and BFP_Block_GrO inputs individually. Previously BBP_Block_GrO input blocked the BFP protection as well.

External starting signal of the breaker failure protection is received on dedicated binary input channels.

The operation mode can be Current or Contact:

Current condition

For operation, at least one of the phase currents of the bay must be above the level, as set by an integer parameter value for each bay. Also, the time delay of the function and the duration of the pulse are parameter values.

Contact condition

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.

Enumerated parameter for the breaker failure protection function to enabling or disabling the operation:

Table. 8.3 - 31. Enumerated parameter of the breaker failure protection function

Parameter name	Title	Selection range	Default
Parameter to enable the trip command distribution of the breaker failure protection function:			
Busbar_BFPOper_EPar_	Intertrip	Off, On	Off

The breaker failure protection function needs parameters related to the bays individually.

The following parameters are in the bay unit device.

These parameters are as follows:

Enumerated parameters for the breaker failure protection function, bay modules:

Table. 8.3 - 32. Enumerated parameter of the breaker failure protection function in bay unit devices

Parameter name	Title	Selection range	Default
Parameter to enable the bay to participate in the breaker failure protection function:			
BRF50_Oper_EPar_	Operation	Off, Current, Contact,Current/Contact	Off

Table. 8.3 - 33. Integer parameter of the breaker failure protection function in bay unit devices

Parameter name	Title	Unit	Min	Max	Step	Default
Current condition for the breaker failure protection :						
BRF50_StCurrPh_IPar_	Start Ph Current	%	20	200	1	30

Table. 8.3 - 34. The timer parameters of the breaker failure protection function in bay unit devices

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for the backup trip of breaker failure protection function :						
BRF50_BUDel_TPar_	Backup Time Delay	ms	60	1000	1	200
Trip pulse duration:						
BRF50_Pulse_TPar_:	Pulse Duration	ms	0	60000	1	100
Time delay for the retrip of breaker failure protection function :						
BRF50_TrDel_TPar_	Retrip Time Delay	ms	0	1000	1	100

8.4 The configuration of the function

8.4.1 The applied function blocks

The capabilities of the busbar differential protection function depend on the hardware configuration. Based on the ordering, the required number of current inputs, binary inputs for disconnector status signals and the required number of trip outputs are assembled into the device. The number and type of hardware modules depend on:

- The size, complexity and functionality of the busbar;
- Whether the protection is a three-phase version or the system consists of three single-phase units.

At the same time, in the factory configuration process, the required software function blocks are configured. The applied functions blocks are as in the following sections.

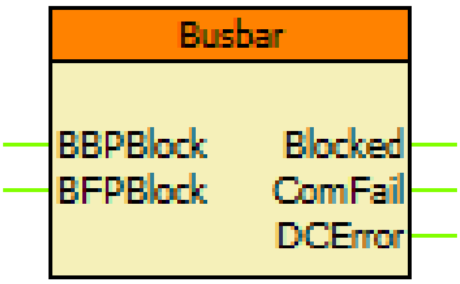
“Busbar” function block

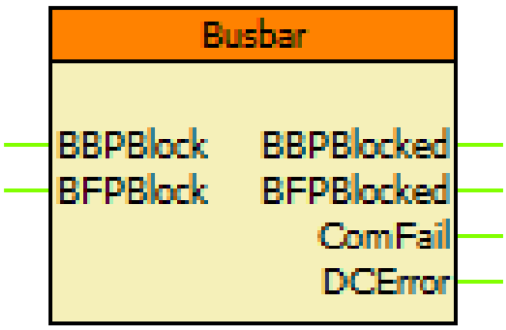
This performs the organization of the busbar protection system, and also the numerical calculations and decisions are performed in this module. Based on the disconnector status information received from the bus sections “Measuring elements” are composed. A “Measuring element” processes all currents, 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 graphic logic editor, is as follows. Separated BBP blocked and BFP blocked version is on the right side of the picture as mentioned in The breaker failure protection function chapter.

The “ComFail” communication failure output is active only in distributed version.

Figure. 8.4.1 - 55. Busbar function blocks.



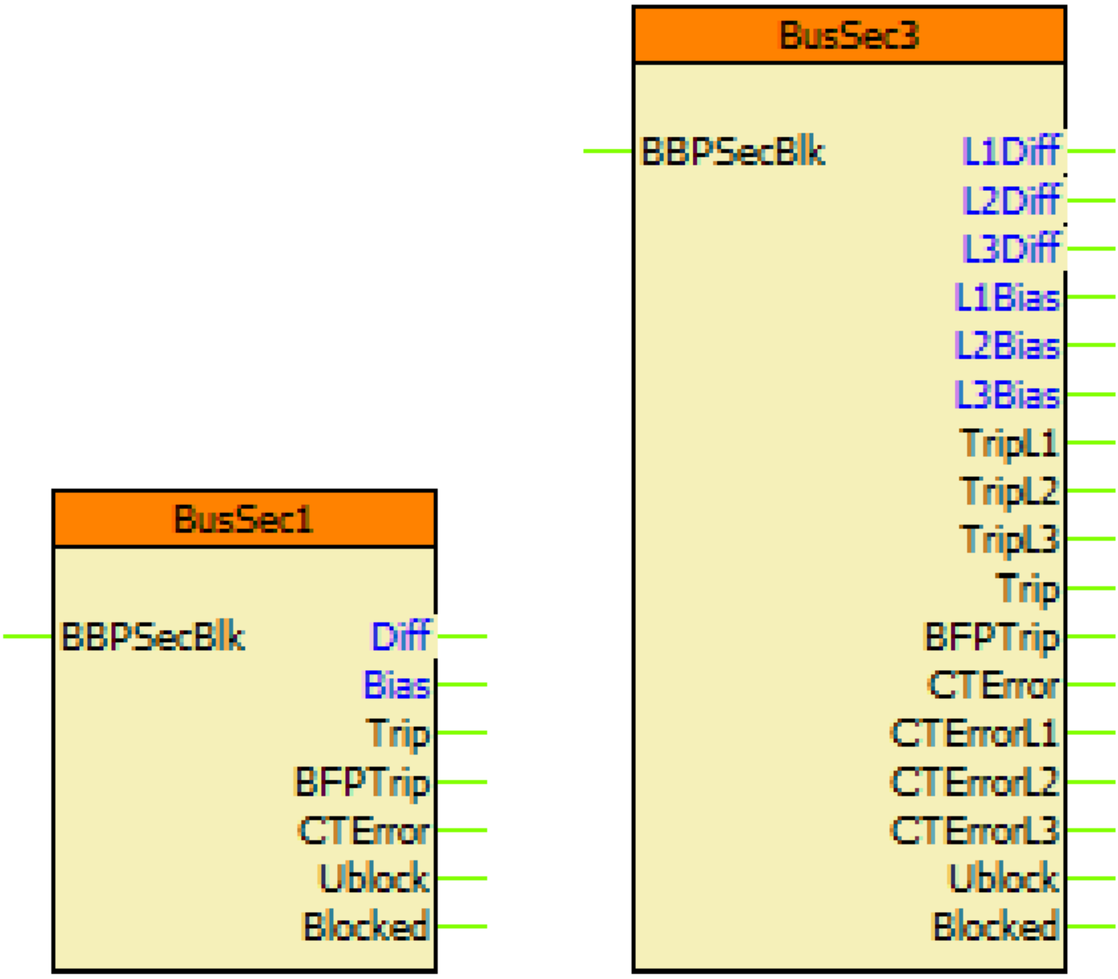


“Bus section” function blocks

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 ”Measuring element” performs the algorithm for the interconnected busbar sections, as it is described in The protection algorithm chapter. The symbol of the “Bus section” function block, as it appears in the graphic logic editor, is as follows. Differential and bias current outputs can be used in OLMRep function which reports the measured online value.

Blocked output is added as an output of the function. CT failure signals are also added for each phases, it is introduced in firmware version 2.10.2.3010.

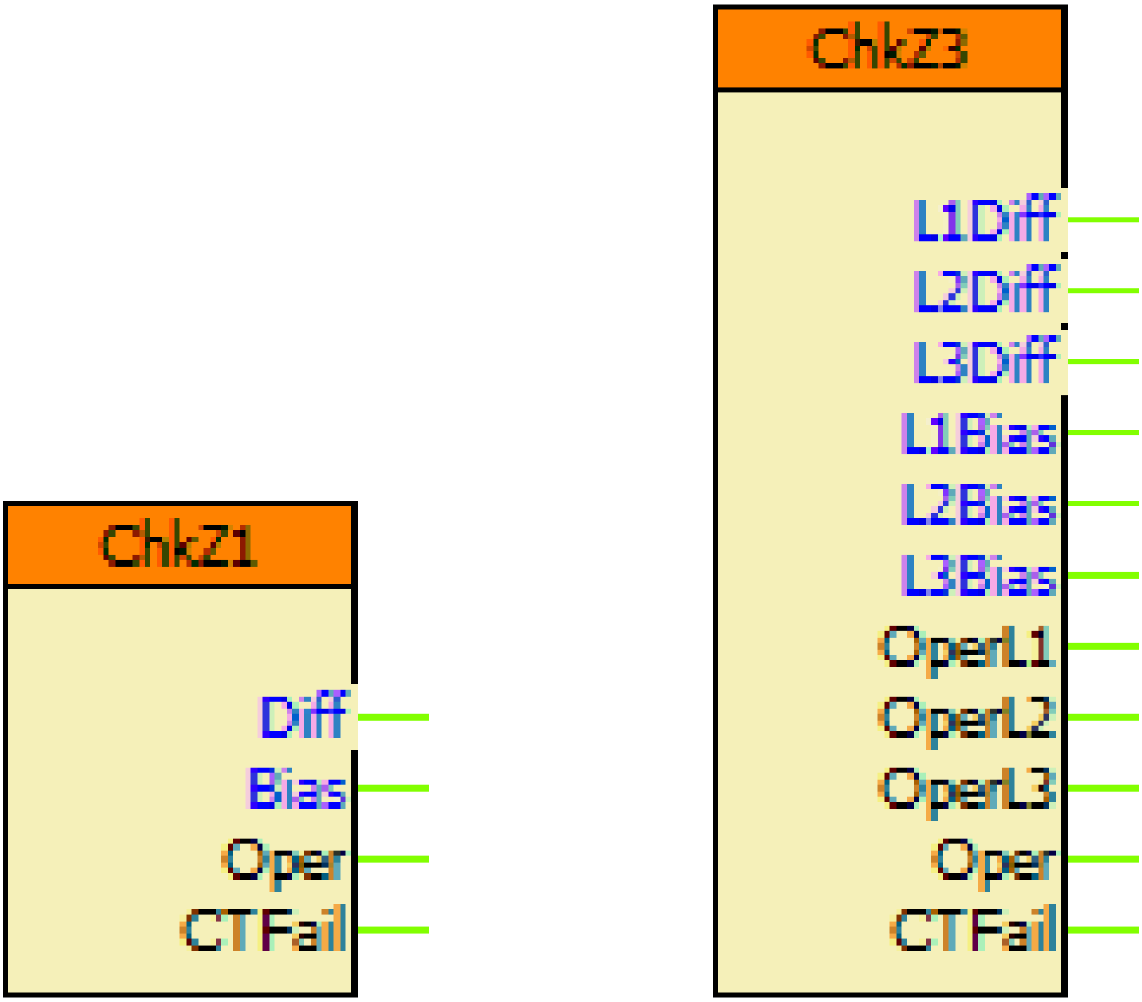
Figure. 8.4.1 - 56. Bus section function blocks



Check Zone function blocks

From firmware version 2.10.2.3022. and up, these functions are similar to the Bus Section function blocks described in the point above. These represent the binary output signals of the Check Zone. This way, the operation of the Check Zone can be monitored as well.

Figure. 8.4.1 - 57. Check Zone function blocks



“Bay unit” function blocks

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 type)
- Voltages (Three phase voltages or one phase voltage, depending of the selected type)
- Status signals of the disconnectors: these signals are received with dual signals (disconnector open and diconnector 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.

Ubus2Sel input selects the second analog input voltages when the input is active. It is used in double busbar systems to select the connected bus voltage for the voltage breakdown condition.

Figure. 8.4.1 - 58. Bay unit function in the central unit

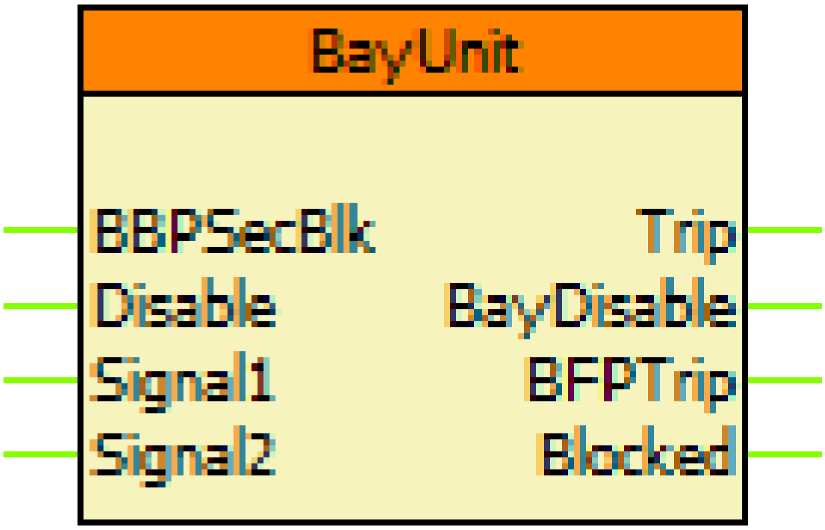


Figure. 8.4.1 - 59. Bay unit function in the bay unit

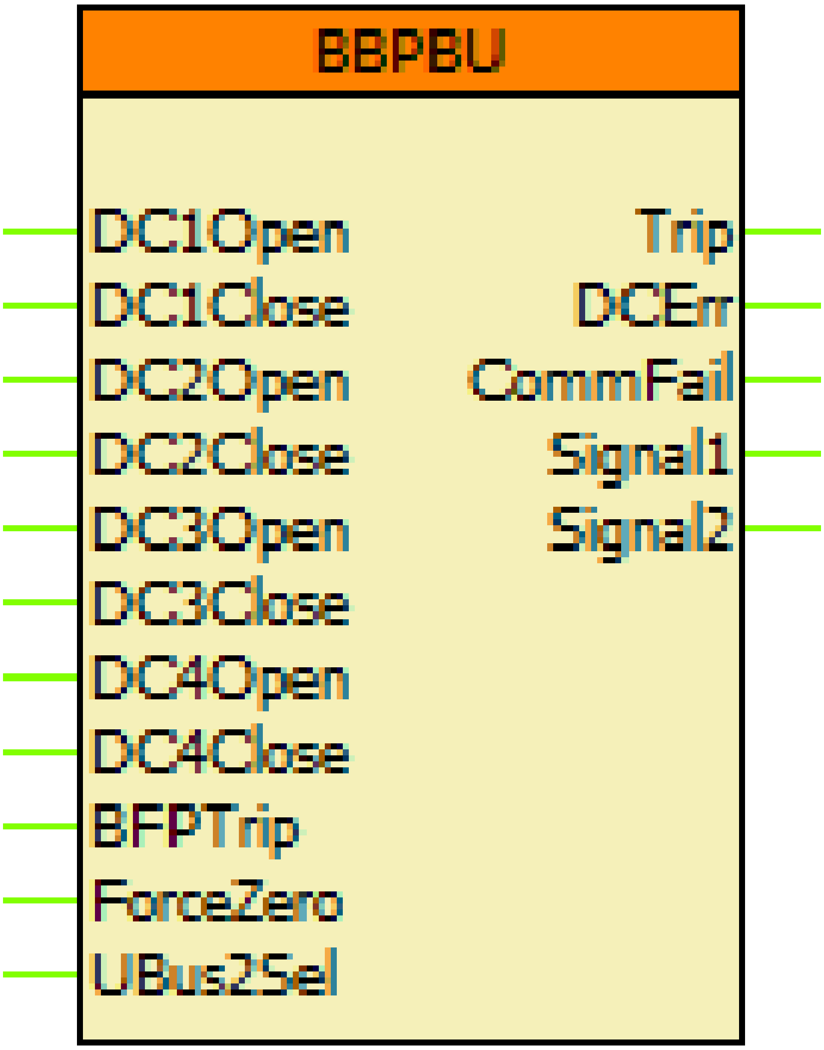
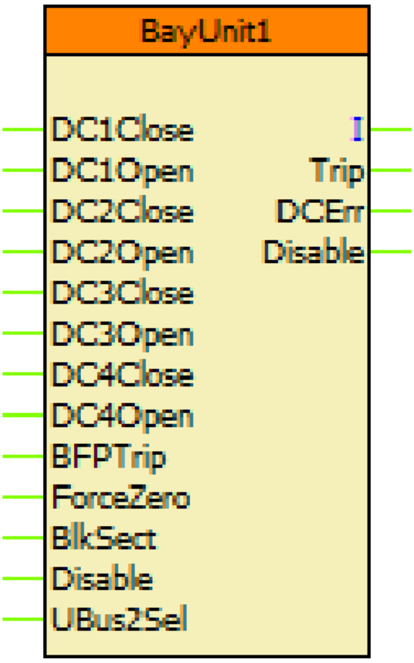
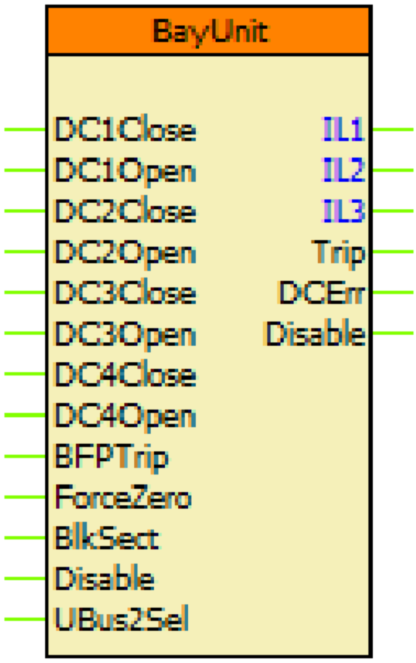


Figure. 8.4.1 - 60. 1Ph and 3Ph versions of the bay unit function in centralized version

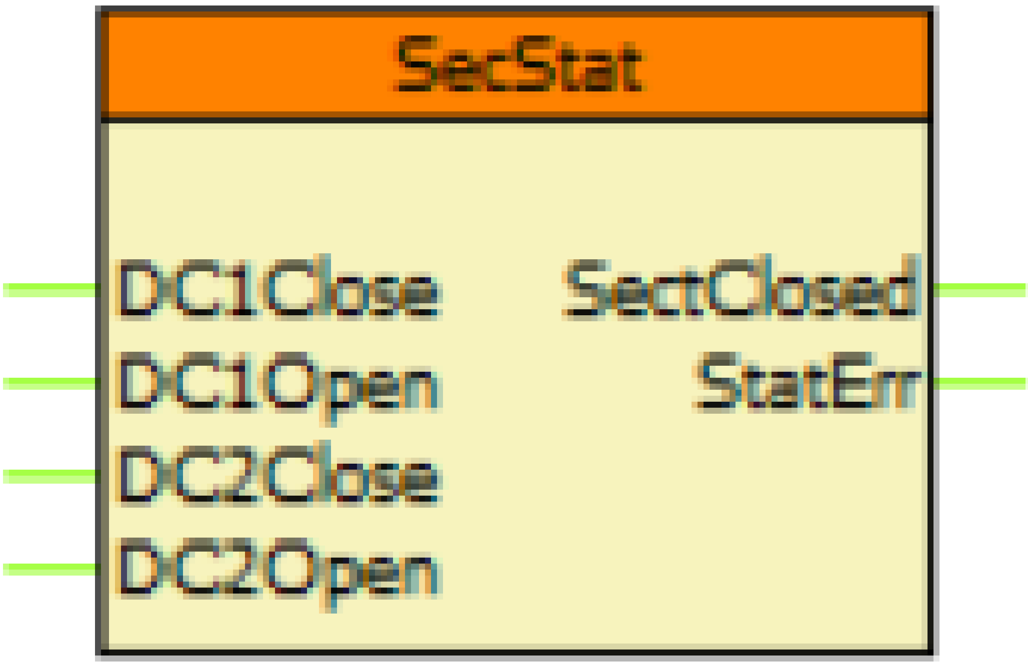




“Sectionalizer unit” function blocks

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 - 61.



8.4.2 The parameters of the busbar differential protection function

The parameters of the busbar differential protection function are explained in the following tables.

Parameters of the busbar general function block

Table. 8.4.2 - 35. Enumerated parameters of the busbar differential protection.

Parameter name	Title	Selection range	Default
Parameter to enable the centralized busbar differential protection function:			
Busbar_BBPOper_EPar__	Operation	Off, On	Off
Parameter to enable the supervision by the “check zone”			
Busbar_CheckOper_EPar_	CheckZone	Off, On	Off
Toleration of the disconnector status signal errors			
Busbar_BadTol_EPar_	Badstate Tolerate	Off, On	Off
Intertrip operation of breaker failure			
Busbar_BFPOper_EPar_	Intertrip	Off, On	Off

Table. 8.4.2 - 36. Integer parameters of the busbar differential protection.

Parameter name	Title	Unit	Min	Max	Step	Default
Percentage characteristic, base sensitivity						
Busbar_ZoneSens_IPar_	Base Sensitivity	A	100	10000	1	1000
Percentage characteristic, slope						
Busbar_ZoneK_IPar_	Slope ofCharacteristic	%	60	90	1	80
Checkzone percentage characteristic, base sensitivity						
Busbar_CheckSens_IPar_	Base Sensitivity - CheckZone	A	100	10000	1	1000
Checkzone percentage characteristic, slope						
Busbar_CheckK_IPar_	Slope of Char - CheckZone	%	40	80	1	50
CT error detection, base sensitivity						
Busbar_CTErrSens_IPar_	Base Sensitivity - CT failure	A	50	5000	1	500
Maximum load current in normal operation						
Busbar_Offset_IPar_	Max Load Current	A	0	10000	1	1000

Table. 8.4.2 - 37. Timer parameters of the busbar differential protection

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for signaling CT error						
Busbar_CTErrDelay_TPar_	CT Failure Delay	msec	100	60000	1	1000

Parameters of the bus section unit

The bus section units do not need parameter setting.

Parameters of the bay unit

Table. 8.4.2 - 38. Enumerated parameter for the bay unit of busbar differential protection

Parameter name	Title	Selection range	Default
CT secondary rated current:			
BayUnit_Nom_EPar_	Rated Secondary	1A, 5A	1A
Location of the CT star point for the CT-s in three lines:			
BayUnit_Dif_EPar_	Star point I1-3	Line, Bus	Line

Table. 8.4.2 - 39. Integer parameter for the bay unit of busbar differential protection

Parameter name	Title	Unit	Min	Max	Step	Default
CT primary rated current:						
BayUnit_CTNom_IPar_	Rated Primary	A	100	10000	1	1000

Table. 8.4.2 - 40. Boolean parameter for the bay unit of busbar differential protection

Parameter name	Title	Selection range	Default
BayUnit_BayDisable_BPar_	Bay Disable	0	0 means enabling;1 means that the current values andthe status signals received from thebay are not considered (to be appliedfor maintenance purposes or forspare bays).

Table. 8.4.2 - 41. Timer parameter for the bay unit in bay unit IED of busbar differential protection

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for signaling bad state						
BBPBU_BadDelay_TPar_	BadState Delay	msec	100	60000	1	1000

Parameters of the sectionalizer unit

Table. 8.4.2 - 42. Timer parameter for sectionalizer of busbar differential protection

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for signaling bad state						
SecStat_BadDelay_TPar_	BadState Delay	msec	100	60000	1	1000

8.4.3 Binary output status signals

The binary output status signals of the units for the centralized busbar differential protection function are summarized in the tables below.

Binary output status signals of the busbar general function

Table. 8.4.3 - 43. The binary output status signals of busbar differential protection, central unit

Binary output signals	Signal title	Explanation
Busbar_Blocked_Grl_Busbar_BBPBlocked_Gr	BlockedBBP Blocked	The busbar protection is in blocked stateNew name from FW version 3015 andabove
Busbar_BFPBlocked_Gr	BFP Blocked	The breaker failure protection is in blockedstate
Busbar_ComFail_Grl_	CommFail	Communication failure, it is active only indistributed version
Busbar_DCError_Grl_	Status Error	Disconnector status error

Binary output status signals of the bus section function block

Table. 8.4.3 - 44. The binary output status signals of busbar differential protection, bus section

Binary output signals	Signal title	Explanation
BusSec_TripL1_Grl_*	Trip L1*	L1 trip signal for the bus section
BusSec_TripL2_Grl_*	Trip L2*	L2 trip signal for the bus section
BusSec_TripL3_Grl_*	Trip L3*	L3 trip signal for the bus section
BusSec_Trip_Grl_	Trip	General trip command for the bus section
BusSec_BFPTrip_Grl_	BFP Trip	Trip command generated by the breakerfailure protection function
BusSec_CTError_Grl_	CT Failure	General error signal of currentmeasurement
BusSec_CTErrorL1_Grl_	CT Failure L1*	Error in current measurement of L1 phase
BusSec_CTErrorL2_Grl_	CT Failure L2*	Error in current measurement of L2 phase
BusSec_CTErrorL3_Grl_	CT Failure L3*	Error in current measurement of L3 phase
BusSec_Ublock_Grl_	U block	The differential protection is blocked byvoltage condition

Binary output signals	Signal title	Explanation
BusSec3_Blocked_Grl_	Blocked	Bus section signal

* Valid in three-pole version only

Binary output status signals of the checkzone function block

Table. 8.4.3 - 45. The binary output status signals of busbar differential protection, checkzone (3ph)

Binary output signals	Signal title	Explanation
ChkZ3_OperL1_Grl_	Operate L1*	L1 operation signal for the checkzone
ChkZ3_OperL2_Grl_	Operate L2*	L2 operation signal for the checkzone
ChkZ3_OperL3_Grl_	Operate L3*	L3 operation signal for the checkzone
ChkZ3_Oper_Grl_	Operate	Operation signal for the checkzone
ChkZ3_CTError_Grl_	CT Failure	Error in current measurement

Binary output status signals of the bay unit function block

Table. 8.4.3 - 46. The binary output status signals of busbar differential protection, bay unit

Binary output signals	Signal title	Explanation
BayUnit_DC1_Grl_	Disconn. 1closed	Disconnector 1 closed status, only shownon the online page
BayUnit_DC2_Grl_	Disconn. 2closed	Disconnector 2 closed status, only shownon the online page
BayUnit_DC3_Grl_	Disconn. 3closed	Disconnector 3 closed status, only shownon the online page
BayUnit_DC4_Grl_	Disconn. 4closed	Disconnector 4 closed status, only shownon the online page
BayUnit_DCErr_Grl_	Disconnector Error	Disconnector error signal
BayUnit_Trip_Grl_1	Trip	Trip command to the circuit breaker of thebay
BayUnit_BayDisable_Grl_	Bay disabled	Bay disabled

Table. 8.4.3 - 47. The binary output status signals of distributed busbar differential protection, bay unit IED

Binary output signals	Signal title	Explanation
BBPBU_DCErr_Grl_	DisconnectorError	Disconnector error signal
BBPBU_Trip_Grl_	Trip	Trip command to the circuit breaker of thebay
BBPBU_CommFail_Grl_	CommFail	Communication failure
BBPBU_Signal1_Grl_	Receive signal 1	Received signal 1 from the central unit viafiber optic cable
BBPBU_Signal2_Grl_	Receive signal 2	Received signal 2 from the central unit viafiber optic cable

Binary output status signals of the sectionalizer function block

Table. 8.4.3 - 48. The binary output status signals of busbar differential protection, sectionalizer unit

Binary output signals	Signal title	Explanation
BRF50BB_BuTr_GrI_	Backup Trip	Trip command for the bay, generated bythe breaker failure function
BRF50_ReTrL1_GrI_	Retrip L1	Retrip command for the bay in L1 phase
BRF50_ReTrL2_GrI_	Retrip L2	Retrip command for the bay in L2 phase
BRF50_ReTrL3_GrI_	Retrip L3	Retrip command for the bay in L3 phase

8.4.4 Binary input status signals

The busbar differential protection functions have binary input signals, which serve the purpose of disabling the function. The conditions of disabling are defined by the user applying the graphic equation editor.

The binary input status signals of the units for the centralized busbar differential protection function are summarized in the Tables below.

Binary input status signals of the busbar general function block

Table. 8.4.4 - 49. The binary input status signals of busbar general function block

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

Binary input status signals of the bus section function block

Table. 8.4.4 - 50. The binary input status signals of bus section function block

Binary input signals	Signal title	Explanation
BusSec_BBPSecBlk_GrO_	Block section	Blocking the bus section of busbar differentialprotection

Binary input status signals of the bay unit function block

Table. 8.4.4 - 51. The binary input status signals of bay unit function block

Binary input signals	Signal title	Explanation
BayUnit_BFPTrip_GrO_	BFP Trip	Breaker failure signal from the protection ofthe bay. The breaker failure protection passesthis signal to all bays of the interconnectedbus sections, related to this particular bay
BayUnit_DC1Close_GrO_	DC1 Close	Disconnector 1 in closed state

Binary input signals	Signal title	Explanation
BayUnit_DC2Close_GrO_	DC2 Close	Disconnector 2 in closed state
BayUnit_DC3Close_GrO_	DC3 Close	Disconnector 3 in closed state
BayUnit_DC4Close_GrO_	DC4 Close	Disconnector 4 in closed state
BayUnit_DC1Open_GrO_	DC1 Open	Disconnector 1 in open state
BayUnit_DC2Open_GrO_	DC2 Open	Disconnector 2 in open state
BayUnit_DC3Open_GrO_	DC3 Open	Disconnector 3 in open state
BayUnit_DC4Open_GrO_	DC4 Open	Disconnector 4 in open state
BayUnit_ForceZero_GrO_*	Force Zero*	In TRUE state of this input signal the bay unitsends zero value as the sampled current
BayUnit_BlkSect_GrO_	Blk Sect	In TRUE state of this input signal themeasuring element related to this bay gets inblocked state
BayUnit_Disable_GrO_	Disable	Disable the bay unit, only in the centralizedversion
BayUnit_UBus2Sel_GrO_	U Bus2 Select	Select Bus2 voltage for voltage breakdown

Table. 8.4.4 - 52. The binary input status signals of bay unit function block in central unit of distributed version

Binary input signals	Signal title	Explanation
BayUnit_BlkSect_GrO_	Blk Sect	In TRUE state of this input signal themeasuring element related to this bay gets inblocked state
BayUnit_Disable_GrO_	Disable	Disable the bay unit, only in the centralizedversion
BayUnit_Signal1_GrO_	Signal 1	Sending signal 1 to the bay unit via fiber opticcable
BayUnit_Signal2_GrO_	Signal 2	Sending signal 2 to the bay unit via fiber opticcable

Binary input status signals of the sectionalizer function block

Table. 8.4.4 - 53. The binary input status signals of sectionalizer function block

Binary input signals	Signal title	Explanation
SecStat_DC1Close_GrO_	DC1 Close	Disconnector 1 in closed state
SecStat_DC1Open_GrO_	DC1 Open	Disconnector 1 in open state

Binary input signals	Signal title	Explanation
SecStat_DC2Close_GrO_	DC2 Close	Disconnector 2 in closed state
SecStat_DC2Open_GrO_	DC2 Open	Disconnector 2 in open state

Binary input status signals of the breaker failure function block

Table. 8.4.4 - 54. The binary input status signals of breaker failure function block

Binary input signals	Signal title	Explanation
BRF50_Blk_GrO_	Block	Blocking the breaker failure protection function
BRF50_CBOnL1_GrO_	CB closed L1	Signal indicating the closed state ofthe circuit breaker in phase L1
BRF50_CBOnL2_GrO_	CB closed L2	Signal indicating the closed state ofthe circuit breaker in phase L2
BRF50_CBOnL3_GrO_	CB closed L3	Signal indicating the closed state ofthe circuit breaker in phase L3
BRF50_GenSt_GrO_	General Start	Starting the breaker failure protection
BRF50_StL1_GrO_	Start L1	Starting signal in phase L1
BRF50_StL2_GrO_	Start L2	Starting signal in phase L2
BRF50_StL3_GrO_	Start L3	Starting signal in phase L3

Events

The following events are generated in the event list, as well as sent to SCADA according to the configuration.

Table. 8.4.4 - 55. Events of the busbar differential protection functions

Event	Value	Explanation	IEC61850 data attribute
BBP Blocked	off, on	The busbar protection is in blocked state	BUSGGIO1STBlk$stVal
BBP Blocked	off, on	The breaker failure protection is in blocked state	BFGGIO1STInd$stVal
Comm. Failure	off, on	Communication failure, it is active only in distributed version	BUSGGIO1STCommFail$stVal
Status Error	off, on	Disconnector status error	BUSGGIO1STStatErr$stVal
Trip L1	off, on	L1 trip signal of the bus section	B3PDIF1STOp$phsA
Trip L2	off, on	L2 trip signal of the bus section	B3PDIF1STOp$phsB
Trip L3	off, on	L3 trip signal of the bus section	B3PDIF1STOp$phsC

Event	Value	Explanation	IEC61850 data attribute
Trip	off, on	General trip command of the bus section	B3PDIF1STOp$general
BFP Trip	off, on	Trip command generated by the breaker failure protection function	B3PDIF1STBFPTrip$ stVal
CT failure	off, on	Error in current measurement	B3PDIF1STCtFault$ stVal
CT failure L1	off, on	Error in current measurement of L1 phase	B3PDIF1STCtFaultL1$ stVal
CT failure L2	off, on	Error in current measurement of L2 phase	B3PDIF1STCtFaultL2$ stVal
CT failure L3	off, on	Error in current measurement of L3 phase	B3PDIF1STCtFaultL3$ stVal
U Block	off, on	The differential protection is blocked by voltage condition	B3PDIF1STVoltNOk$ stVal
Backup Trip *	off, on	Trip command for the bay, generated by the breaker failure function	BFRBRF1STOpEx$general

* Only in the centralized version

Table. 8.4.4 - 56. Events of the bay unit function block in the central unit of distributed busbar differential protection

Event	Value	Explanation	IEC61850 data attribute
Trip	off, on	General trip command of the bay unit	BAYTRGGIO1STInd$stVal
BFP Trip	off, on	Trip command generated by the breaker failure protection function	BAYBFGGIO1STInd$stVal
Blocked	off, on	The busbar protection is in blocked state	BAYBLGGIO1STInd$stVal
Bay disabled	off, on	Bay disabled	BAYDGGIO1STInd$stVal

8.4.5 The function blocks

Figure. 8.4.5 - 62. The function blocks of the busbar differential protection, three phase version

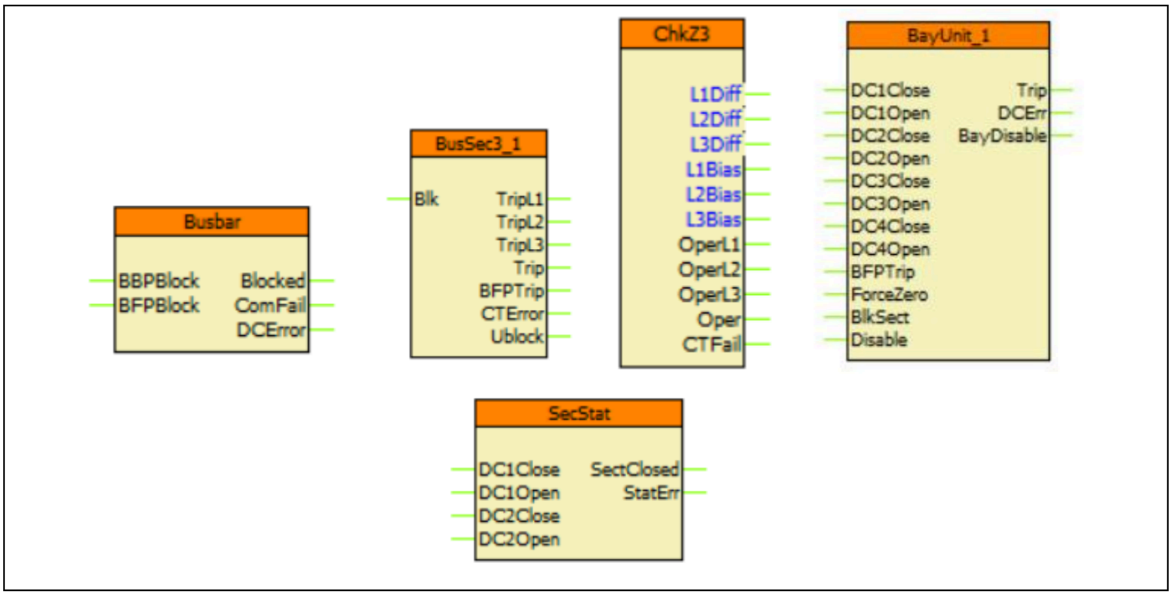


Figure. 8.4.5 - 63. The function blocks of the busbar differential protection, single phase version

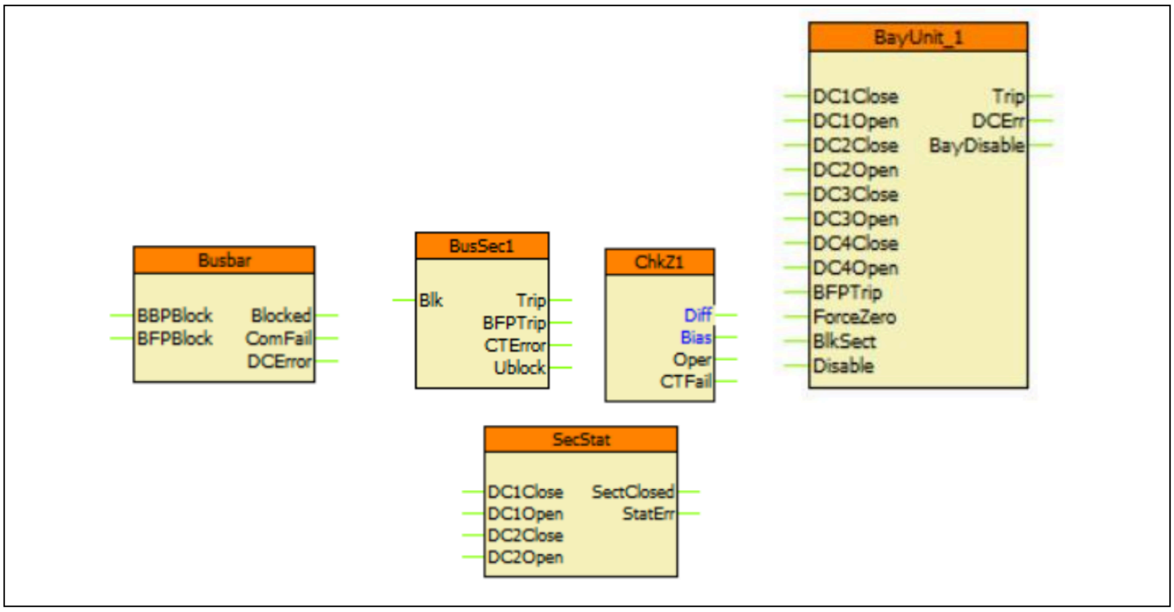
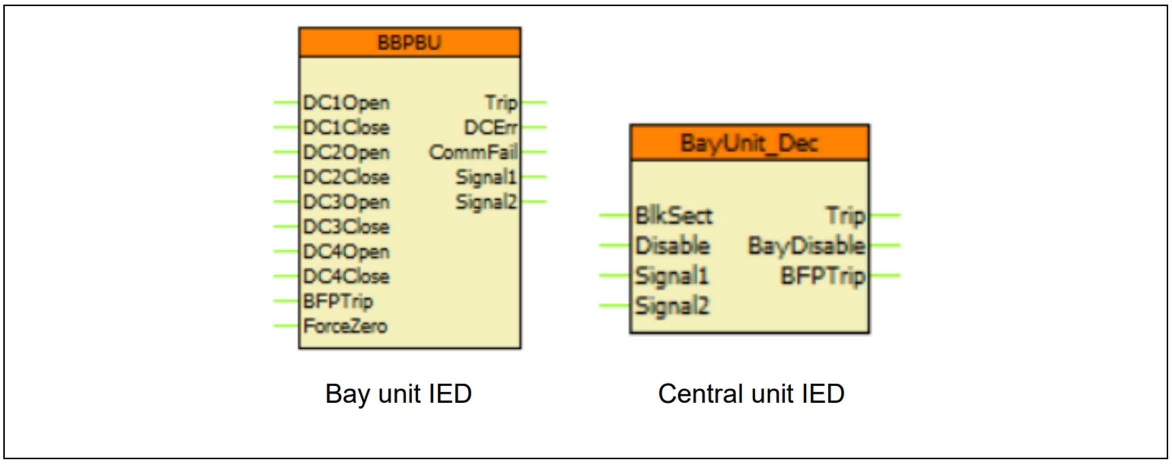


Figure. 8.4.5 - 64. The bay unit function blocks of the distributed version



8.5 Notes for testing

Normally in the AQ 300 series devices the trip contacts are assigned to the Trip Logic function block, and not to the protection function blocks. Because of this, the testing personnel must make sure that the Trip Logic is switched on ('Operation' parameter is set to other than 'Off') before starting the testing, otherwise there will be no physical trip on the relay.

Notes for testing the operation characteristics:

- In case of detected through fault, the slope of the characteristic is dynamically changed to 90%. When tested, the applied method results a constant 90% measured value for the slope, in 2.8.13.2030 version and below.
- 2.8.13.2060 and above this dynamically changing is removed, so during testing the value of the slope is according to the settings, as well as in the 2.10.2.xxxx system version.
- Bias currents are 0A in normal operation. Checking the currents of a bay adding to the busbar system during commissioning, it is necessary to see the bias current. IED shows it in Test/Blocked mode.

Notes for testing the voltage breakdown condition:

- A voltage monitoring function can allow trip command only for 0.5 s for all bus sections, then the function is disabled until the measured voltage returns to healthy state again, or a new initializing is performed (caused by disconnector status change, switching on or off, parameter changes).
- If all voltage monitoring functions assigned to a measuring element detect low voltage then the bus-bar section is considered to be disconnected, and the operation of the busbar differential protection is enabled again (to cover the switch-on-to-fault condition).

8.6 The procedure of the busbar protection configuration

8.6.1 Configuration in the factory

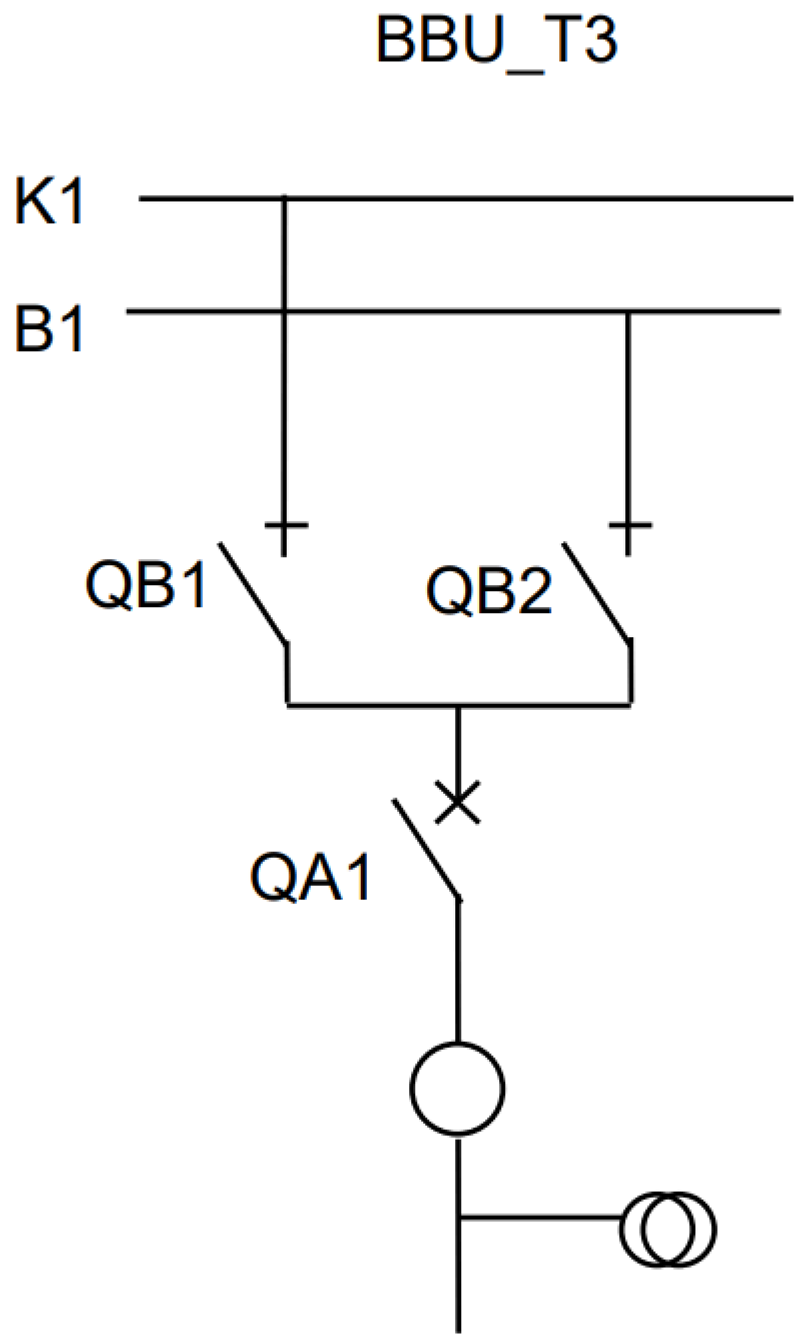
The factory configuration assembles the needed number of hardware elements and the related software elements. If the description of the bay system is not specified at ordering, or if the substation is extended by new elements, then the user has the task to describe the busbar topology.

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.

8.6.2 Defining the bay topology

The definition of a topology is illustrated with the example of a bay T3 connected to a double busbar below:

Figure. 8.6.2 - 65. Example of a bay T3 connected to a double busbar

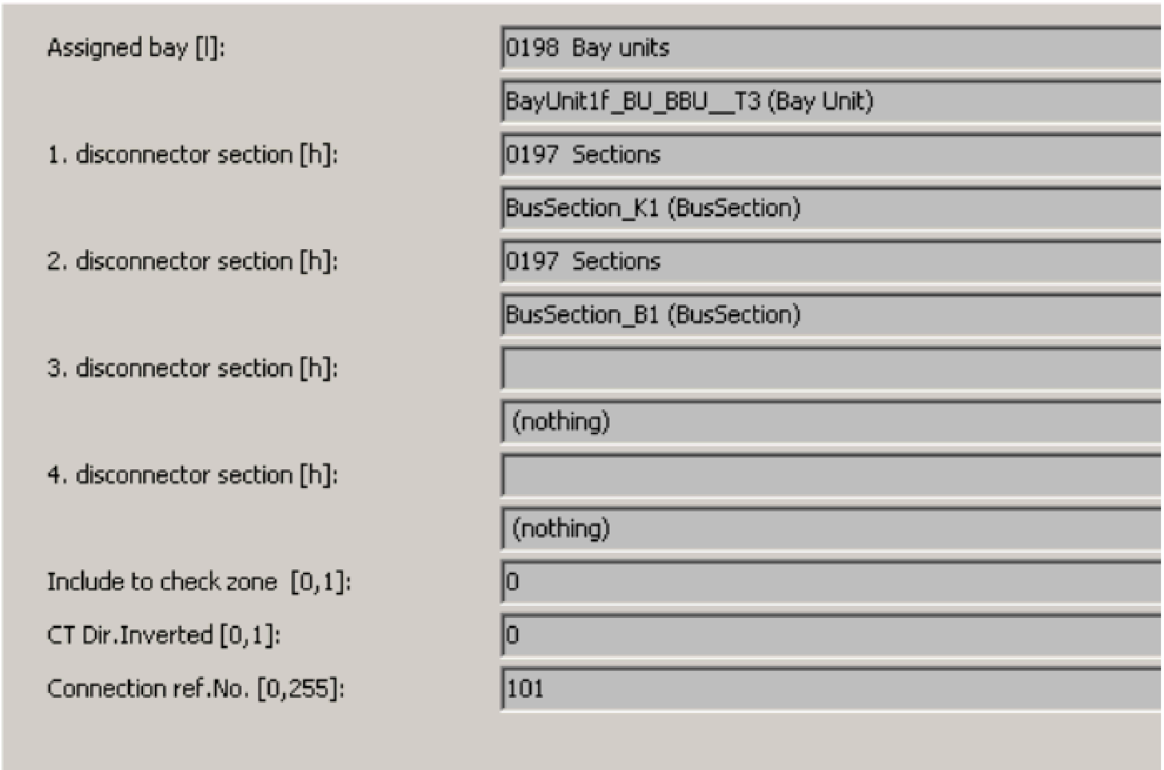


The user describes the topology, stating to which busbar sections the given bay is connected. This is performed using the AQtivate 300 configuration software with the application of dialog window of the “Topology element” as in the figure below. In the topology element related to this window the bay “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 opposite example, the current transformer direction in a bus coupler bay must be inverted for one of the bus sections.)

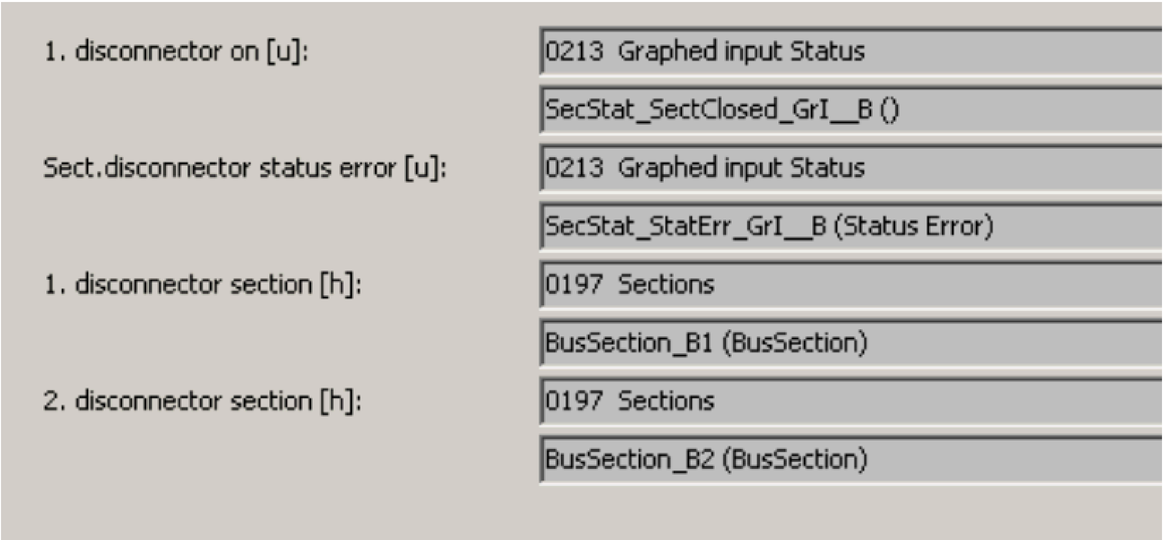
The “Connection ref. No.” setting is usually 0, indicating that the bay is not interconnected with any of other bays. The code number deviating from zero means that the bay is interconnected with bays having the same value for this parameter (see e.g. Example 6 below).



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

8.6.3 Defining the sectionalizers

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



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 the condition using the graphic logic for the binary variable “SecStat_SectClosed_GrI_B()”.

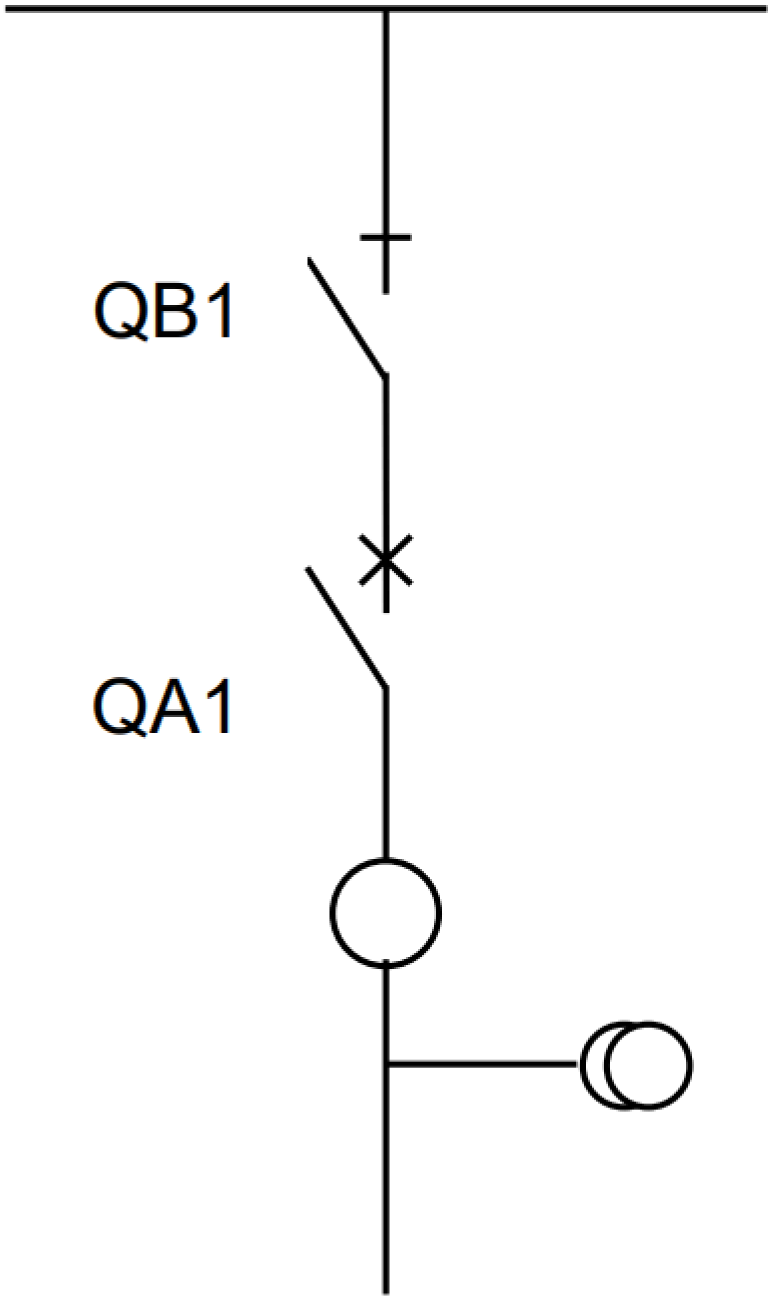
Similarly the disconnector status error is composed using the graphic logic for the binary variable “SecStat_StatErr_GrI_B(Status Error”").

The chapter below shows further application examples for some frequent practical cases.

8.7 Application examples

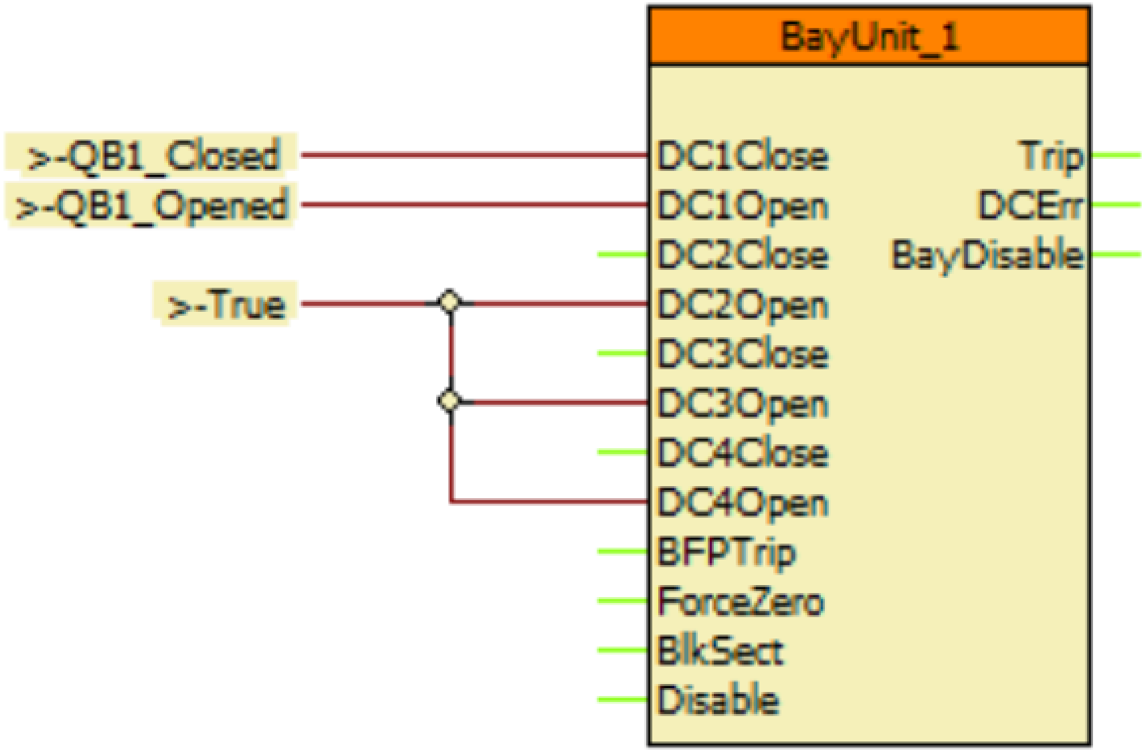
These application examples show typical solutions for defining the busbar topology. Based on these examples, also the details of here not discussed busbar configurations can be defined. The individual examples show the graphic connections of the bay units and the parameter setting of the topology objects.

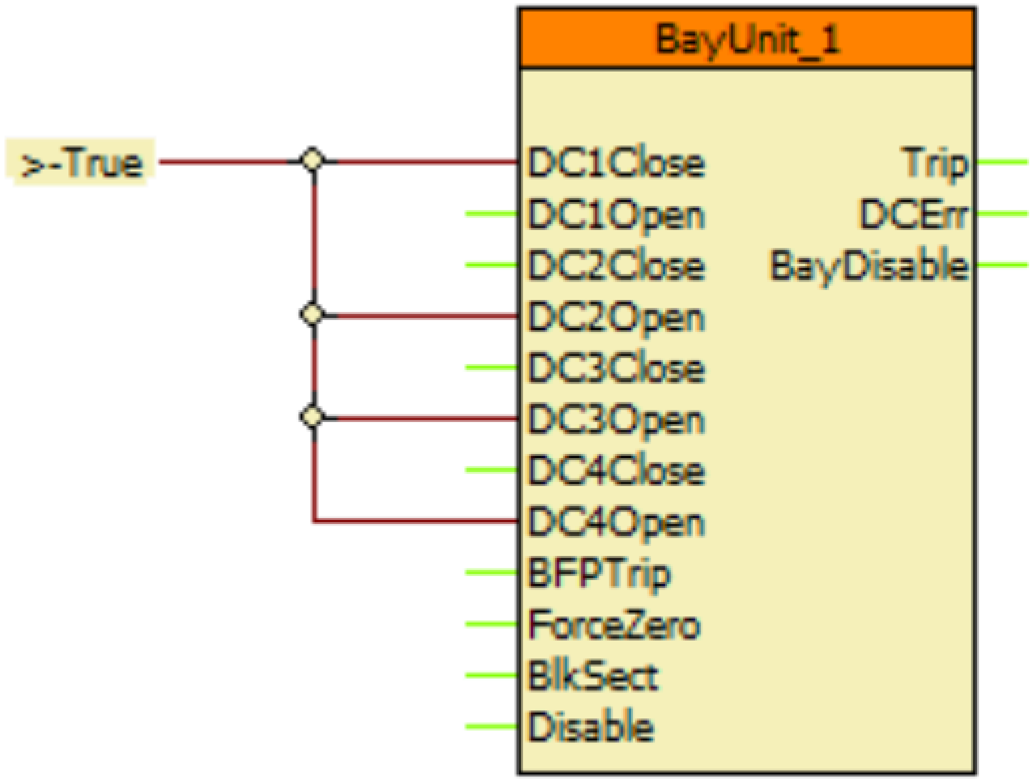
8.7.1 Example 1: Bay connected to a single busbar



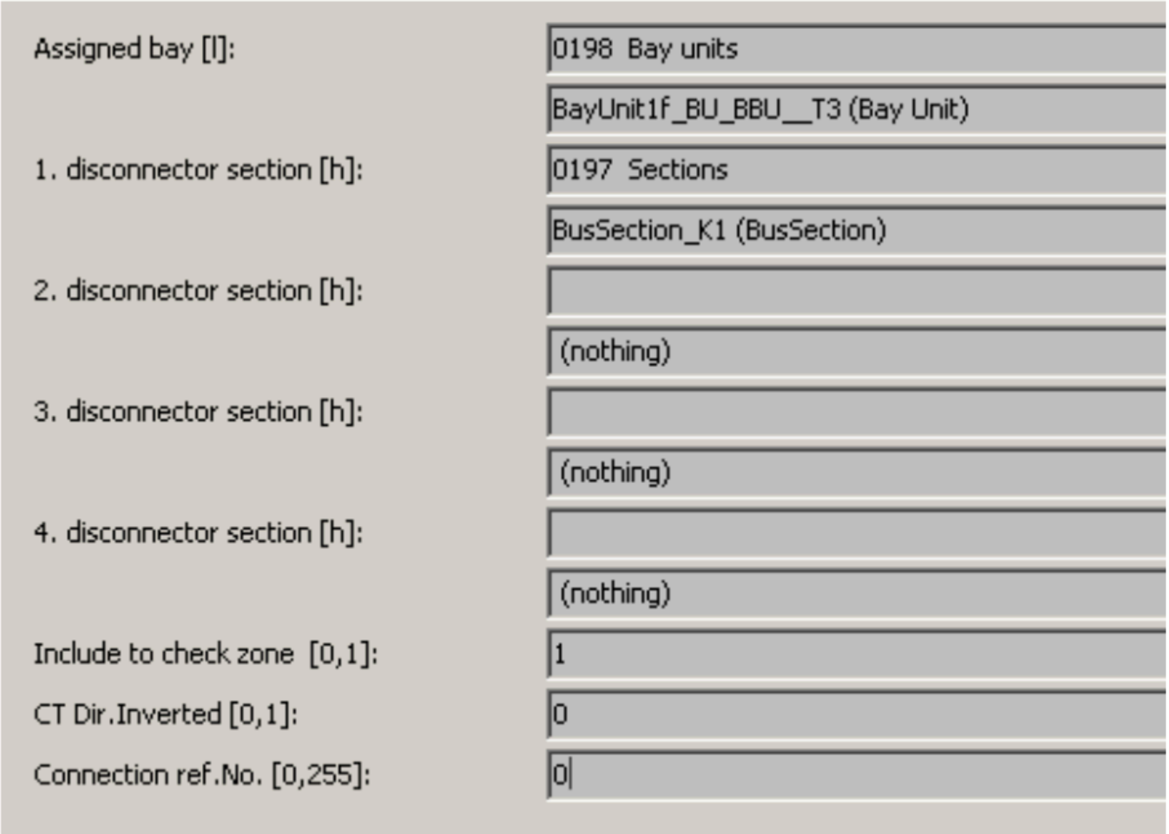
In this simple bay configuration the status signals indicating the closed and open state of the disconnector are connected to “DC1Close” and “DC1Open inputs”. All other “DCOpen” inputs are connected to logic “True”.

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

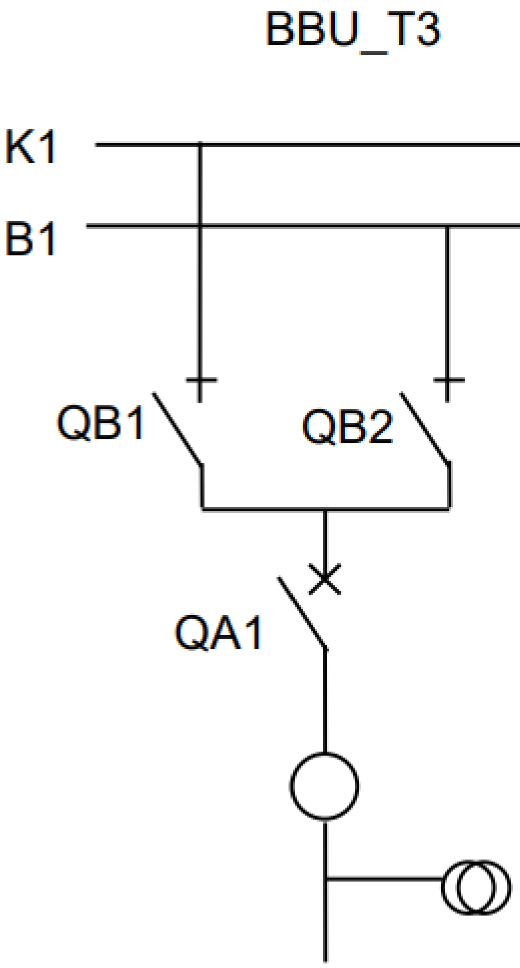




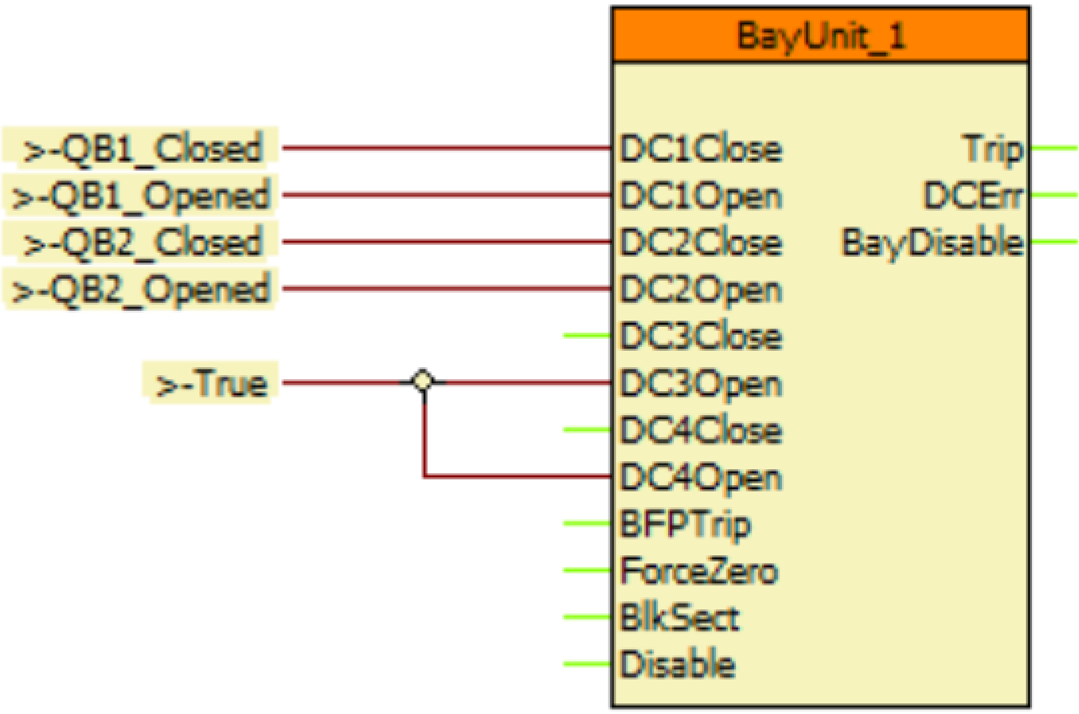
The parameters describing the topology are shown in figure below:


Assigned bay [l]:
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

8.7.2 Example 2: Bay connected to a double busbar



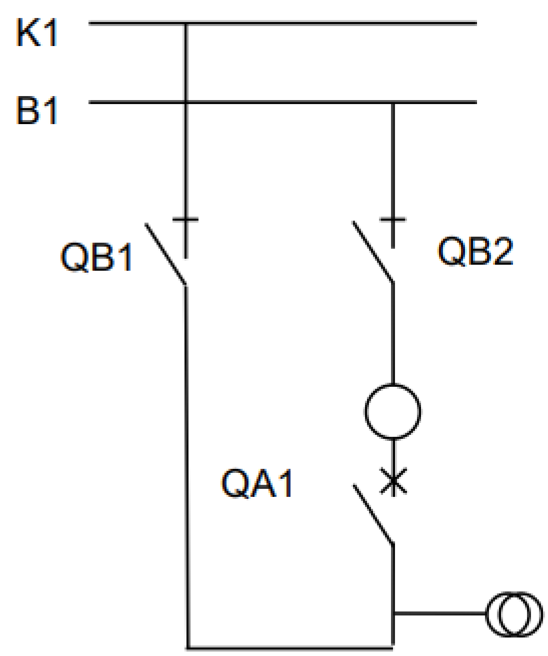
The function block:

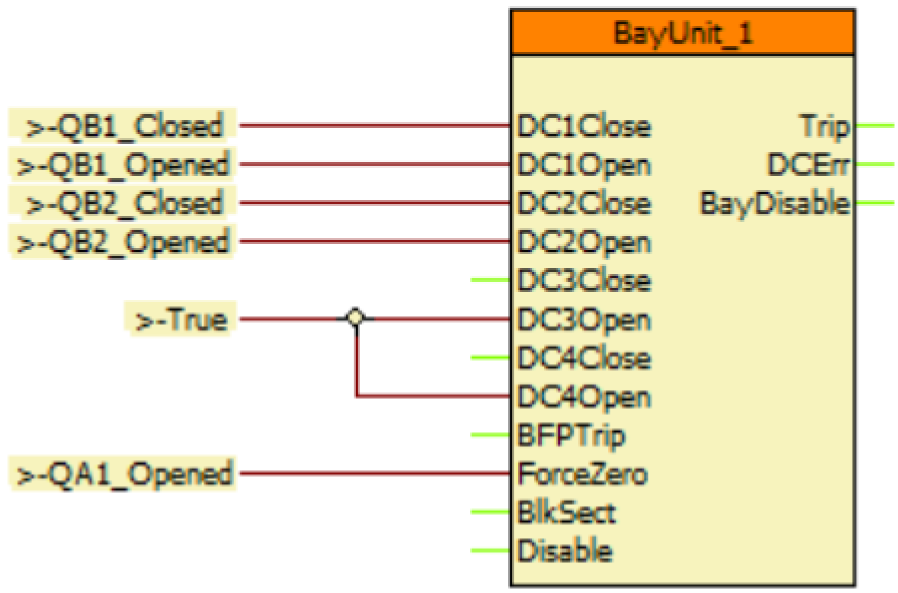


The parameters describing the topology are shown in figure below:

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]:	0197 Sections
	BusSection_B1 (BusSection)
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

8.7.3 Example 3: Bus coupler bay with one current transformer





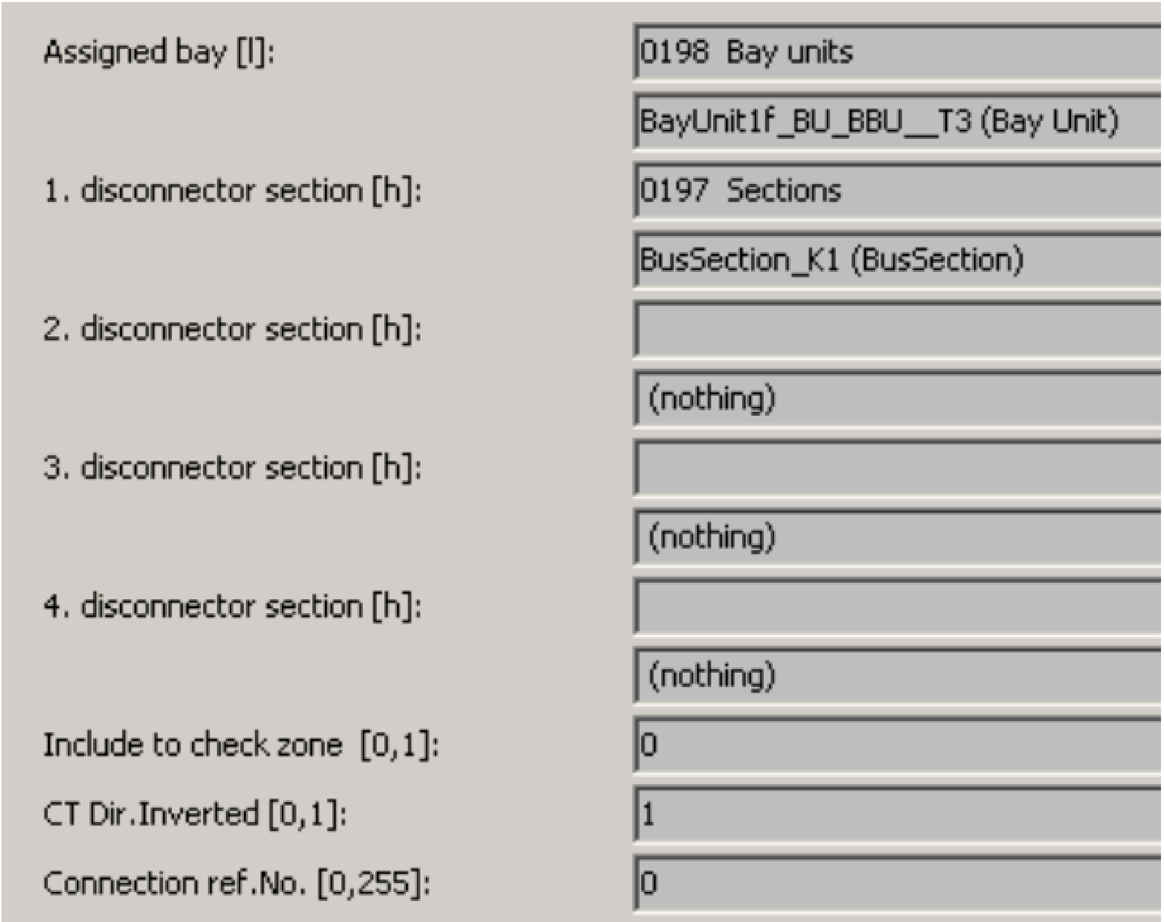
There are two topology elements assigned to this bus coupler bay: one for the side of QB1 and one for the side of QB2, the current positive direction for the second one must be inverted.

Both topology elements refer to the same bay unit

In this application also the state of the circuit breaker is 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. 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.

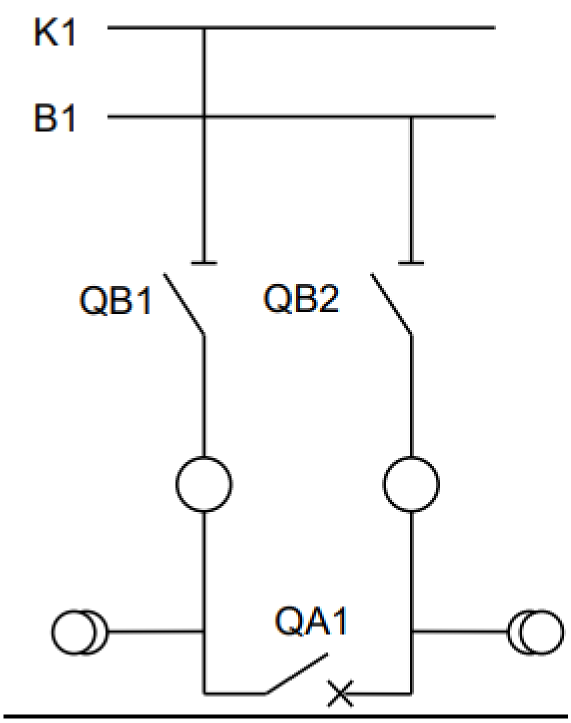
The topology element related to QB1 is as follows:



The topology element related to QB2 is as follows:

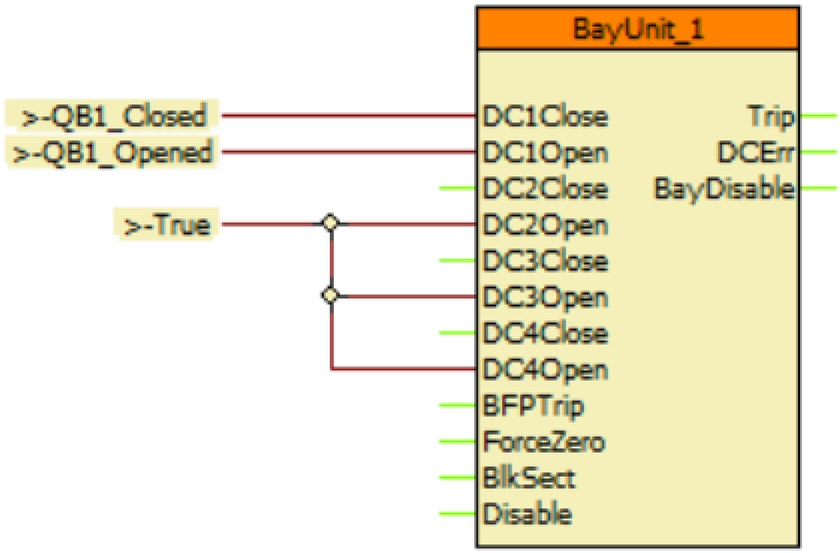
Assigned bay [I]:	0198 Bay units
	BayUnit1f_BU_BBU__T3 (Bay Unit)
1. disconnector section [h]:	
	(nothing)
2. disconnector section [h]:	0197 Sections
	BusSection_B1 (BusSection)
3. disconnector section [h]:	
	(nothing)
4. disconnector section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted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

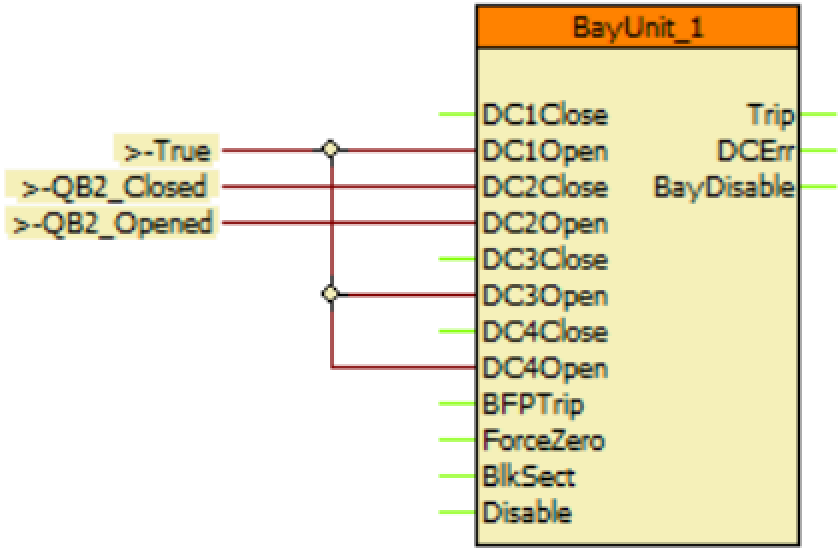
8.7.4 Example 4: Bus coupler bay with two current transformers



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.

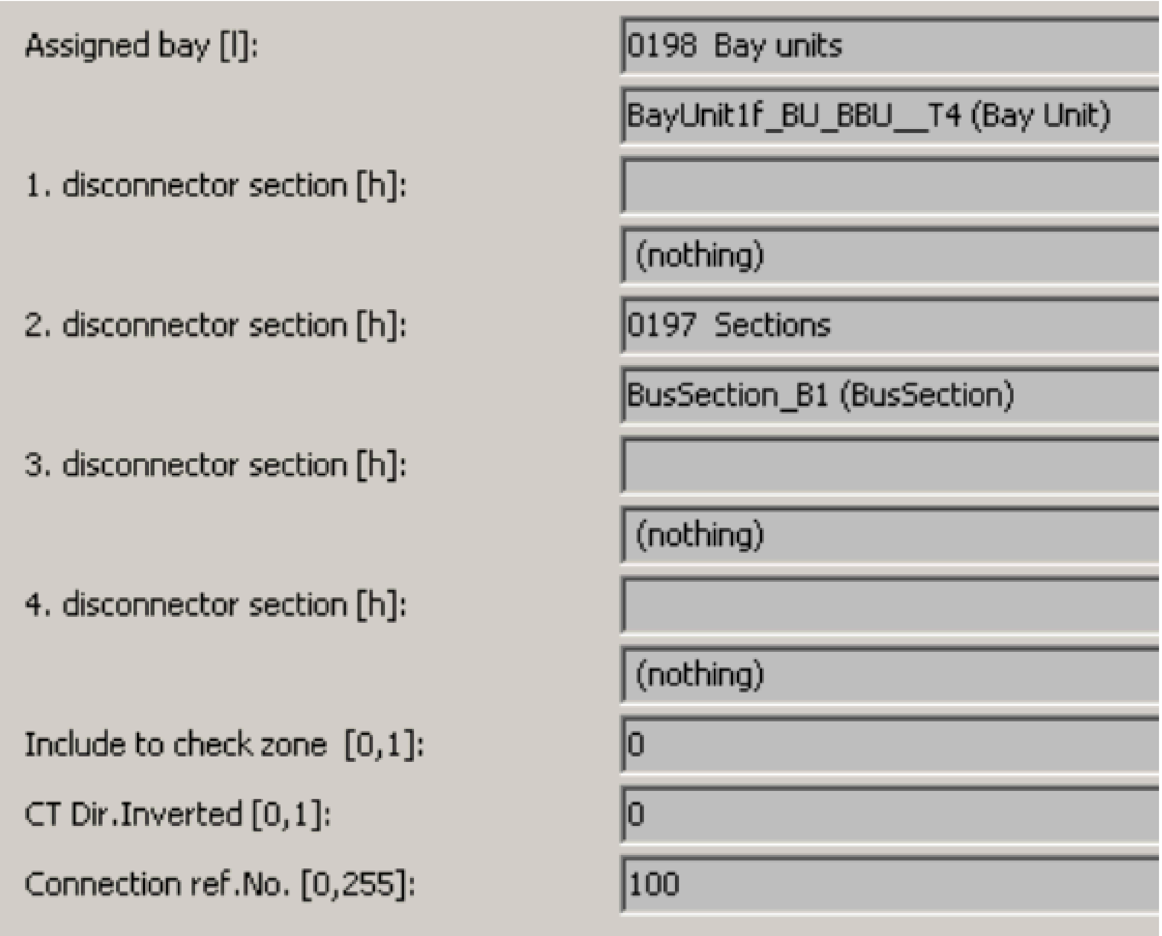




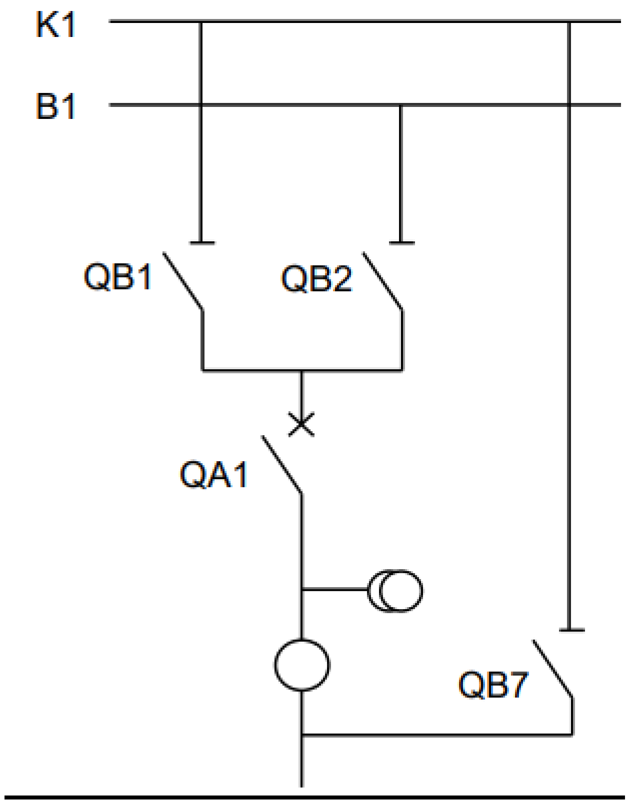
The topology element related to QB1 is as follows:

Assigned bay [l]:	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]:	0
Connection ref.No. [0,255]:	100

The topology element related to QB2 is as follows:


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

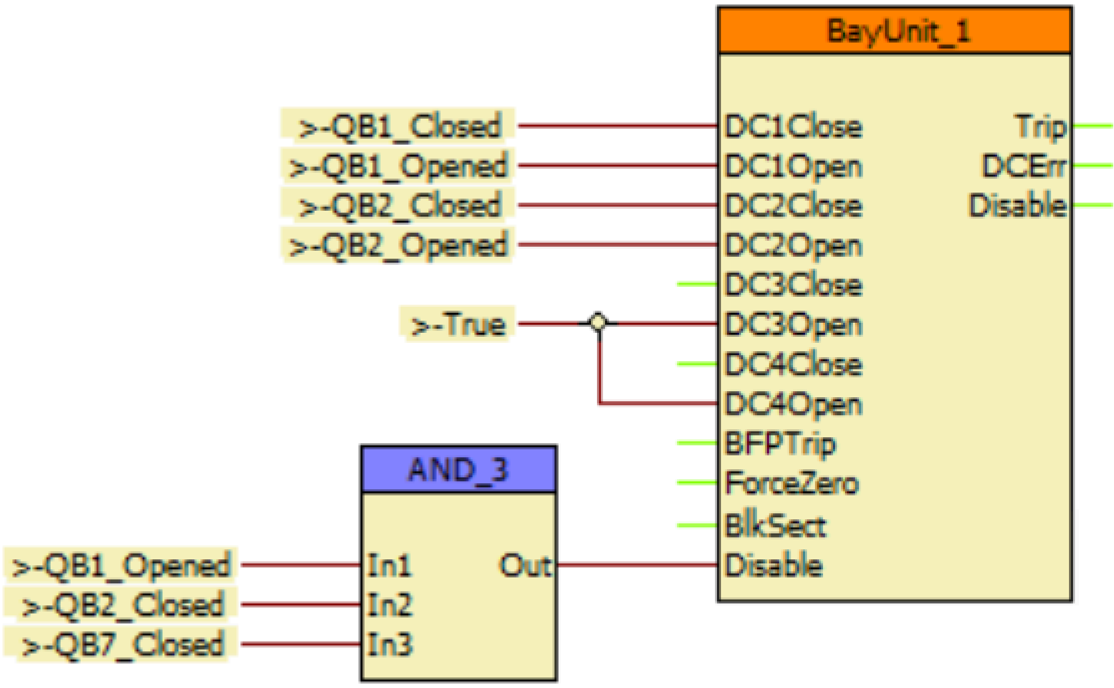
8.7.5 Example 5: Double bus connection with bypass



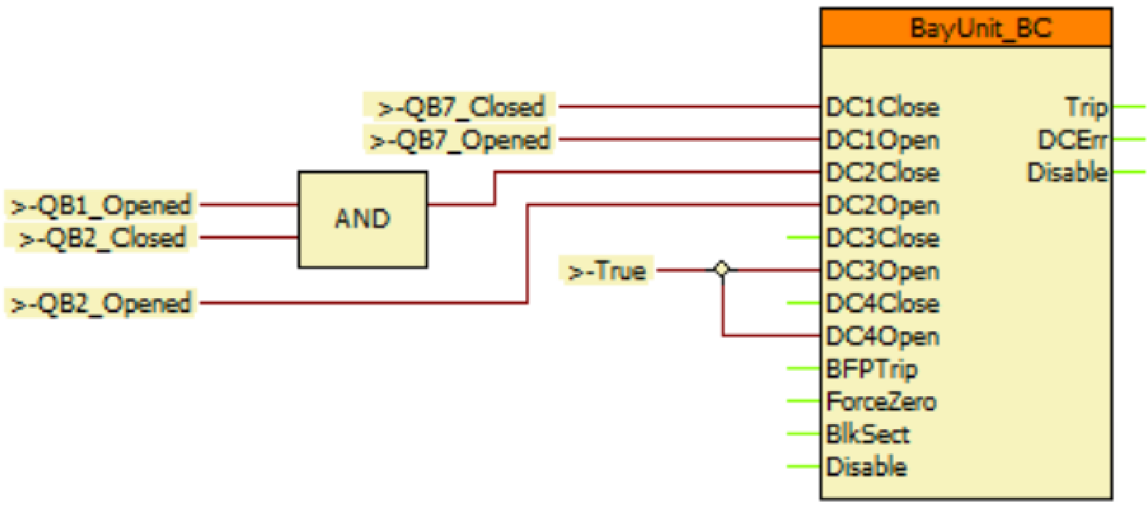
This bay can serve as bus coupler or as a feeder bay. This topology requires an extra Bay Unit function block which will be used as bus coupler.

Feeder part of this topology have to block while works as bus coupler.

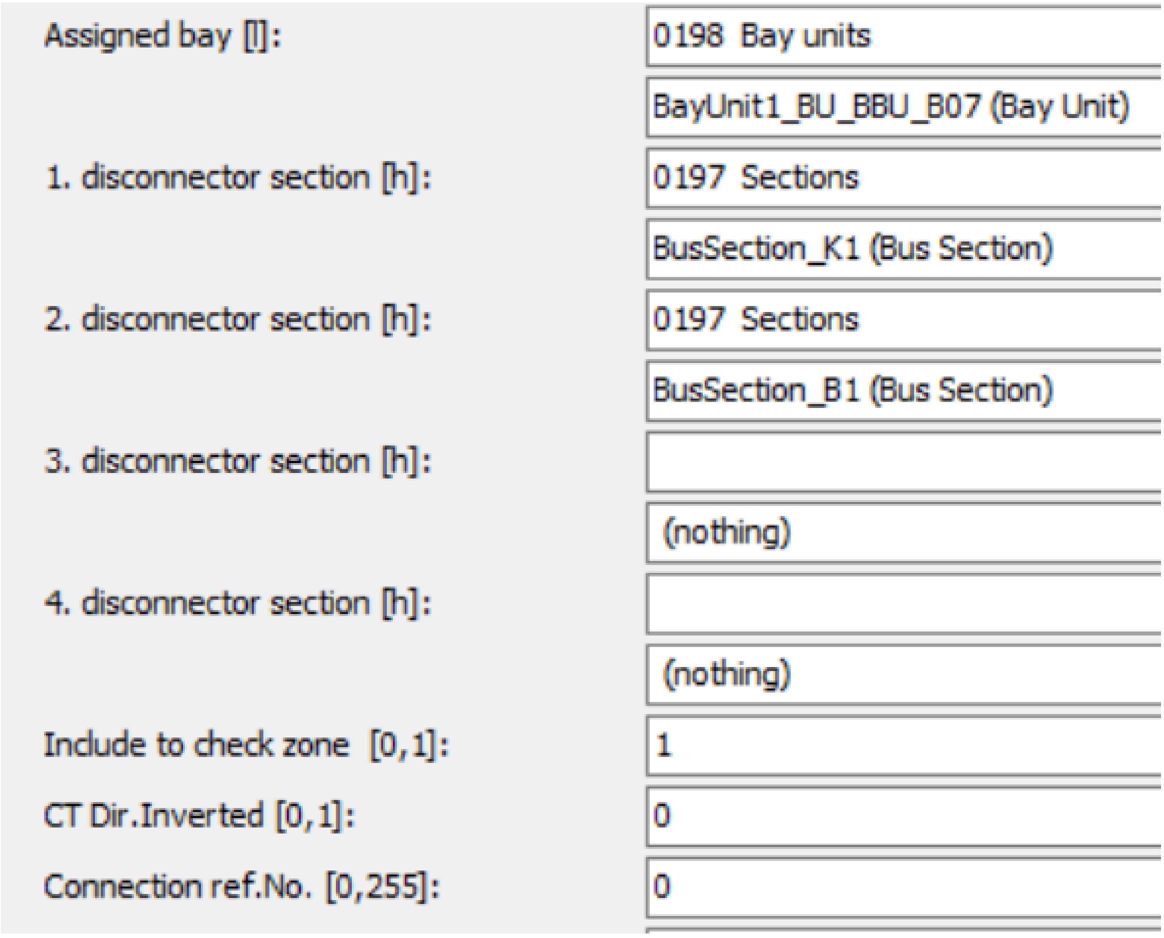
The graphical connections of the feeder bay unit is as follows:



The graphical connections of the bus coupler bay unit is as follows:

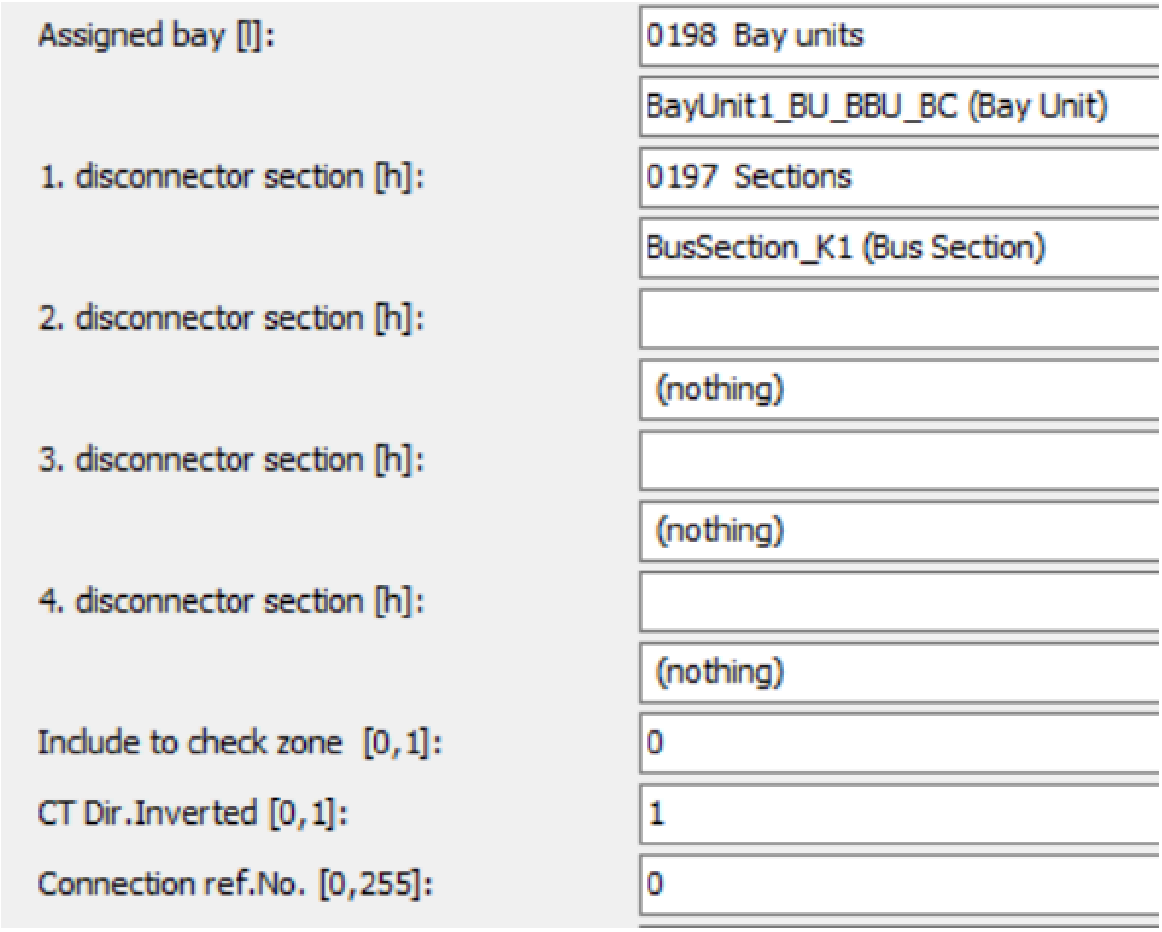


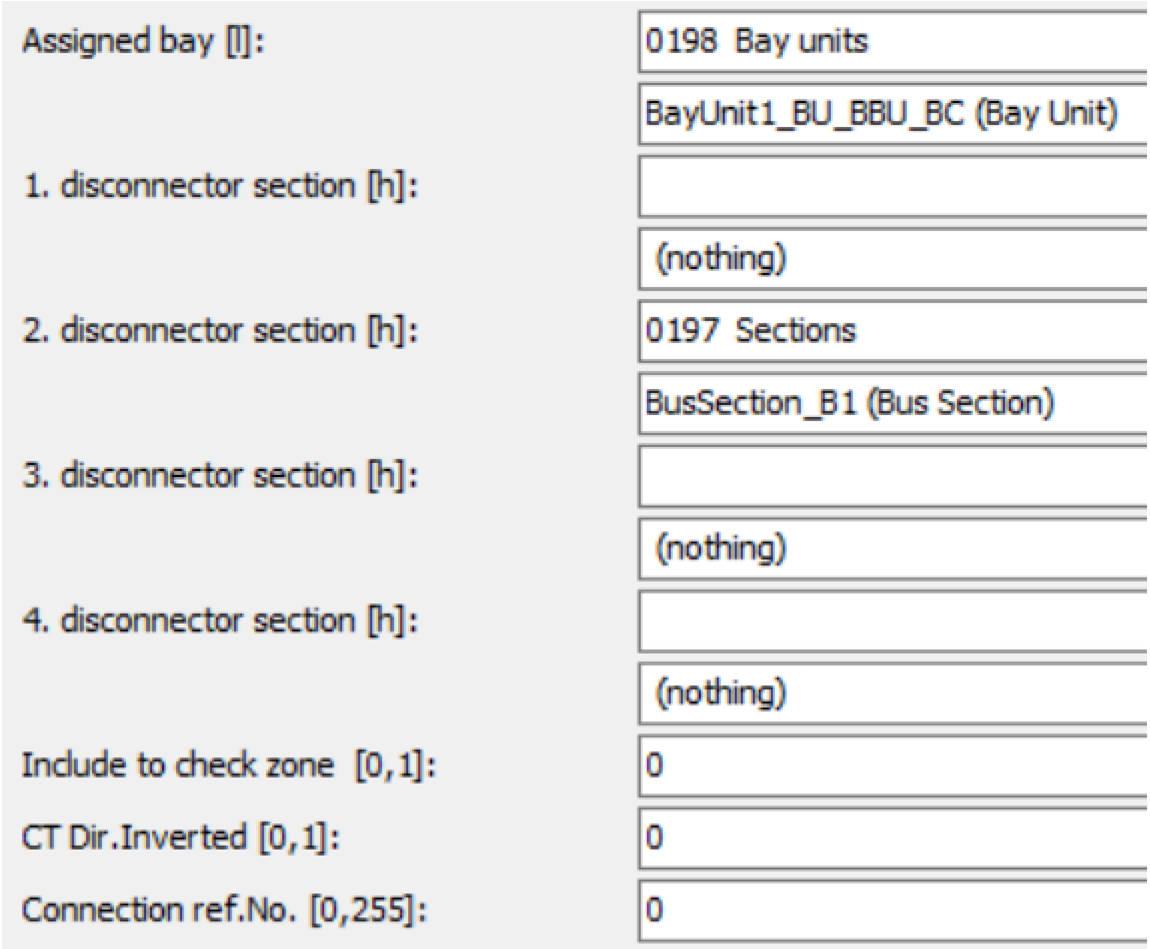
The related topology element of the feeder bay:



Assigned bay []:	0198 Bay units
	BayUnit1_BU_BBU_B07 (Bay Unit)
1. disconnector section [h]:	0197 Sections
	BusSection_K1 (Bus Section)
2. disconnector section [h]:	0197 Sections
	BusSection_B1 (Bus Section)
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

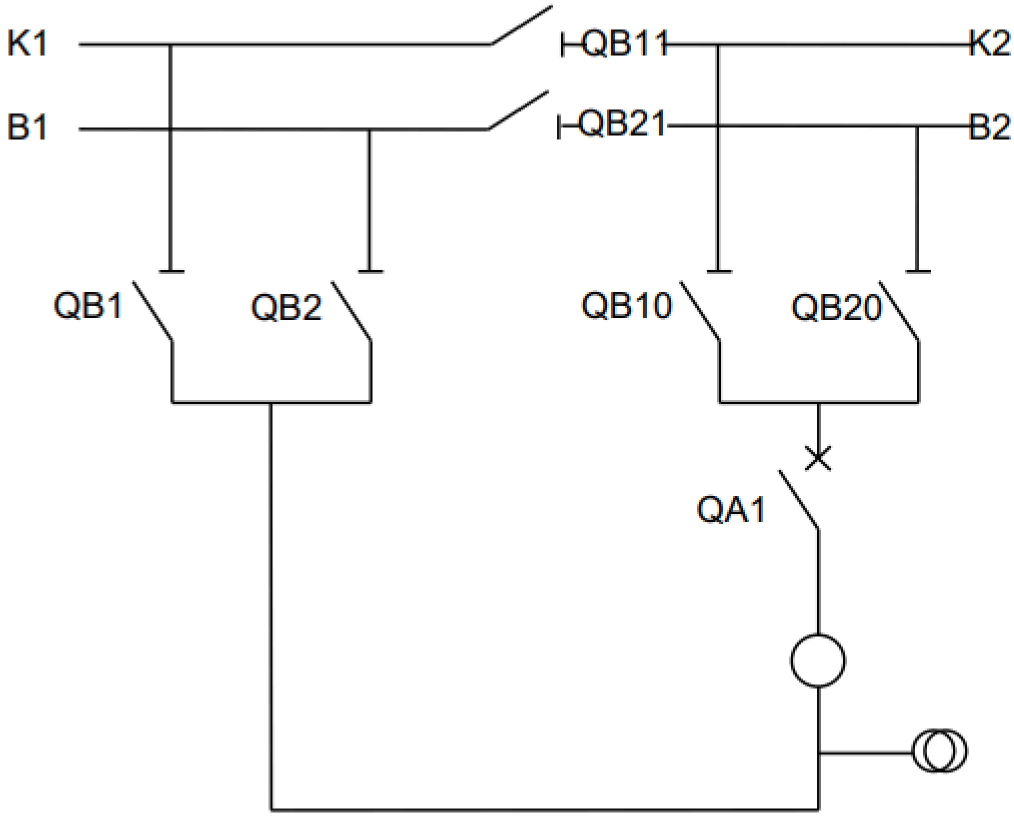
The related topology elements of the bus coupler bay as follows:


Assigned bay [l]:
0198 Bay units
BayUnit1_BU_BBU_BC (Bay Unit)
1. disconnector section [h]:
0197 Sections
BusSection_K1 (Bus Section)
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



Assigned bay [l]:	0198 Bay units
	BayUnit1_BU_BBU_BC (Bay Unit)
1. disconnector section [h]:	
	(nothing)
2. disconnector section [h]:	0197 Sections
	BusSection_B1 (Bus Section)
3. disconnector section [h]:	
	(nothing)
4. disconnector section [h]:	
	(nothing)
Include to check zone [0,1]:	0
CT Dir.Inverted [0,1]:	0
Connection ref.No. [0,255]:	0

8.7.6 Example 6: Bus coupler in a double busbar system

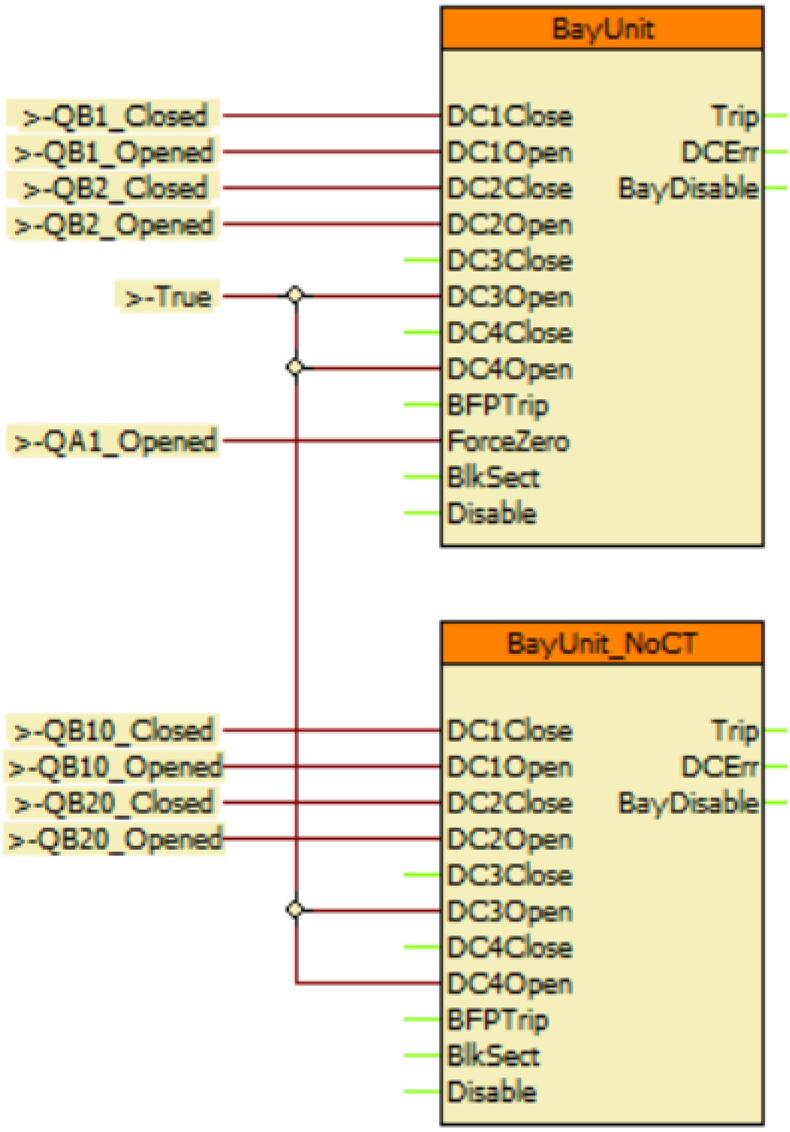


This configuration can be describes in two ways:

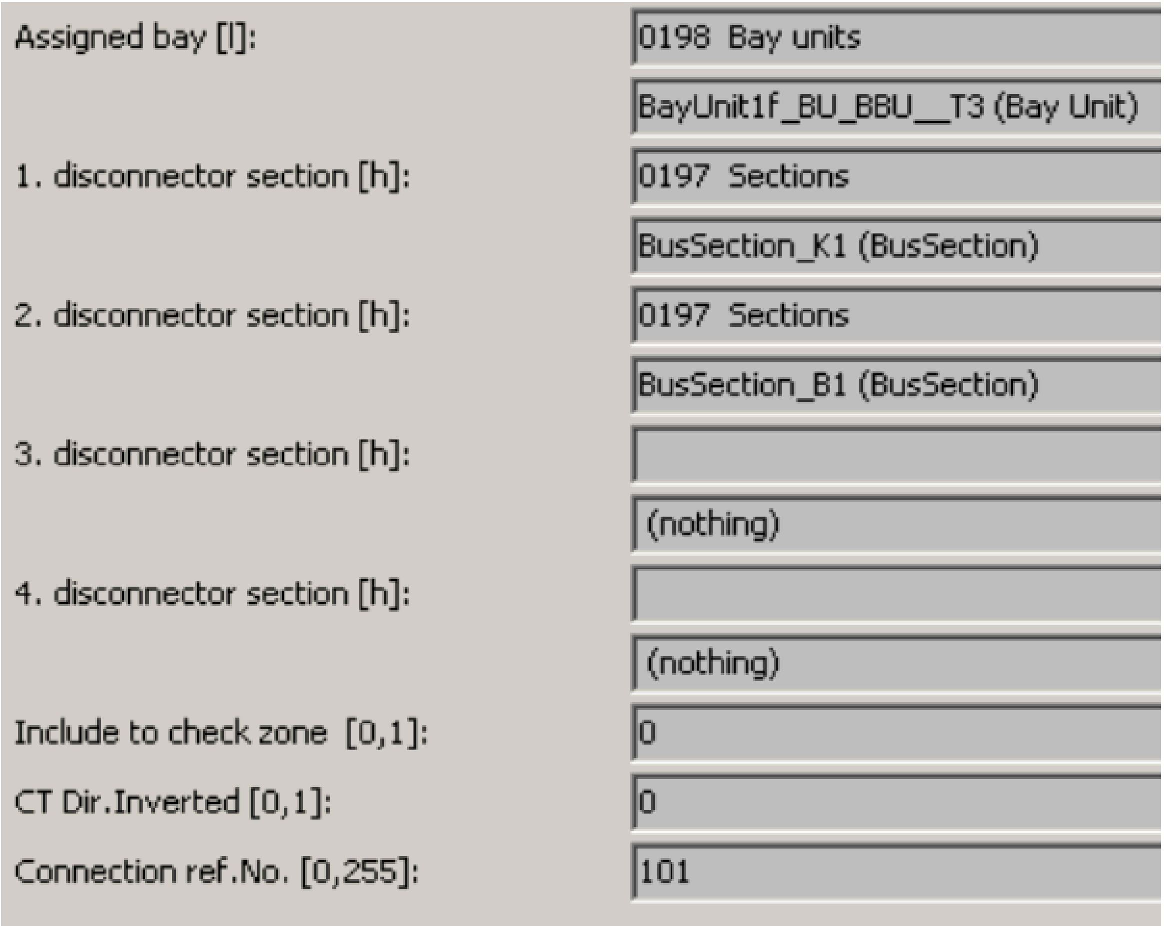
If the description is realized with a single bay unit, then the method is the same as a bay single bay coupler with a single current transformer. The only difference is that two disconnectors are applied in both sides. One of them is connected to the inputs DC1-DC2, the other side applies the inputs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

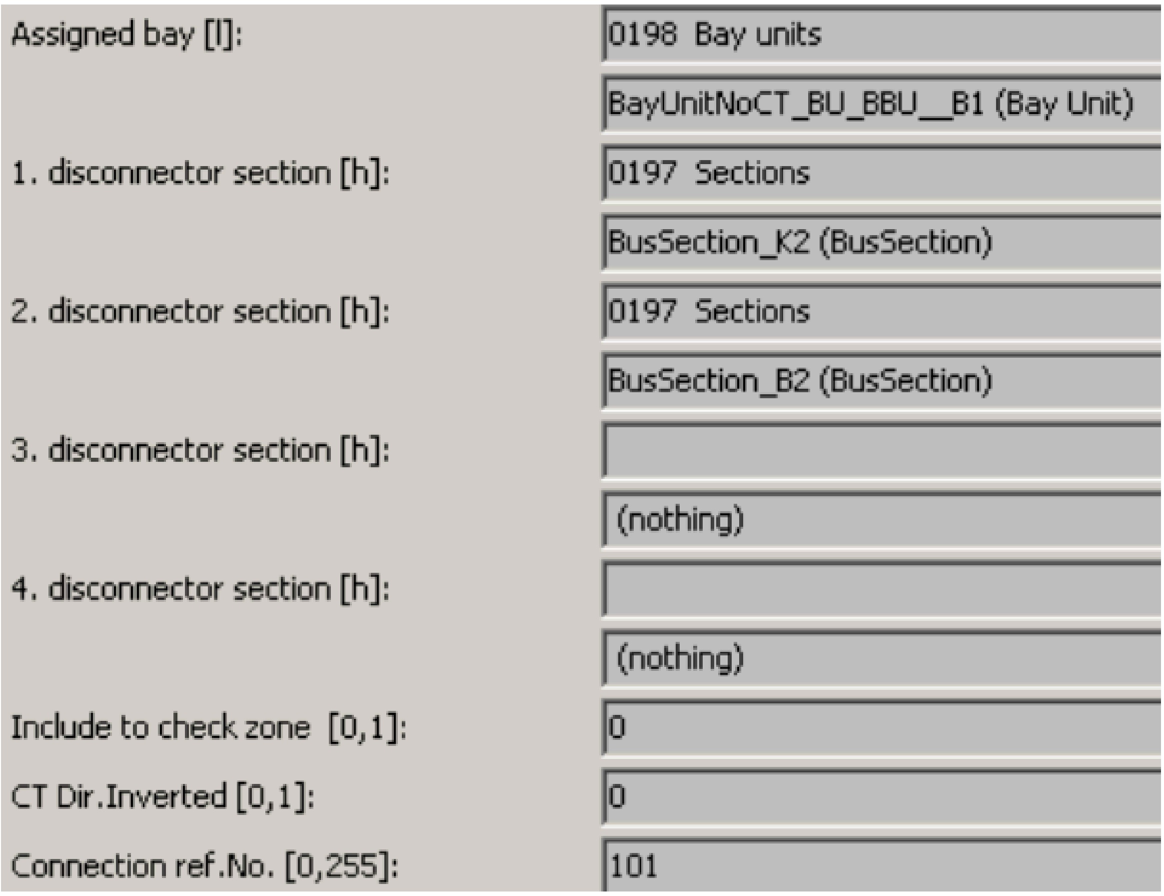
If the description applies two bay units, or if the number of busbars is more than two (e.g. triple bay system) then the solution is as follows:

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.



The setting of the topology elements is as follows:


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


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

9 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.

9.1 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.

9.2 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.

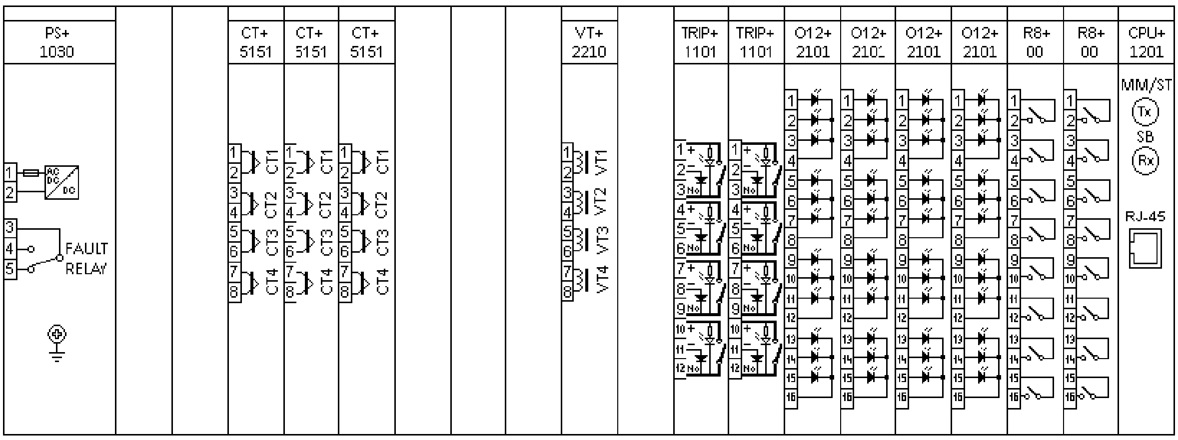
There are different variants for centralized busbar differential protection configurations. The maximum configuration in one AQ B398 unit contains six current transformer input cards and two voltage transformer input cards. This means that maximum 3-phase protection configuration is for six bays and 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.

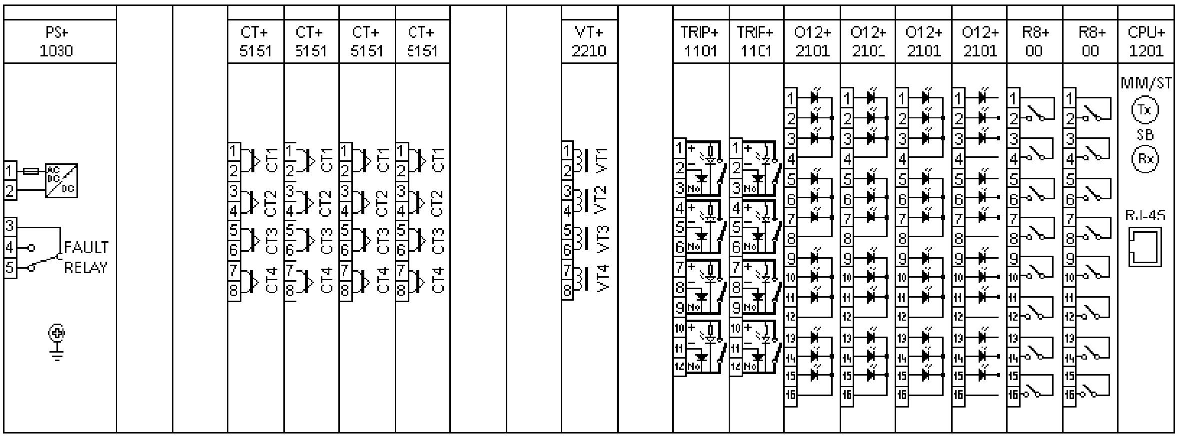
Figure. 9.2 - 66. Hardware variant of three CT cards and one VT card.



Centralized busbar hardware configuration with four CT cards and one VT cardCentralized 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 beused for 16 single phase bays and four single phase bus sections.

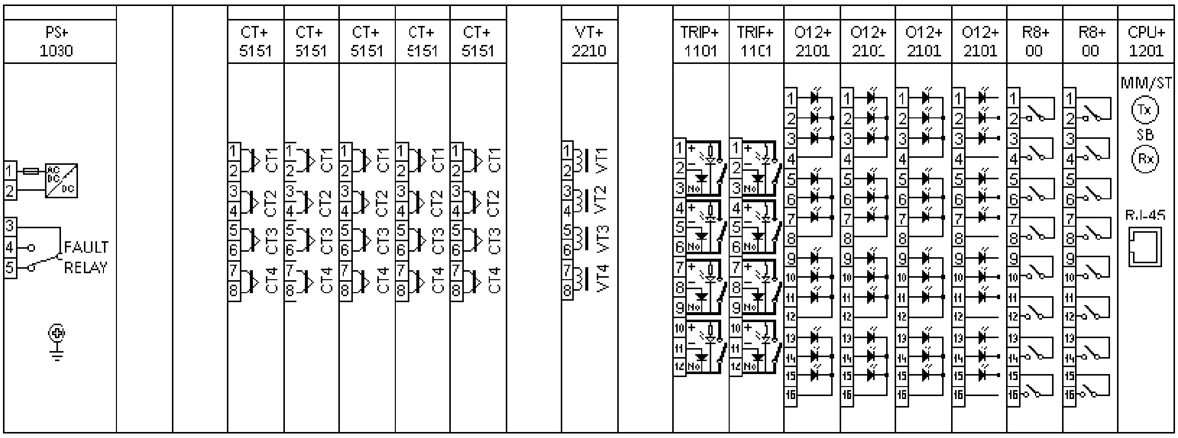
Figure. 9.2 - 67. Hardware variant of four CT cards and one VT card.



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 beused for 20 single phase bays and four single phase bus sections.

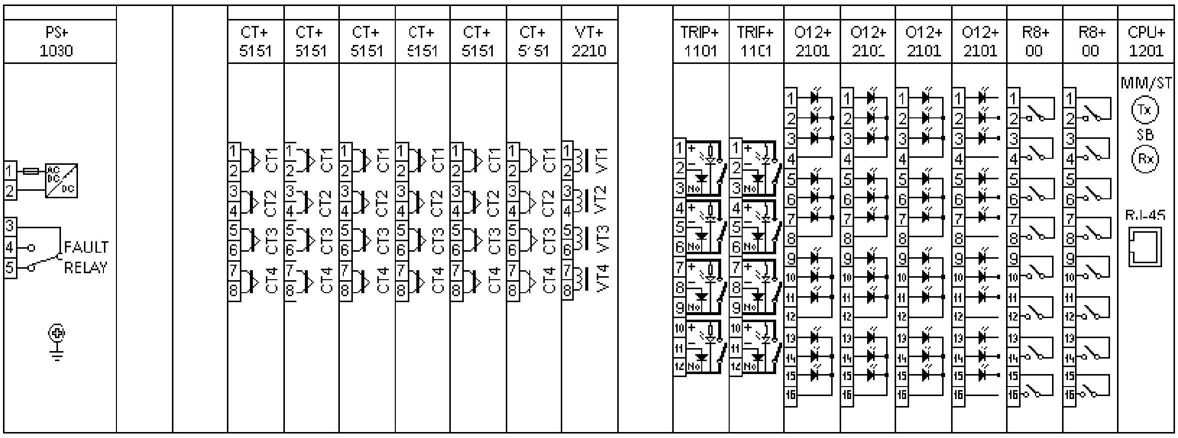
Figure. 9.2 - 68. Hardware variant of five CT cards and one VT card.



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 beused for 24 single phase bays and four single phase bus sections.

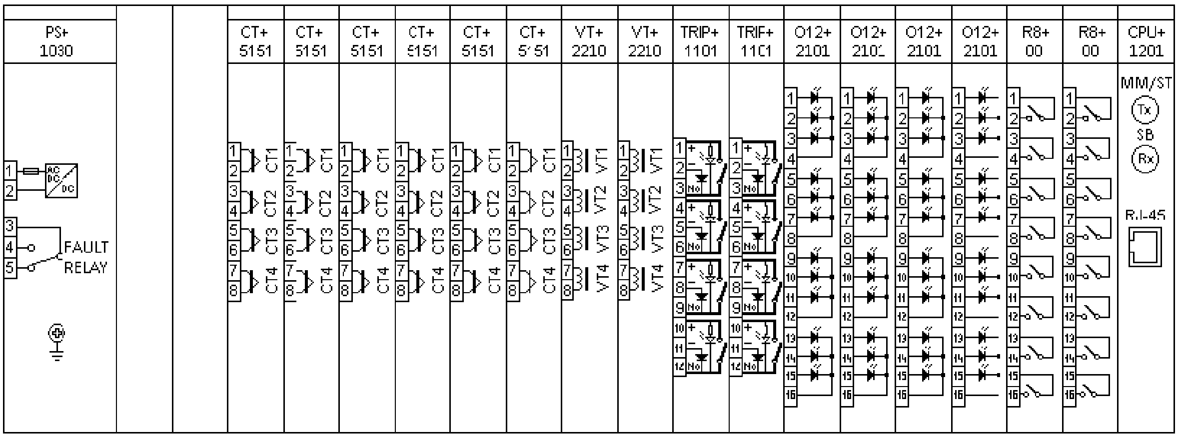
Figure. 9.2 - 69. Hardware variant of six CT cards and one VT card.



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

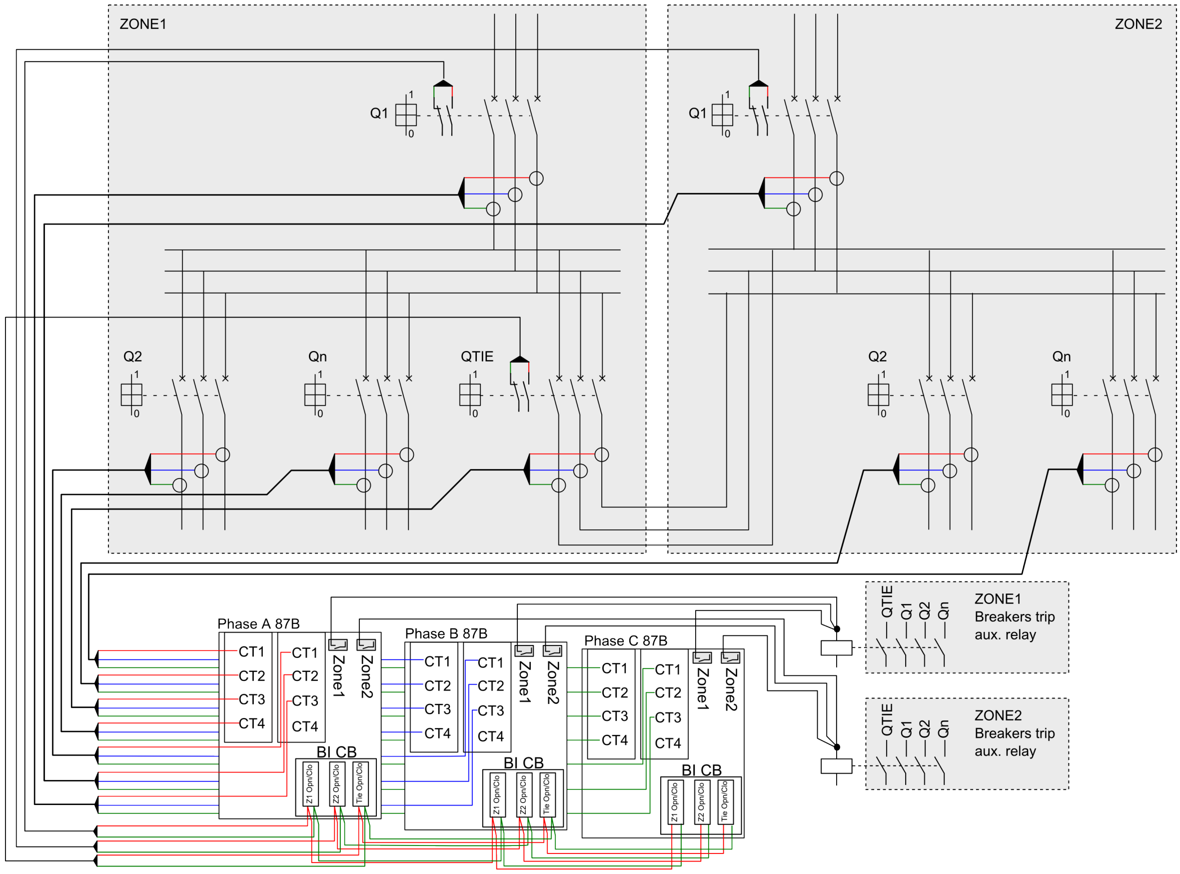
The hardware variant in the figure below contains six current transformer input cards and two voltage transformer input cards. This variant can be utilized for 3-phase busbar differential protection of maximum six bays and two busbar sections. Alternatively this unit can beused for 24 single phase bays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

Figure. 9.2 - 70. Hardware variant of six CT cards and two VT card.



9.3 Generic busbar protection application example

Figure. 9.3 - 71. Generic busbar protection application example.



10 Construction and installation

10.1 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. 10.1 - 72. An example module arrangement configuration of the AQ-B398 IED.

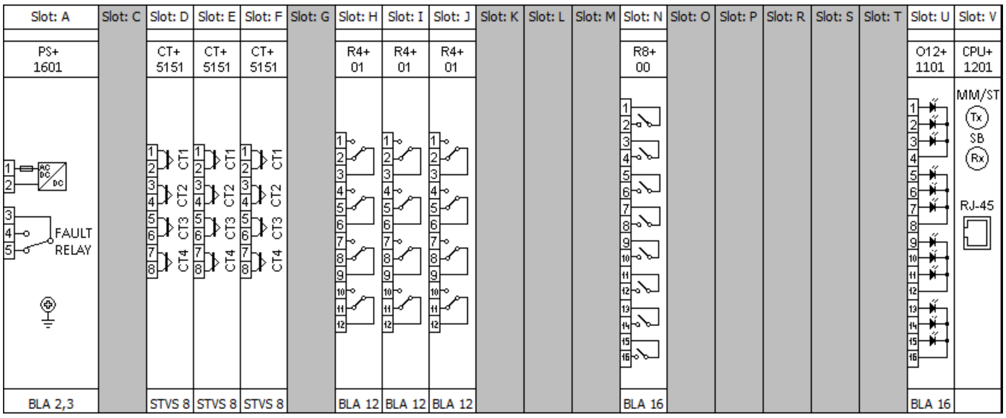


Table. 10.1 - 57. Descriptions of the hardware modules for AQ-B398.

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	—

10.2 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:

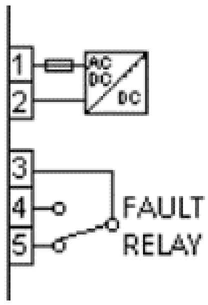
- Station bus (100Base-FX Ethernet).
- Redundant Station bus (100Base-FX Ethernet).
- Process bus (100Base-FX Ethernet).
- EOB (Ethernet over Board) user interface.
- Optional 100Base-TX port via RJ-45 connector.

Other communication:

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

10.3 Power supply module

Figure. 10.3 - 73. 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.

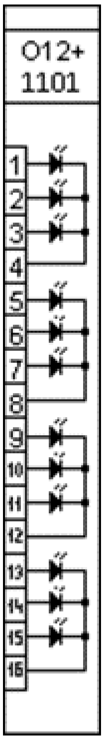
Main features of the power supply module:

- 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.

10.4 Binary input module(s)

Figure. 10.4 - 74. The binary input module O12+ 1101.



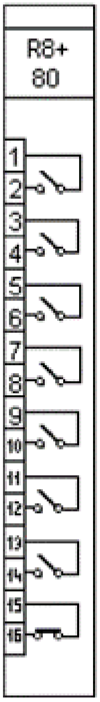
The inputs are galvanic isolated and the module converts high-voltage signals to the voltagelevel and format of the internal circuits. This module is also used as an external IRIG-B synchronization input. Dedicated synchronization input (input channel 1) is used for this purpose.

The binary input modules are:

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

10.5 Binary output module(s)

Figure. 10.5 - 75. The binary output module R8+ 80.



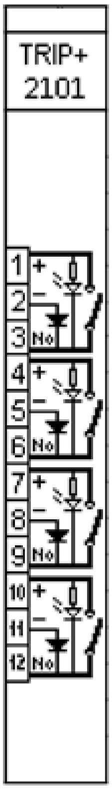
The signaling output modules can be ordered as 8 relay outputs with dry contacts.

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

10.6 Tripping module

Figure. 10.6 - 76. The tripping module TRIP+ 2101.



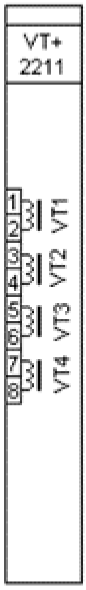
The tripping module applies direct control of a circuit breaker. The module provides fast operation and is rated for heavy duty controlling.

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.

10.7 Voltage measurement module

Figure. 10.7 - 77. 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.

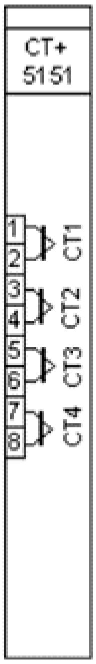
For capacitive voltage measurement of the synchrocheck reference, the voltage measurement module can be ordered with reduced burden in channel VT4. In this module the burden is < 50 mVA.

The main characteristics of the voltage measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Selectable rated voltage (Un): 100/√3, 100 V, 200/√3, 200 V by parameter.
- Voltage measuring range: 0.05 Un – 1.2 Un.
- Continuous voltage withstand: 250 V.
- Power consumption of voltage input: ≤1 VA at 200 V (with special CVT module the burden is < 50 mVA for VT4 channel).
- Relative accuracy: ±0.5 %.
- Frequency measurement range: ±0.01 % at Ux 25 % of rated voltage.
- Measurement of phase angle: 0.5º Ux 25 % of rated voltage.

10.8 Current measurement module

Figure. 10.8 - 78. 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 chracteristics of the current measurement module:

- Number of channels: 4.
- Rated frequency: 50 Hz, 60 Hz.
- Electronic iron-core flux compensation.
- Low consumption: ≤0.1 VA at rated current.
- Current measuring range: 35 x In.
- 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: ±0.5 %.
- Measurement of phase angle: 0.5º, Ix 10 % rated current.

10.9 Installation and dimensions

Figure. 10.9 - 79. Dimensions of AQ-x39x IED.

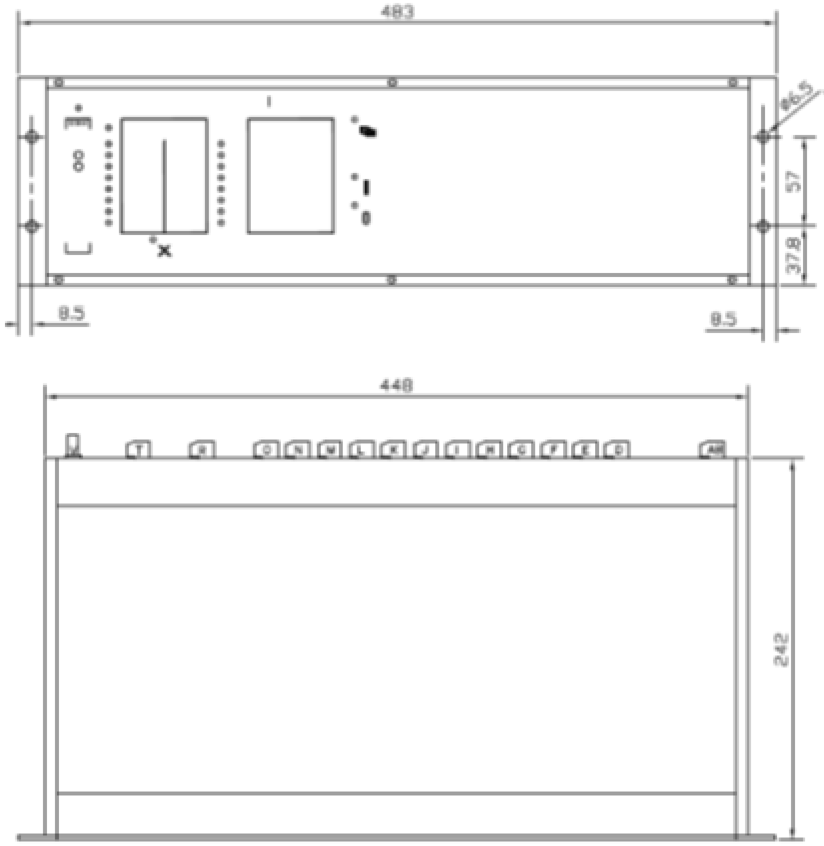
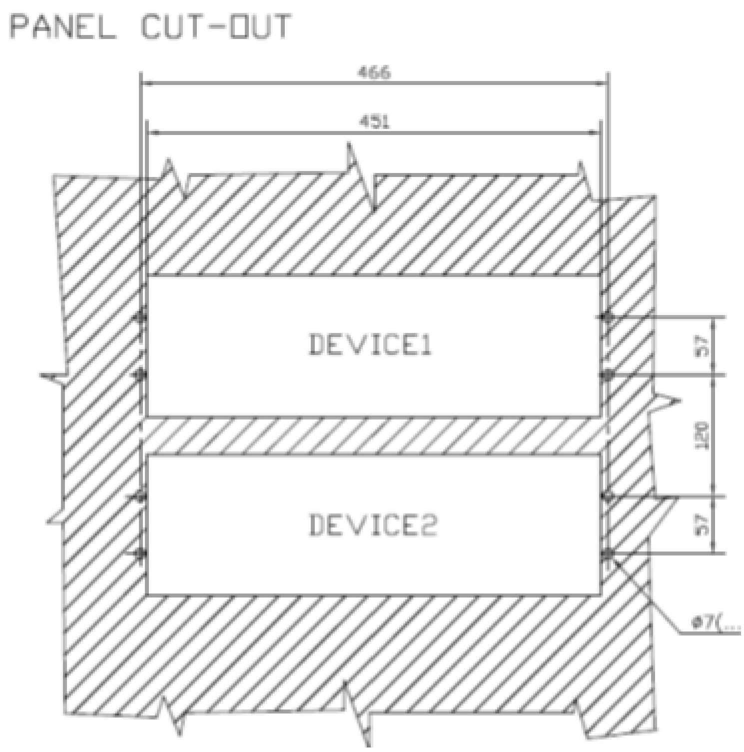


Figure. 10.9 - 80. Panel cut-out and spacing of AQ-x39x IED.



11 Technical data

11.1 Busbar differential protection

Table. 11.1 - 58. Technical data for centralized busbar protection.

Operation time: • Idiff > 2xIn • Idiff > 5xIn	typically <20 ms typically <15 ms
Reset ratio	0.7
Reset time	60 ms
Measurement inaccuracy	2 %

Table. 11.1 - 59. Technical data for distributed busbar protection.

Operation time: • Idiff > 2xIn • Idiff > 5xIn	typically <30 ms typically <20 ms
Reset ratio	0.7
Reset time	60 ms
Measurement inaccuracy	2 %

11.2 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 Ix ≥ 10% ± 1 digit	≤ 0.5 º
Relative accuracy [%] ± 1 digit	± 1 (> 0.5In) with 1A rated current ± 1 (> 0.4In) with 5A rated current

Voltage measurement module

Rated voltage Un	100/√3, 100V, 200/√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	0.05-1.2xUn
Power consumption	0.61VA at 200V 0.2 VA at 100V
Relative accuracy	±0.5 % (>0.6Un)
Frequency measurement range	±0.01 % at Ux ≥ 25% of rated voltage
Phase angle accuracy	≤ 0.5 º at Ux ≥ 25% of rated voltage

Binary input module

Rated voltage Un	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 Un	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)

11.3 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, 1.2/50us, 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

12 Ordering information

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

13 Contact and reference information

Manufacturer

Arcteq Relays Ltd.

Visiting and postal address

Kvartsikatu 2 A 1
65300 Vaasa, Finland

Contacts

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Technical support:	arcteq.com/support-login +358 10 3221 388 (EET 9:00 – 17.00)
E-mail (sales):	sales@arcteq.com