RELION® 611 SERIES

Busbar and Multipurpose Differential Protection and Control REB611

Application Manual

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Table of contents

Section 1 Introduction

1.1 This manual

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

1.2 Intended audience

This manual addresses the protection and control engineer responsible for planning, pre-engineering and engineering.

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as protection schemes and principles.

1.3 Product documentation

1.3.1 Product documentation set

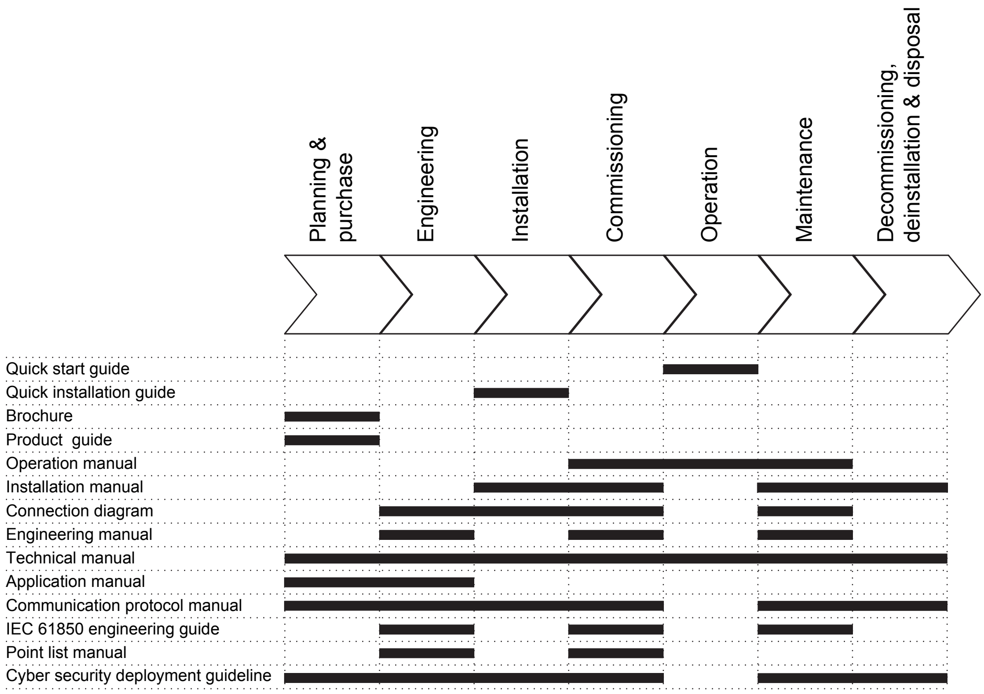

Figure 1: The intended use of manuals in different lifecycles

Product series- and product-specific manuals can be downloaded from the ABB Web site http://www.abb.com/relion.

1.3.2 Document revision history

Document revision/date	Product version	History
A/2011-11-18	1.0	First release
B/2016-02-22	2.0	Content updated to correspond to the product version
C/2016-10-11	2.0	Content updated
D/2017-10-31	2.0	Content updated
E/2019-04-10	2.0	Content updated

Download the latest documents from the ABB Web site http://www.abb.com/substationautomation.

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS757461
IEC 61850 Engineering Guide	1MRS757465
Engineering Manual	1MRS241255
Installation Manual	1MRS757452
Operation Manual	1MRS757453
Technical Manual	1MRS757454
Cyber Security Deployment Guideline	1MRS758337

1.4 Symbols and conventions

1.4.1 Symbols

The electrical warning icon indicates the presence of a hazard which could result in electrical shock.

The warning icon indicates the presence of a hazard which could result in personal injury.

The caution icon indicates important information or warning related to the concept discussed in the text. It might indicate the presence of a hazard which could result in corruption of software or damage to equipment or property.

The information icon alerts the reader of important facts and conditions.

The tip icon indicates advice on, for example, how to design your project or how to use a certain function.

Although warning hazards are related to personal injury, it is necessary to understand that under certain operational conditions, operation of damaged equipment may result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Document conventions

A particular convention may not be used in this manual.

- Abbreviations and acronyms are spelled out in the glossary. The glossary also contains definitions of important terms.
- Push button navigation in the LHMI menu structure is presented by using the push button icons.
  To navigate between the options, use and .
- Menu paths are presented in bold.
  Select **Main menu/Settings**.
- LHMI messages are shown in Courier font.
  To save the changes in nonvolatile memory, select `Yes` and press .
- Parameter names are shown in italics.
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks.
  The corresponding parameter values are "On" and "Off".
- Input/output messages and monitored data names are shown in Courier font.
  When the function starts, the `START` output is set to TRUE.
- This document assumes that the parameter setting visibility is "Advanced".

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Non-directional earth-fault protection, low stage, instance 1	EFLPTOC1	Io> (1)	51N-1 (1)
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
High-impedance differential protection for phase A, instance 1	HIAPDIF1	dHi>(1)	87(1)
High-impedance differential protection for phase B, instance 2	HIBPDIF1	dHi>(2)	87(2)
High-impedance differential protection for phase C, instance 3	HICPDIF1	dHi>(3)	87(3)
Other			

Table continues on next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Input switch group[1]	ISWGAPC	ISWGAPC	ISWGAPC
Output switch group[2]	OSWGAPC	OSWGAPC	OSWGAPC
Selector[3]	SELGAPC	SELGAPC	SELGAPC
Minimum pulse timer (2 pcs)[4]	TPGAPC	TP	TP
Move (8 pcs), instance 1	MVGAPC	MV (1)	MV (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Condition monitoring and supervision			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Phase segregated CT supervision function for phase A, instance 1	HZCCASPVC1	MCS 1I(1)	MCS 1I(1)
Phase segregated CT supervision function for phase B, instance 2	HZCCBSPVC1	MCS 1I(2)	MCS 1I(2)
Phase segregated CT supervision function for phase C, instance 3	HZCCCSPVC1	MCS 1I(3)	MCS 1I(3)
Logging			
Disturbance recorder	RDRE1	DR (1)	DFR(1)
Fault recorder	FLTRFRC1	-	FR
Measurement			
Three-phase current measurement, instance 1[5]	CMMXU1	3I	3I
Residual current measurement, instance 1	RESCMMXU1	Io	In

1) 10 instances
2) 20 instances
3) 6 instances
4) 10 instances
5) Used for measuring differential phase currents

Section 2 REB611 overview

2.1 Overview

REB611 is a dedicated busbar protection relay for phase-segregated short-circuit protection, control, and supervision of single busbars. REB611 is intended for use in high-impedance-based applications within utility substations and industrial power systems. In addition, the protection relay can be utilized in restricted earth-fault and residual earth-fault applications for the protection of generators, motors, transformers and reactors.

REB611 is a member of ABB's Relion® product family and part of the 611 protection and control product series. The 611 series relays are characterized by their compactness and withdrawable-unit design.

The 611 series offers simplified yet powerful functionality for most applications. Once the application-specific parameter set has been entered, the installed protection relay is ready to be put into service. The further addition of communication functionality and interoperability between substation automation devices offered by the IEC 61850 standard adds flexibility and value to end users as well as electrical system manufacturers.

The 611 series relays fully support the IEC 61850 standard for communication and interoperability of substation automation devices, including fast GOOSE (Generic Object Oriented Substation Event) messaging, and can now also benefit from the extended interoperability provided by Edition 2 of the standard. The relays further support the parallel redundancy protocol (PRP) and the high-availability seamless redundancy (HSR) protocol. The 611 series relays are able to use IEC 61850 and Modbus® communication protocols simultaneously.

2.1.1 Product version history

Product version	Product history
1.0	Product released
2.0	• High-availablity seamless redundancy (HSR) protocol • Parallel redundancy protocol (PRP-1) • Two selectable indication colors for LEDs (red or green) • Online binary signal monitoring with PCM600 • IEEE 1588 v2 time synchronization • Profibus adapter support • Import/export of settings via WHMI • Setting usability improvements • HMI event fitering tool • IEC 61850 Edition 2 • Support for configuration migration (starting from Ver.1.0 to Ver.2.0) • Software closable Ethernet ports • Report summary via WHMI

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.7 or later
- REB611 Connectivity Package Ver.2.0 or later
    - Communication Management
    - Configuration Wizard
    - Disturbance Handling
    - Event Viewer
    - Fault Record tool
    - Firmware Update
    - HMI Event Filtering
    - IEC 61850 Configuration
    - IED Compare
    - IED Configuration Migration
    - IED User Management
    - Label Printing
    - Lifecycle Traceability
    - Parameter Setting
    - Signal Matrix
    - Signal Monitoring

Download connectivity packages from the ABB Web site http://www.abb.com/substationautomation or directly with Update Manager in PCM600.

2.2 Operation functionality

2.2.1 Optional functions

- Modbus TCP/IP or RTU/ASCII
- IEEE 1588 time v2 synchronization
- High-availability seamless redundancy protocol (HSR)
- Parallel redundancy protocol (PRP)

2.3 Physical hardware

The protection relay consists of two main parts: plug-in unit and case. The content depends on the ordered functionality.

Table 2: Plug-in unit and case

Main unit	Slot ID	Content options	
Plug-in unit	-	HMI	Small (4 lines, 16 characters)
	X100	Auxiliary power/BO module	48...250 V DC/100...240 V AC; or 24...60 V DC 2 normally-open PO contacts 1 change-over SO contacts 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X120	AI/BI module	Configuration A: 3 differential phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1)] 4 binary inputs
Case	X000	Optional communication module	See technical manual for details about different type of communication modules.

1) The 0.2/1 A input is normally used in applications requiring sensitive earth-fault protection and featuring core-balance current transformers.

Rated values of the current and voltage inputs are basic setting parameters of the protection relay. The binary input thresholds are selectable within the range 16…176 V DC by adjusting the binary input setting parameters.

See the installation manual for more information about the case and the plug-in unit.

The connection diagrams of different hardware modules are presented in this manual.

Table 3: Number of physical connections in configuration

Conf.	Analog channels		Binary channels	
	CT	VT	BI	BO
A	4	-	4	6

2.4 Local HMI

The LHMI is used for setting, monitoring and controlling the protection relay. The LHMI comprises the display, buttons, LED indicators and communication port.

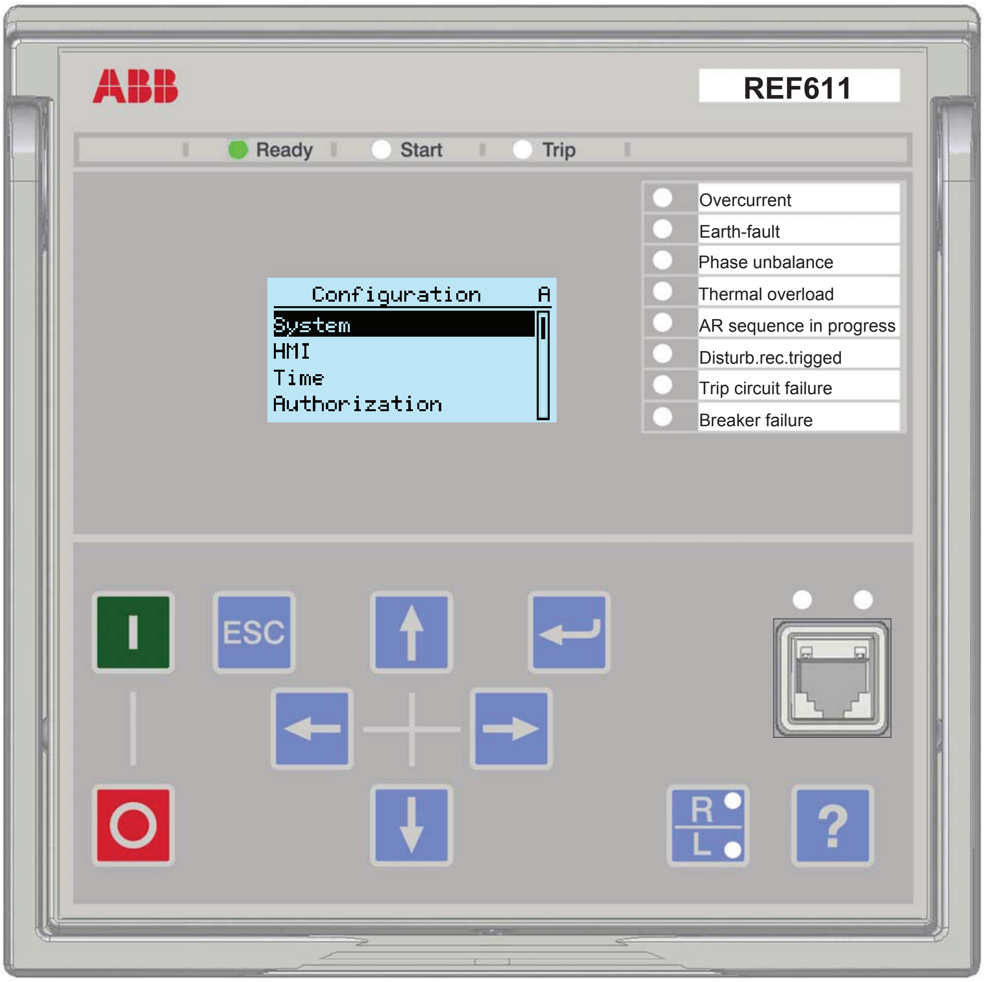

Figure 2: Example of the LHMI

2.4.1 Display

The LHMI includes a graphical display that supports two character sizes. The character size depends on the selected language. The amount of characters and rows fitting the view depends on the character size.

Table 4: Small display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

1) Depending on the selected language

The display view is divided into four basic areas.

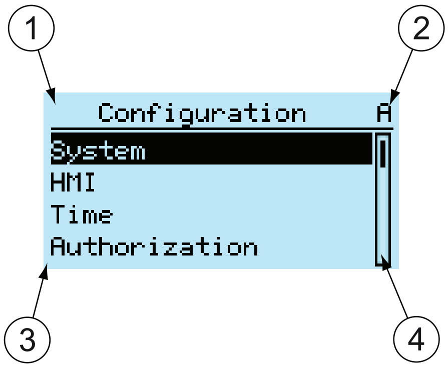

Figure 3: Display layout

1 Header

2 Icon

3 Content

4 Scroll bar (displayed when needed)

2.4.2 LEDs

The LHMI includes three protection indicators above the display: Ready, Start and Trip.

There are also 8 programmable LEDs on front of the LHMI. The LEDs can be configured with the LHMI, WHMI or PCM600.

2.4.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. With the push buttons you can give open or close commands to one object in the primary circuit, for example, a circuit breaker, a contactor or a disconnector. The push buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

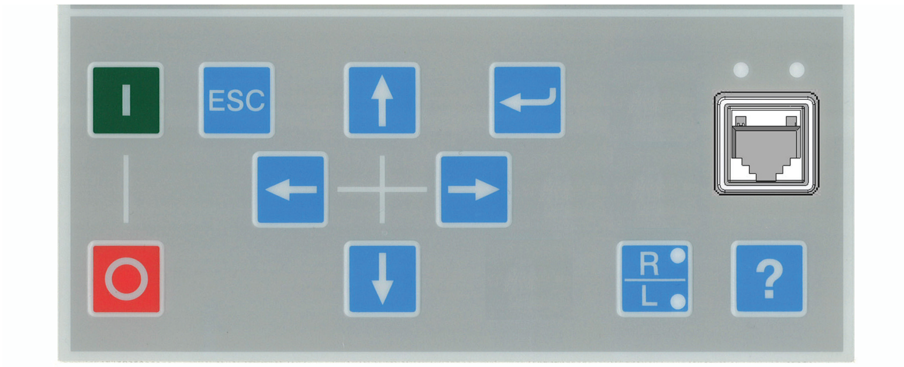

Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. When the *Secure Communication* parameter in the protection relay is activated, the Web server is forced to take a secured (HTTPS) connection to WHMI using TLS encryption.The WHMI is verified with Internet Explorer 8.0, 9.0, 10.0 and 11.0.

WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Fault records
- Phasor diagram
- Signal configuration
- Importing/Exporting parameters
- Report summary

The menu tree structure on the WHMI is almost identical to the one on the LHMI.

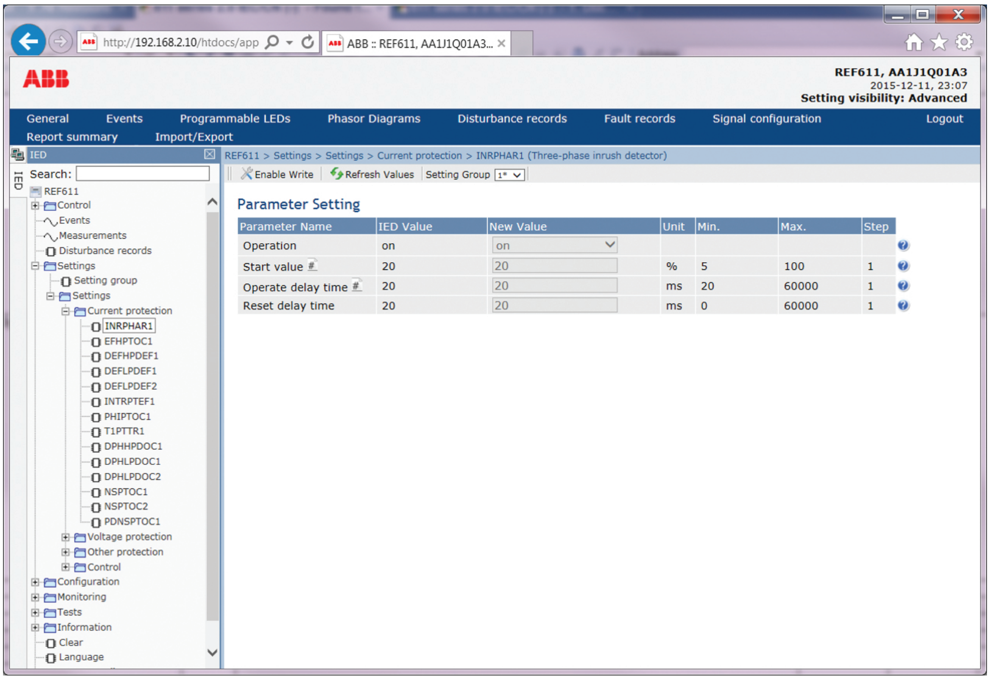

Figure 5: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting the laptop to the protection relay via the front communication port.
- Remotely over LAN/WAN.

2.5.1 Command buttons

Command buttons can be used to edit parameters and control information via the WHMI.

Table 5: Command buttons

Name	Description
Enable Write	Enabling parameter editing
Disable Write	Disabling parameter editing
Write to IED	Writing parameters to the protection relay
Refresh Values	Refreshing parameter values
Print	Printing out parameters
Commit	Committing changes to protection relay's nonvolatile flash memory

Table continues on next page

Name	Description
Reject	Rejecting changes
	Showing context sensitive help messages
	Error icon
Clear events	Clearing events
Manual trigger	Triggering the disturbance recorder manually
Save	Saving values to TXT or CSV file format
Freeze	Freezing the values so that updates are not displayed
Continue	Receiving continuous updates to the monitoring view
Delete	Deleting the disturbance record
Delete all	Deleting all disturbance records
	Saving the disturbance record files
View all	Viewing all fault records
Clear records	Clearing all fault records
Import Settings	Importing settings
Export Settings	Exporting settings
Select all	Selecting all
Clear all	Clearing all selections
Refresh	Refreshing the parameter list view

2.6 Authorization

Four user categories have been predefined for the LHMI and the WHMI, each with different rights and default passwords.

The default passwords in the protection relay delivered from the factory can be changed with Administrator user rights.

User authorization is disabled by default for LHMI but WHMI always uses authorization.

Table 6: Predefined user categories

Username	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with (only locally) • Changing setting groups • Controlling • Clearing indications
ENGINEER	• Changing settings • Clearing event list • Clearing disturbance records • Changing system settings such as IP address, serial baud rate or disturbance recorder settings • Setting the protection relay to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.6.1 Audit trail

The protection relay offers a large set of event-logging functions. Critical system and protection relay security-related events are logged to a separate nonvolatile audit trail for the administrator.

Audit trail is a chronological record of system activities that allows the reconstruction and examination of the sequence of system and security-related events and changes in the protection relay. Both audit trail events and process related events can be examined and analyzed in a consistent method with the help of Event List in LHMI and WHMI and Event Viewer in PCM600.

The protection relay stores 2048 audit trail events to the nonvolatile audit trail. Additionally, 1024 process events are stored in a nonvolatile event list. Both the audit trail and event list work according to the FIFO principle. Nonvolatile memory is based on a memory type which does not need battery backup nor regular component change to maintain the memory storage.

Audit trail events related to user authorization (login, logout, violation remote and violation local) are defined according to the selected set of requirements from IEEE 1686. The logging is based on predefined user names or user categories. The user audit trail events are accessible with IEC 61850-8-1, PCM600, LHMI and WHMI.

Table 7: Audit trail events

Audit trail event	Description
Configuration change	Configuration files changed
Firmware change	Firmware changed
Firmware change fail	Firmware change failed
Attached to retrofit test case	Unit has been attached to retrofit case
Removed from retrofit test case	Removed from retrofit test case
Setting group remote	User changed setting group remotely
Setting group local	User changed setting group locally
Control remote	DPC object control remote
Control local	DPC object control local
Test on	Test mode on
Test off	Test mode off
Reset trips	Reset latched trips (TRPPTRC*)
Setting commit	Settings have been changed
Time change	Time changed directly by the user. Note that this is not used when the protection relay is synchronised properly by the appropriate protocol (SNTP, IRIG-B, IEEE 1588 v2).
View audit log	Administrator accessed audit trail
Login	Successful login from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Logout	Successful logout from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Password change	Password changed
Firmware reset	Reset issued by user or tool
Audit overflow	Too many audit events in the time period
Violation remote	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.
Violation local	Unsuccessful login attempt from IEC 61850-8-1 (MMS), WHMI, FTP or LHMI.

PCM600 Event Viewer can be used to view the audit trail events and process related events. Audit trail events are visible through dedicated Security events view. Since only the administrator has the right to read audit trail, authorization must be used in PCM600. The audit trail cannot be reset, but PCM600 Event Viewer can filter data. Audit trail events can be configured to be visible also in LHMI/WHMI Event list together with process related events.

To expose the audit trail events through Event list, define the *Authority logging* level parameter via **Configuration/ Authorization/Security**. This exposes audit trail events to all users.

Table 8: Comparison of authority logging levels

Audit trail event	Authority logging level					
	None	Configuration change	Setting group	Setting group, control	Settings edit	All
Configuration change		•	•	•	•	•
Firmware change		•	•	•	•	•
Firmware change fail		•	•	•	•	•
Attached to retrofit test case		•	•	•	•	•
Removed from retrofit test case		•	•	•	•	•
Setting group remote			•	•	•	•
Setting group local			•	•	•	•
Control remote				•	•	•
Control local				•	•	•
Test on				•	•	•
Test off				•	•	•
Reset trips				•	•	•
Setting commit					•	•
Time change						•
View audit log						•
Login						•
Logout						•
Password change						•
Firmware reset						•
Violation local						•
Violation remote						•

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850 and Modbus®. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the protection relays, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the IEC 60255-24 standard COMTRADE file format. The protection relay can send and receive binary signals from other devices (so-called horizontal communication) using the IEC 61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard.

The protection relay can support five simultaneous clients. If PCM600 reserves one client connection, only four client connections are left, for example, for IEC 61850 and Modbus.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber-optic LC connector (100Base-FX). An optional serial interface is available for RS-485 communication.

2.7.1 Self-healing Ethernet ring

For the correct operation of self-healing loop topology, it is essential that the external switches in the network support the RSTP protocol and that it is enabled in the switches. Otherwise, connecting the loop topology can cause problems to the network. The protection relay itself does not support link-down detection or RSTP. The ring recovery process is based on the aging of the MAC addresses, and the link-up/link-down events can cause temporary breaks in communication. For a better performance of the self-healing loop, it is recommended that the external switch furthest from the protection relay loop is assigned as the root switch (bridge priority = 0) and the bridge priority increases towards the protection relay loop. The end links of the protection relay loop can be attached to the same external switch or to two adjacent external switches. A self-healing Ethernet ring requires a communication module with at least two Ethernet interfaces for all protection relays.

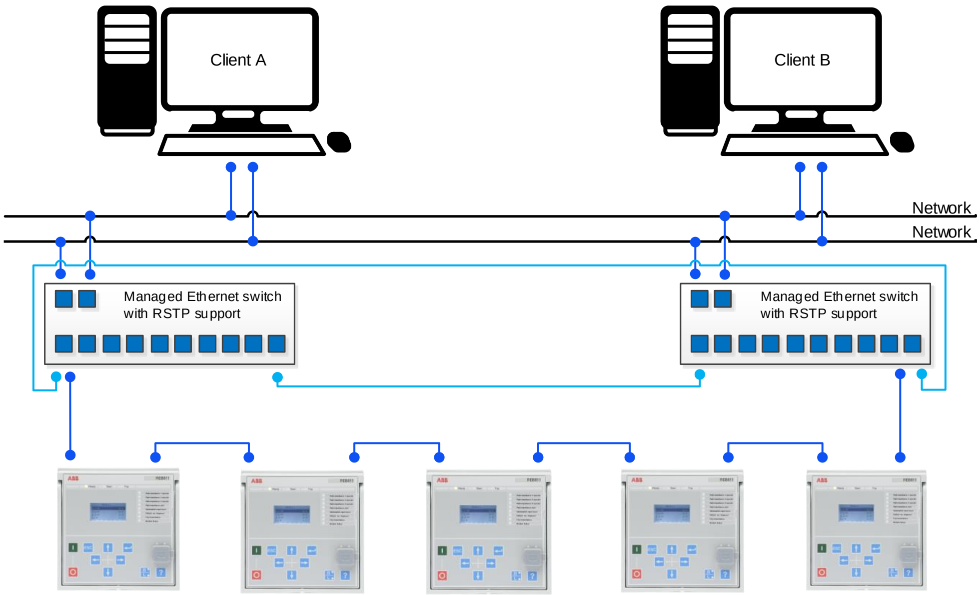

Figure 6: Self-healing Ethernet ring solution

The Ethernet ring solution supports the connection of up to 30 protection relays. If more than 30 protection relays are to be connected, it is recommended that the network is split into several rings with no more than 30 protection relays per ring. Each protection relay has a 50-μs store-and-forward delay, and to fulfil the performance requirements for fast horizontal communication, the ring size is limited to 30 protection relays.

2.7.2 Ethernet redundancy

IEC 61850 specifies a network redundancy scheme that improves the system availability for substation communication. It is based on two complementary protocols defined in the IEC 62439-3:2012 standard: parallel redundancy protocol PRP and high-availability seamless redundancy HSR protocol. Both protocols rely on the duplication of all transmitted information via two Ethernet ports for one logical network connection. Therefore, both are able to overcome the failure of a link or switch with a zero-switchover time, thus fulfilling the stringent real-time requirements for the substation automation horizontal communication and time synchronization.

PRP specifies that each device is connected in parallel to two local area networks. HSR applies the PRP principle to rings and to the rings of rings to achieve cost-effective redundancy. Thus, each device incorporates a switch element that forwards frames from port to port. The HSR/PRP option is available for all 611 series protection relays.

IEC 62439-3:2012 cancels and replaces the first edition published in 2010. These standard versions are also referred to as IEC 62439-3 Edition 1 and IEC 62439-3 Edition 2. The protection relay supports IEC 62439-3:2012 and it is not compatible with IEC 62439-3:2010.

PRP

Each PRP node, called a double attached node with PRP (DAN), is attached to two independent LANs operated in parallel. These parallel networks in PRP are called LAN A and LAN B. The networks are completely separated to ensure failure independence, and they can have different topologies. Both networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid communication failures. Non-PRP nodes, called single attached nodes (SANs), are either attached to one network only (and can therefore communicate only with DANs and SANs attached to the same network), or are attached through a redundancy box, a device that behaves like a DAN.

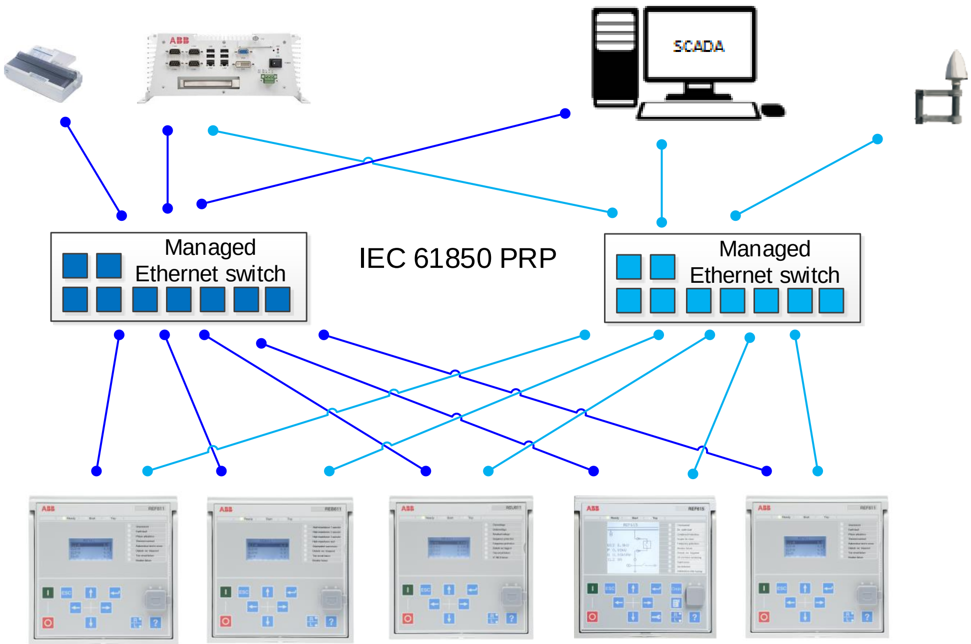

Figure 7: PRP solution

In case a laptop or a PC workstation is connected as a non-PRP node to one of the PRP networks, LAN A or LAN B, it is recommended to use a redundancy box device or an Ethernet switch with similar functionality between the PRP network and SAN to remove additional PRP information from the Ethernet frames. In some cases, default PC workstation adapters are not able to handle the maximum-length Ethernet frames with the PRP trailer.

There are different alternative ways to connect a laptop or a workstation as SAN to a PRP network.

- Via an external redundancy box (RedBox) or a switch capable of connecting to PRP and normal networks
- By connecting the node directly to LAN A or LAN B as SAN
- By connecting the node to the protection relay's interlink port

HSR

HSR applies the PRP principle of parallel operation to a single ring, treating the two directions as two virtual LANs. For each frame sent, a node, DAN, sends two frames, one over each port. Both frames circulate in opposite directions over the ring and each node forwards the frames it receives, from one port to the other. When the originating node receives a frame sent to itself, it discards that to avoid loops; therefore, no ring protocol is needed. Individually attached nodes, SANs, such as laptops and printers, must be attached through a "redundancy box" that acts as a ring element. For example, a 615 or 620 series protection relay with HSR support can be used as a redundancy box.

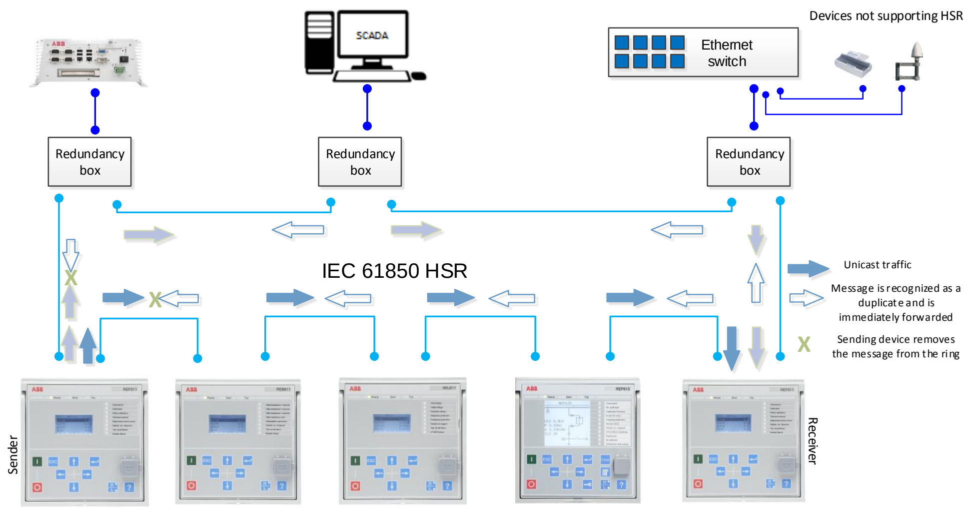

Figure 8: HSR solution

2.7.3 Secure communication

The protection relay supports secure communication for WHMI and file transfer protocol. If the *Secure Communication* parameter is activated, protocols require TLS based encryption method support from the clients. In this case WHMI must be connected from a Web browser using the HTTPS protocol and in case of file transfer the client must use FTPS.

As a factory default, *Secure Communication* is "ON".

Section 3 REB611 standardized configuration

3.1 Standardized configuration

REB611 is available in one configuration.

To increase the user-friendliness of the configuration and to emphasize the relay's simplicity of usage, only the application-specific parameters need setting within the relay's intended area of application.

The standard signal configuration can be altered by local HMI, Web HMI or optional application functionality of Protection and Control IED Manager PCM600.

Table 9: Standardized configuration

Description	Conf.
High-impedance differential	A

Table 10: Supported functions

Function	IEC 61850	A
Protection		
Non-directional earth-fault protection, low stage	EFLPTOC	1 [1)]
Non-directional earth-fault protection, high stage	EFHPTOC	1 [1)]
Circuit breaker failure protection	CCBRBRF	1
Master trip	TRPPTRC	2
High-impedance differential protection for phase A	HIAPDIF	1
High-impedance differential protection for phase B	HIBPDIF	1
High-impedance differential protection for phase C	HICPDIF	1
Control		
Circuit-breaker control	CBXCBR	1
Condition monitoring and supervision		
Trip circuit supervision	TCSSCBR	2
Phase segregated CT supervision function for phase A	HZCCASPVC	1
Phase segregated CT supervision function for phase B	HZCCBSPVC	1
Phase segregated CT supervision function for phase C	HZCCCSPVC	1
Logging		
Disturbance recorder	RDRE	1
Fault recorder	FLTRFRC	1
Measurement		

Table continues on next page

Function	IEC 61850	A
Three-phase current measurement	CMMXU	1
Residual current measurement	RESCMMXU	1
Other		
Input switch group	ISWGAPC	10
Output switch group	OSWGAPC	20
Selector	SELGAPC	6
Minimum pulse timer (2 pcs)	TPGAPC	10
Move (8 pcs)	MVGAPC	1
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standardized configuration. () = optional		

1) "Io measured" is always used

3.2 Switch groups

The default application configurations cover the most common application cases, however, changes can be made according to specific needs through LHMI, WHMI and PCM600.

Programming is easily implemented with three switch group functions including input switch group ISWGAPC, output switch group OSWGAPC and selector switch group SELGAPC. Each switch group has several instances.

Connections of binary inputs to functions, GOOSE signals to functions, functions to functions, functions to binary outputs and functions to LEDs have been preconnected through corresponding switch groups.

The real connection logic and the application configuration can be modified by changing the parameter values of the switch groups. It is also possible to modify the real connection logic and the application configuration through the matrix view in the signal configuration menu in the WHMI.

3.2.1 Input switch group ISWGAPC

The input switch group ISWGAPC has one input and a number of outputs. Every input and output has a read-only description. ISWGAPC is used for connecting the input signal to one or several outputs of the switch group. Each output can be set to be connected or not connected with the input separately via the “OUT_x connection” setting.

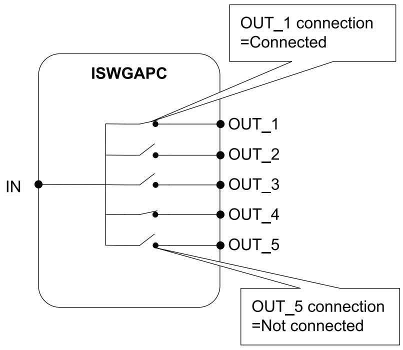

Figure 9: Input switch group ISWGAPC

3.2.2 Output switch group OSWGAPC

The output switch group OSWGAPC has a number of inputs and one output. Every input and output has a read-only description. OSWGAPC is used for connecting one or several inputs to the output of the switch group via OR logic. Each input can be set to be connected or not connected with the OR logic via the “IN_x connection” settings. The output of OR logic is routed to switch group output.

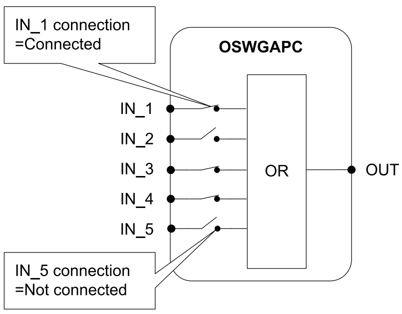

Figure 10: Output switch group OSWGAPC

3.2.3 Selector switch group SELGAPC

The selector switch group SELGAPC has a number of inputs and outputs. Every input and output has a read-only description. Each output can be set to be connected with one of the inputs via the *OUT_x connection* setting. An output can also be set to be not connected with any of the inputs. In SELGAPC, one output signal can only be connected to one input signal but the same input signal can be routed to several output signals.

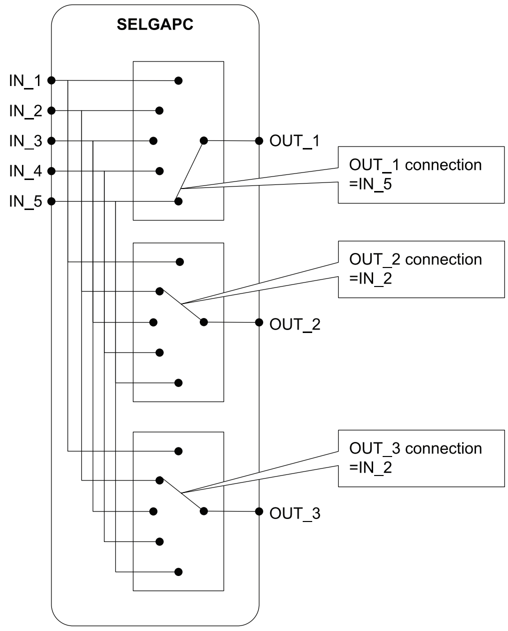

Figure 11: Selector switch group SELGAPC

3.3 Connection diagrams

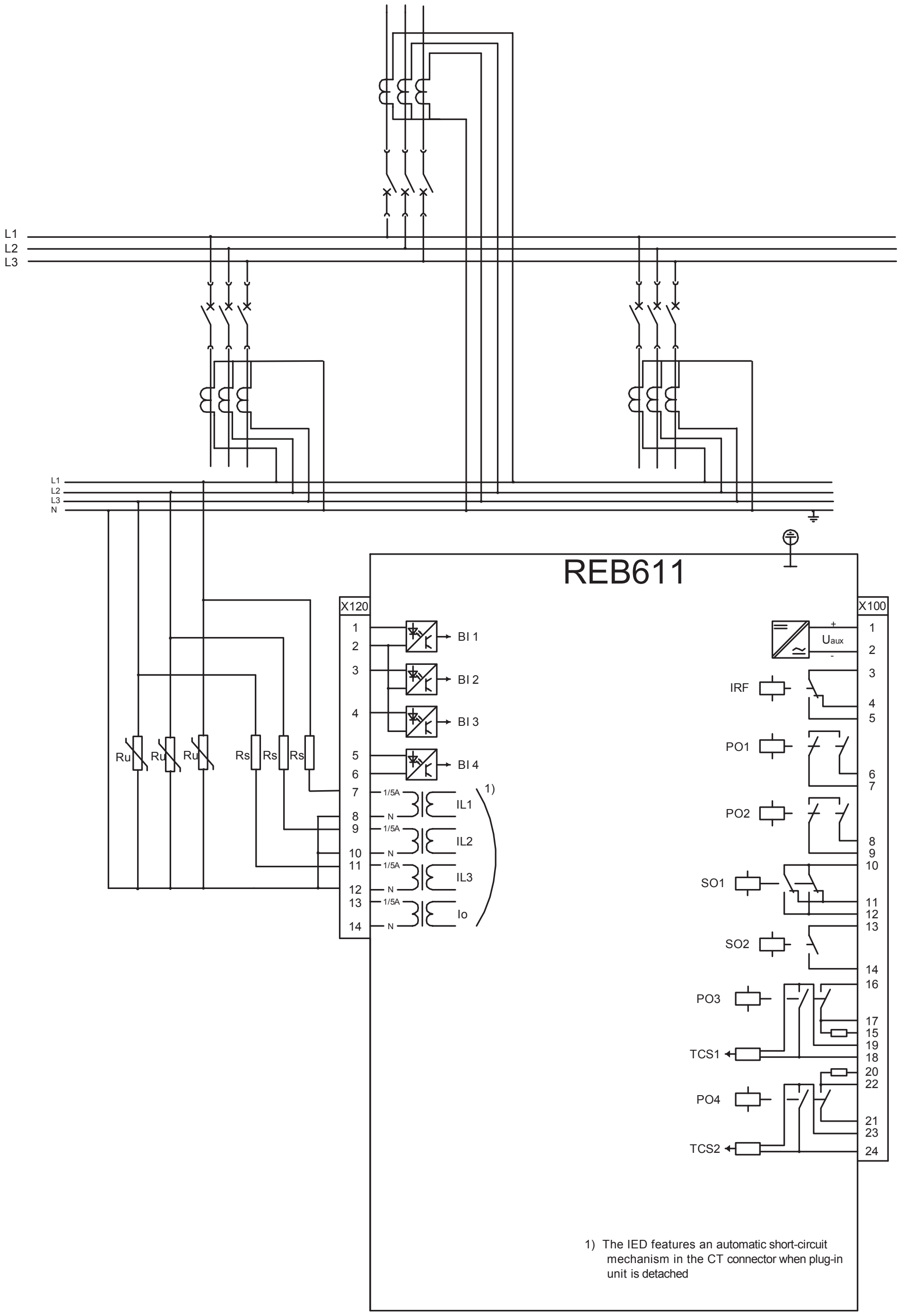

Figure 12: Connection diagram for configuration A when used as busbar differential protection

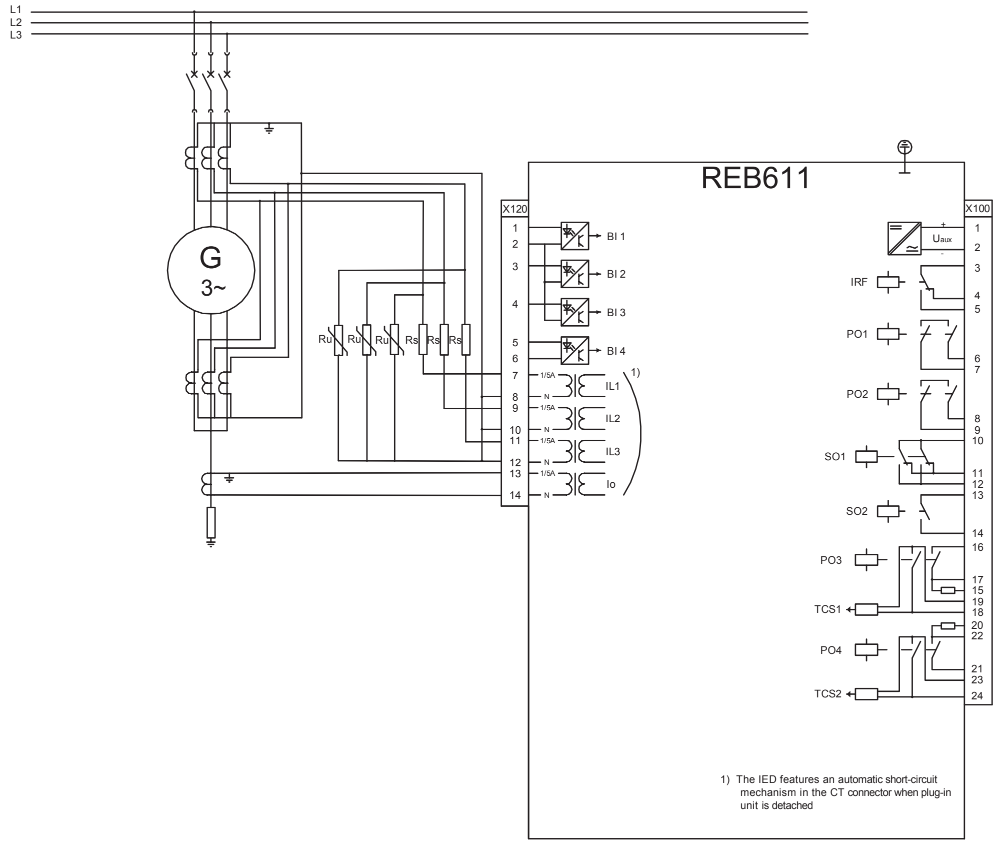

Figure 13: Connection diagram for configuration A when used as rotating machine phase differential protection

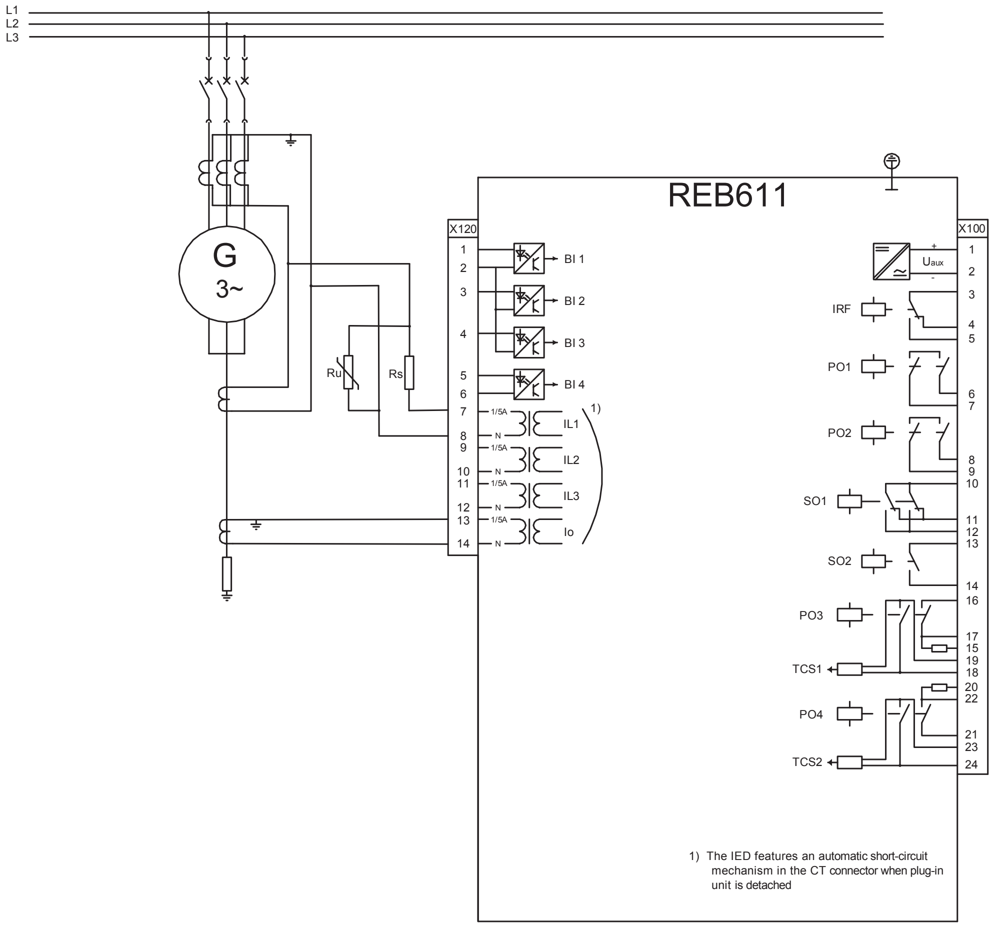

Figure 14: Connection diagram for configuration A when used as rotating machine restricted earth-fault protection

3.4 Configuration A

3.4.1 Applications

Configuration A for phase-segregated high-impedance differential protection and non-directional earth-fault protection is mainly intended for use in high-impedance-based applications within utility substations and industrial power systems. In addition, the protection relay can also be used in restricted earth-fault and residual earth-fault applications for the protection of generators, motors, transformers and reactors.

The protection relay with a standardized configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the protection relay enables this configuration to be further adapted to different primary circuit layouts and the related functionality needs by modifying the internal functionality using PCM600.

Breaker control CBXCBR and breaker failure protection CCBRBRF are always associated with one set of phase current inputs. In REB611, the current inputs are phase differential currents, that is, a vector-sum of all phase feeder currents that flow in or out of the same bus. The bus differential current is not a feeder phase current and is normally zero. If a bus fault occurs and any phase differential protection picks up, all breakers that connect to the bus should be tripped.

As there is only one set of breaker control and breaker failure protection, and multiple breakers are associated with the bus protection especially when multiple source feeders are connected to the bus, these functions must be dealt with application-specifically.

Since the differential current cannot simply reflect any source breaker, the breaker control and breaker failure protection should be turned off.

3.4.2 Functions

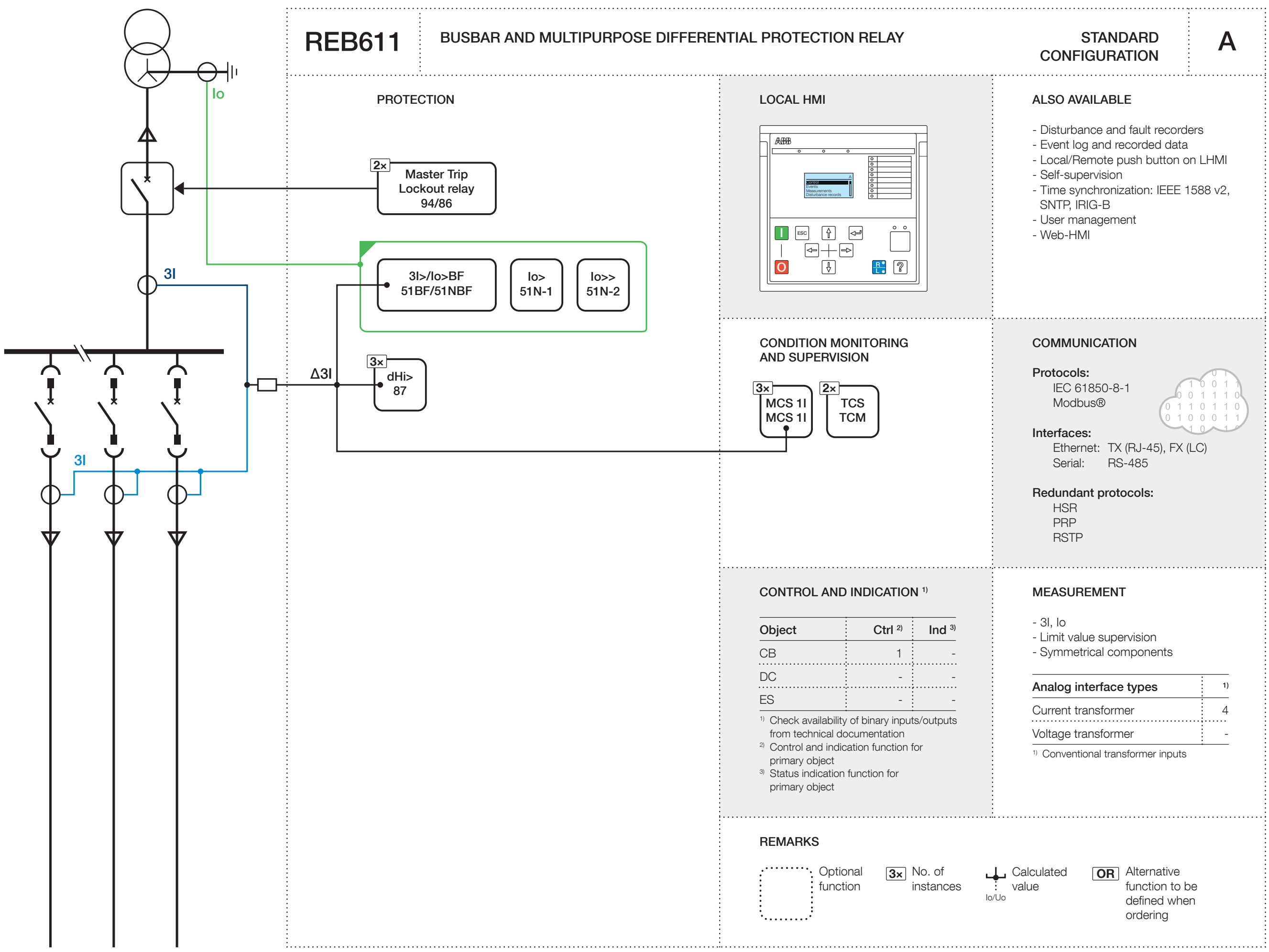

Figure 15: Functionality overview for configuration A

3.4.2.1 Default I/O connections

Table 11: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	-	X120:1-2
X120-BI2	Circuit breaker closed position indication	X120:3,2
X120-BI3	Circuit breaker open position indication	X120:4,2
X120-BI4	Circuit breaker close enable status	X120:5-6

Table 12: Default connections for binary outputs

Binary input	Description	Connector pins
X100-PO1	Close circuit breaker	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-PO3	Open circuit breaker/trip coil 1	X100:15-19
X100-PO4	Open trip coil 2	X100:20-24
X100-SO1	General start indication	X100:10-12
X100-SO2	General operate indication	X100:13-15

Table 13: Default connections for LEDs

LED	Description
1	High-impedance differential protection stage 1 operate
2	High-impedance differential protection stage 2 operate
3	High-impedance differential protection stage 3 operate
4	High-impedance differential protection start
5	Dedicated phase-segregated supervision function alarm
6	Disturbance recorder triggered
7	Trip circuit supervision alarm
8	Circuit-breaker failure operate

3.4.2.2 Predefined disturbance recorder connections

Table 14: Predefined analog channel setup

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io

Additionally, all the digital inputs that are connected by default are also enabled with the setting. Default triggering settings are selected depending on the connected input signal type. Typically all protection START signals are selected to trigger the disturbance recorded by default.

3.4.3 Functional diagrams

The functional diagrams describe the default input, output, programmable LED, switch group and function-to-function connections. The default connections can be viewed and changed with switch groups in PCM600, LHMI and WHMI according to the application requirements.

The analog channels have fixed connections towards the different function blocks inside the protection relay’s configuration. Exceptions from this rule are the four analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder’s parameter settings.

3.4.3.1 Functional diagrams for protection

The functional diagrams describe the protection functionality of the protection relay in detail and picture the factory default connections.

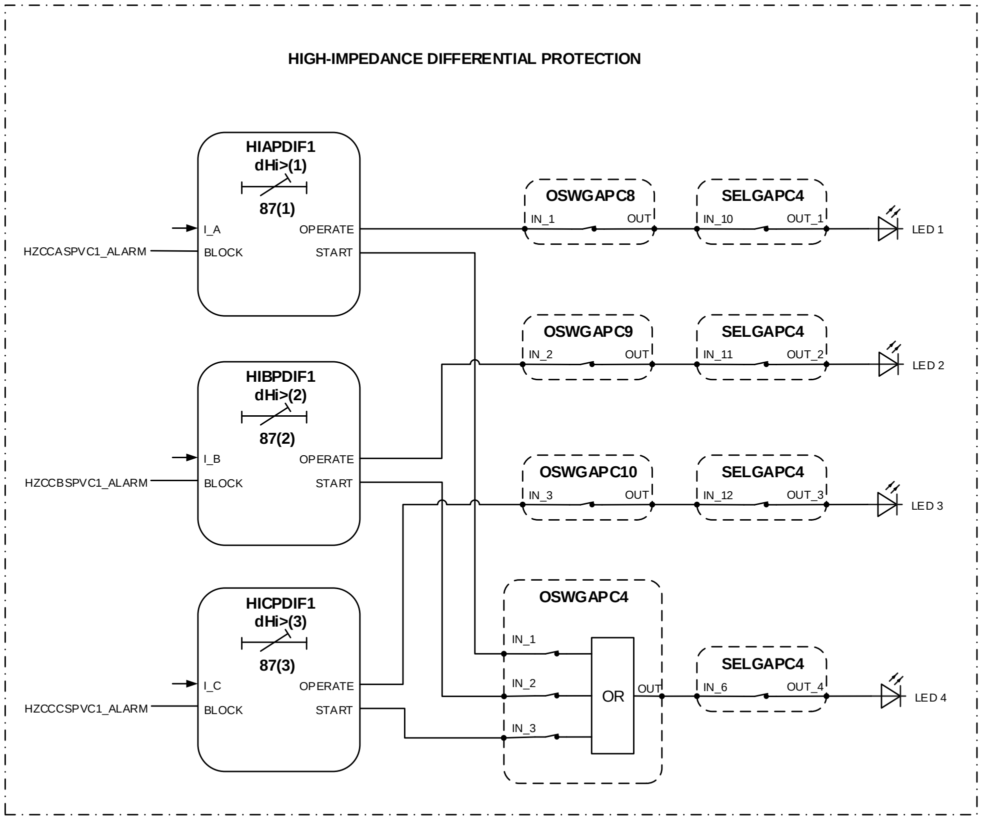

Figure 16: High-impedance differential protection

Three high-impedance differential protection instances are offered. By default, HIAPDIF1 is for phase A current channel, HIBPDIF1 is for phase B current channel, and HICPDIF1 is for phase C current channel. The `ALARM` outputs of the phase-segregated current transformer supervision HZCCxSPVC block HIxPDIF.

HIAPDIF1 operate signal is connected to LED 1, HIBPDIF1 operate signal is connected to LED 2, HICPDIF1 operate signal is connected to LED 3. All the start signals from HIAPDIF1, HIBPDIF1 and HICPDIF1 are connected to LED 4.

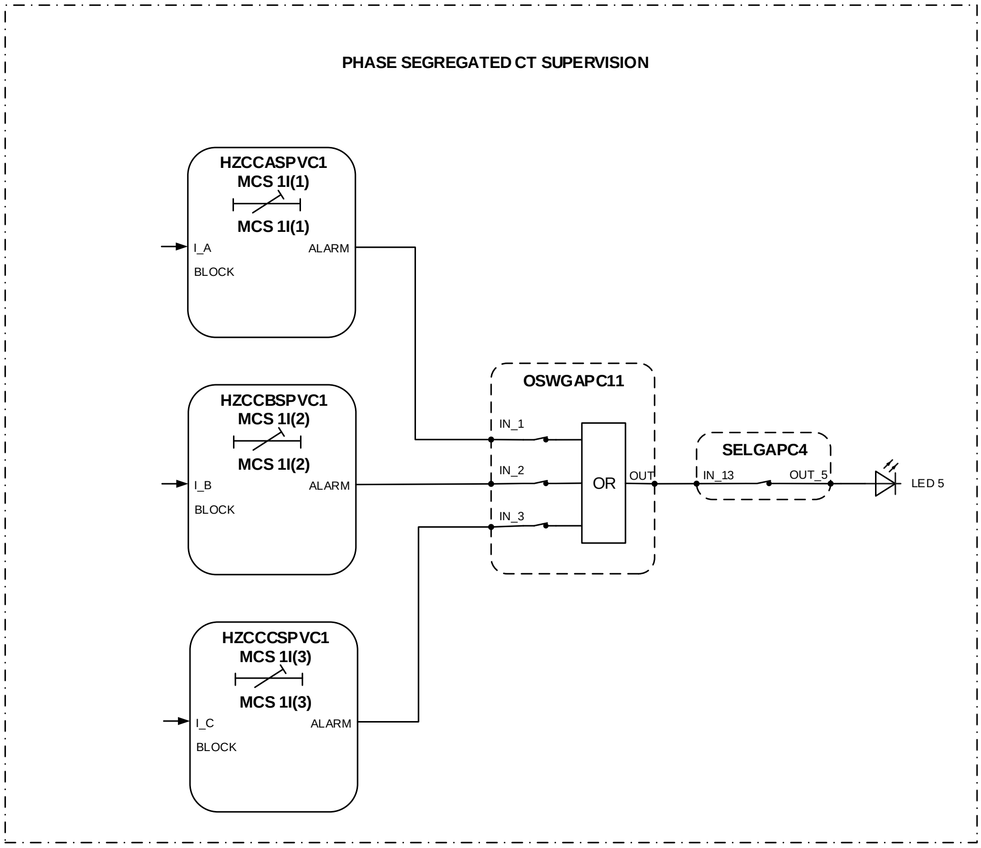

Figure 17: Phase segregated CT supervision

Three phase-segregated current transformer supervision instances are offered. By default, HZCCASPVC1 is for phase A current channel, HZCCBSPVC1 is for phase B current channel, and HZCCCSPVC1 is for phase C current channel.

All the `ALARM` output signals are connected to LED 5.

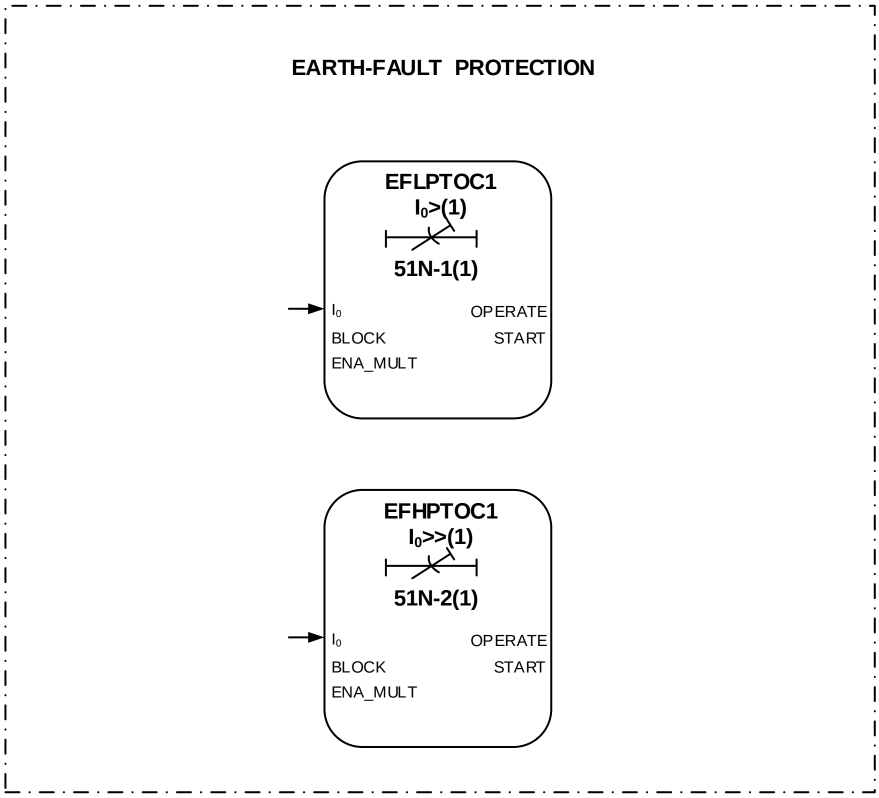

Figure 18: Earth-fault protection

Two stages are offered for non-directional earth-fault protection. The operate signals of the earth-fault protections are connected to the Master Trip.

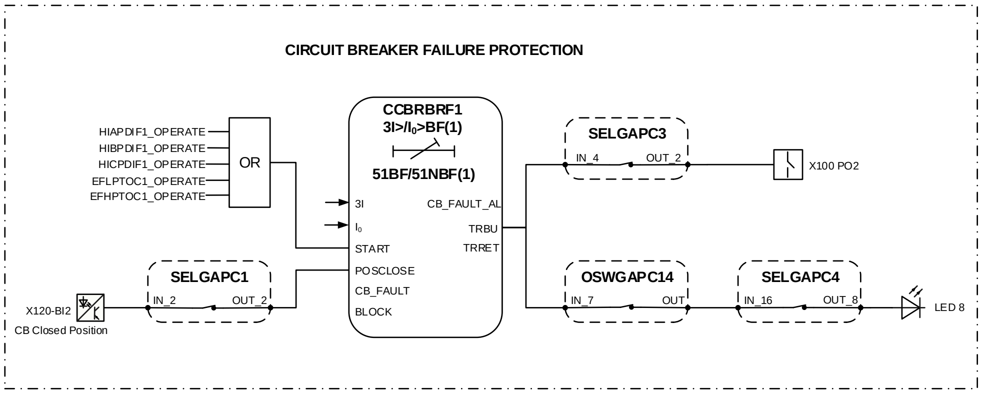

Figure 19: Circuit breaker failure protection

The circuit-breaker failure protection CCBRBRF1 is initiated via the start input by a number of different protection stages in the protection relay. CCBRBRF1 offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. CCBRBRF1 has two operating outputs: `TRRET` and `TRBU`. The `TRRET` operate output is used for retripping its own circuit breaker through Master Trip 2. The `TRBU` output is used to give a backup trip to the circuit-breaker feeding upstream. For this purpose, the TRBU operate output signal is connected to the output PO2 (X100:8-9). LED 8 is used for backup (TRBU) operate indication.

3.4.3.2 Functional diagrams for disturbance recorder

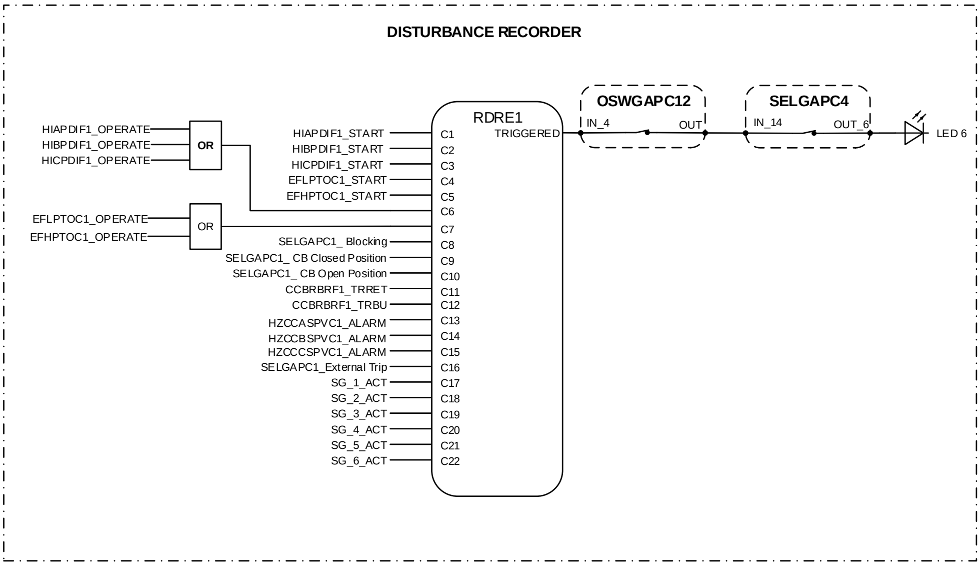

Figure 20: Disturbance recorder

All start and operate signals from the protection stages are routed to trigger the disturbance recorder or alternatively only to be recorded by the disturbance recorder depending on the parameter settings. Additionally, the selected autoreclosing output signals and the three binary inputs from X120 are also connected. The active setting group is also to be recorded via SG_1_ACT to SG_6_ACT. The disturbance recorder triggered signal indication is connected to LED 6.

Table 15: Disturbance recorder binary channel default value

Channel number	Channel id text	Level trigger mode
Binary channel 1	HIAPDIF1_START	1=positive or rising
Binary channel 2	HIBPDIF1_START	1=positive or rising
Binary channel 3	HICPDIF1_START	1=positive or rising
Binary channel 4	EFLPTOC1_START	1=positive or rising
Binary channel 5	EFHPTOC1_START	1=positive or rising
Binary channel 6	HIxPDIF1_OPERATE	4=level trigger off
Binary channel 7	EFxPTOC1_OPERATE	4=level trigger off
Binary channel 8	SELGAPC1_Blocking	4=level trigger off
Binary channel 9	SELGAPC1_CB_Closed	4=level trigger off
Binary channel 10	SELGAPC1_CB_Open	4=level trigger off
Binary channel 11	CCBRBRF1_TRRET	4=level trigger off

Table continues on next page

Channel number	Channel id text	Level trigger mode
Binary channel 12	CCBRBRF1_TRBU	4=level trigger off
Binary channel 13	HZCCASPVC1_ALARM	1=positive or rising
Binary channel 14	HZCCBSPVC1_ALARM	1=positive or rising
Binary channel 15	HZCCCSPVC1_ALARM	1=positive or rising
Binary channel 16	SELGAPC1_External Trip	4=level trigger off
Binary channel 17	SG_1_ACT	4=level trigger off
Binary channel 18	SG_2_ACT	4=level trigger off
Binary channel 19	SG_3_ACT	4=level trigger off
Binary channel 20	SG_4_ACT	4=level trigger off
Binary channel 21	SG_5_ACT	4=level trigger off
Binary channel 22	SG_6_ACT	4=level trigger off

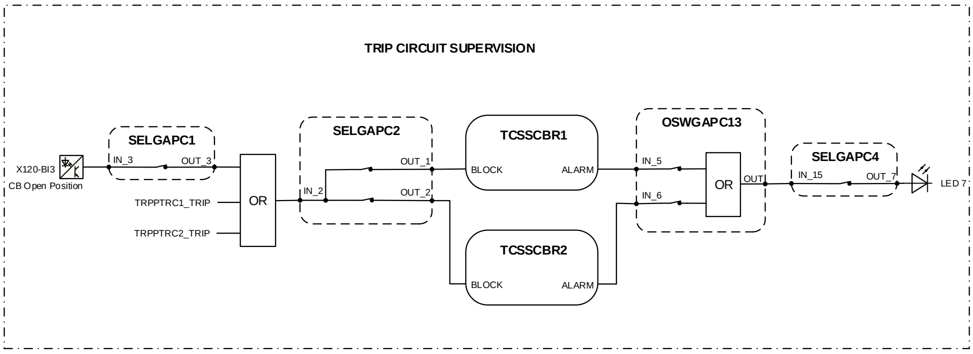

Figure 21: Trip circuit supervision

Two separate trip circuit supervision functions are included, TCSSCBR1 for PO3 (X100:15-19) and TCSSCBR2 for PO4 (X100:20-24). Both functions are blocked by the master trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open position. The TCS alarm indication is connected to LED 7.

3.4.3.3 Functional diagrams for control and interlocking

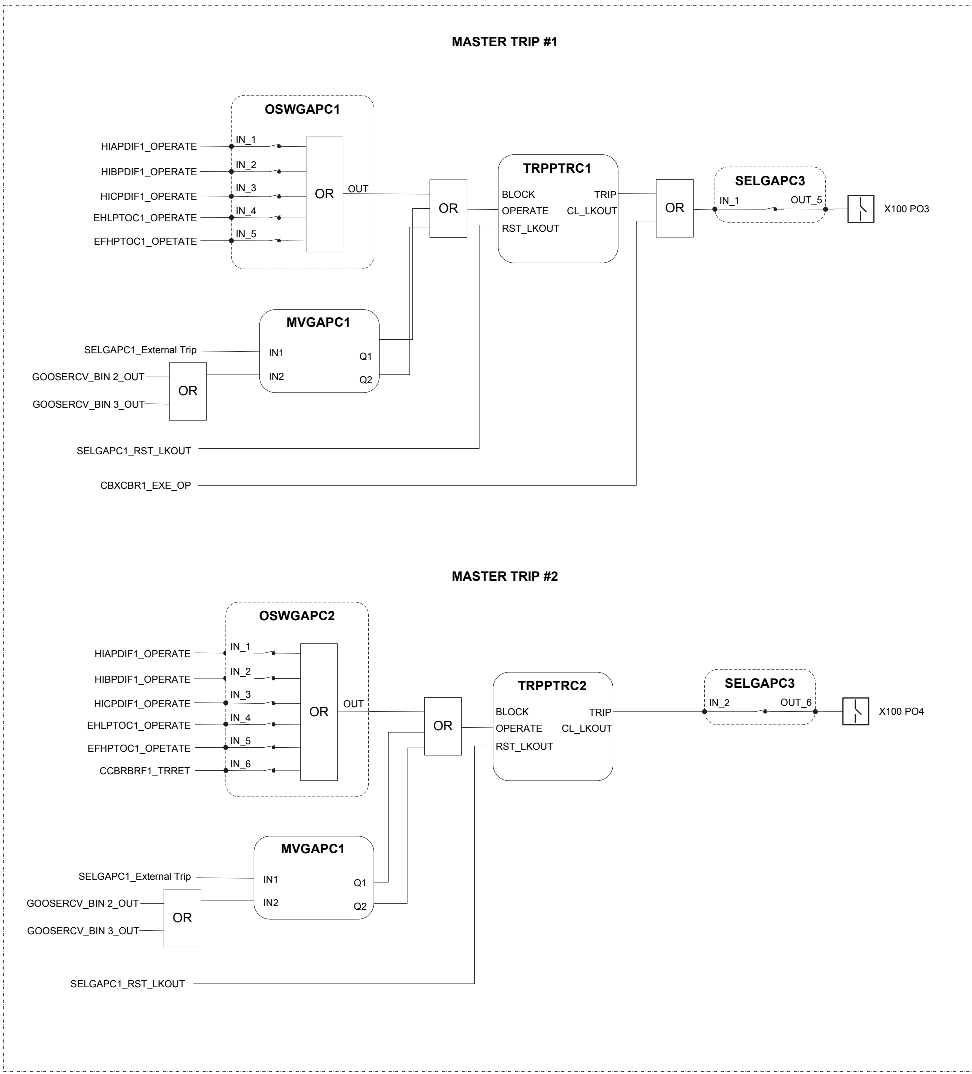

Figure 22: Master trip

The operate signals from the protections and an external trip are connected to the two trip output contacts PO3 (X100:15-19) and PO4 (X100:20-24) via the corresponding master trips TRPPTRC1 and TRPPTRC2. Open control commands to the circuit breaker from local or remote CBXCBR1_EXE_OP or from the autoreclosing DARREC1_OPEN_CB are connected directly to the output contact PO3 (X100:15-19).

TRPPTRC1 and TRPPTRC2 provide the lockout/latching function, event generation and the trip signal duration setting. One binary input through SELGAPC1 can be connected to the `RST_LKOUT` input of master trip. If the lockout operation mode is selected, it is used to enable external reset.

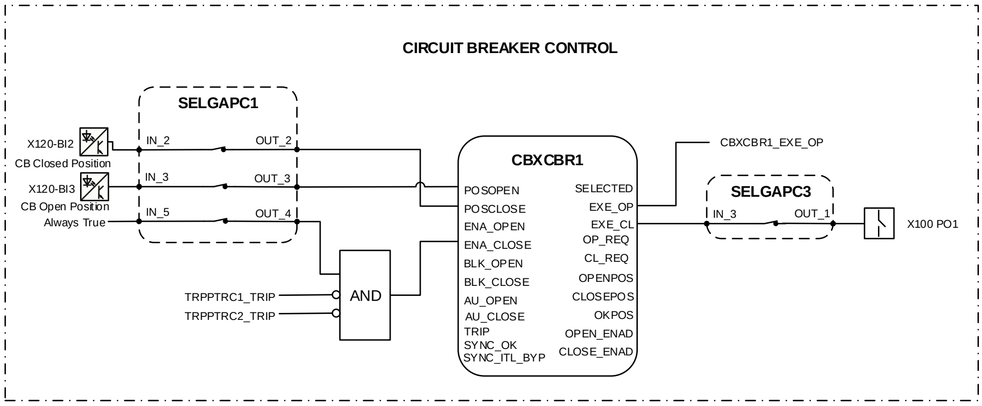

Figure 23: Circuit breaker control

The `ENA_CLOSE` input, which enables the closing of the circuit breaker, is interlocked by two master trip signals. Any one trip will block the breaker from closing. An always true signal is also connected to `ENA_CLOSE` via SELGAPC1 by default. The open operation is always enabled.

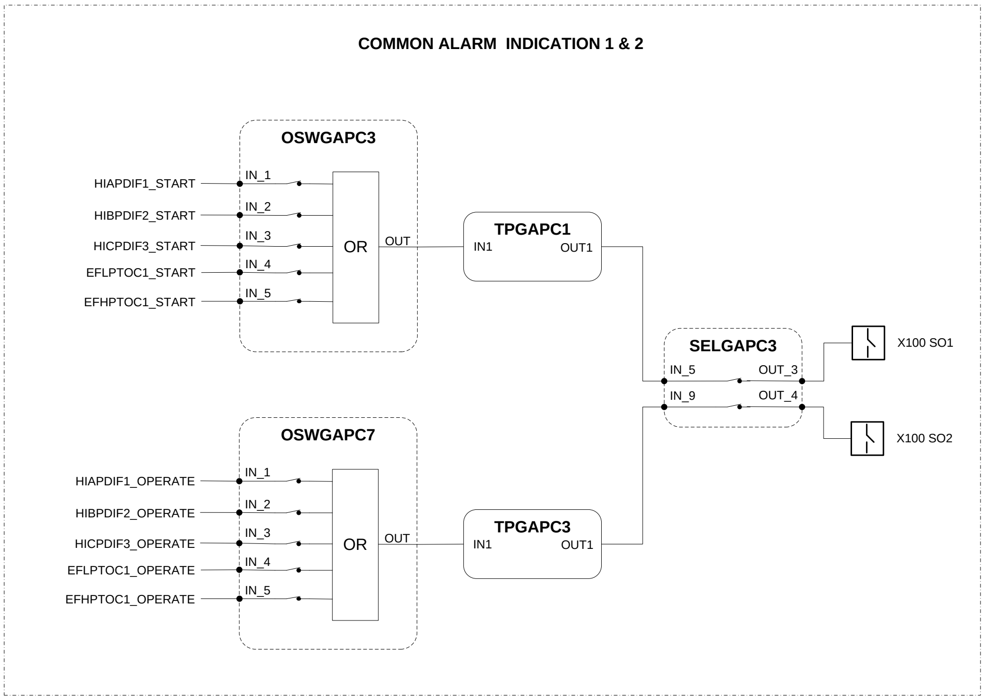

Figure 24: Common alarm indication

The signal outputs from the protection relay are connected to give dedicated information.

- Start of any protection function SO1 (X100:10-12)
- Operation (trip) of any protection function SO2 (X100:13-15)

TPGAPC are timers and used for setting the minimum pulse length for the outputs. There are seven generic timers (TPGAPC1…7) available in the protection relay.

3.4.4 Switch groups

In configuration A, the switch group function blocks are organized in four groups: binary inputs, internal signal, GOOSE as well as binary outputs and LEDs.

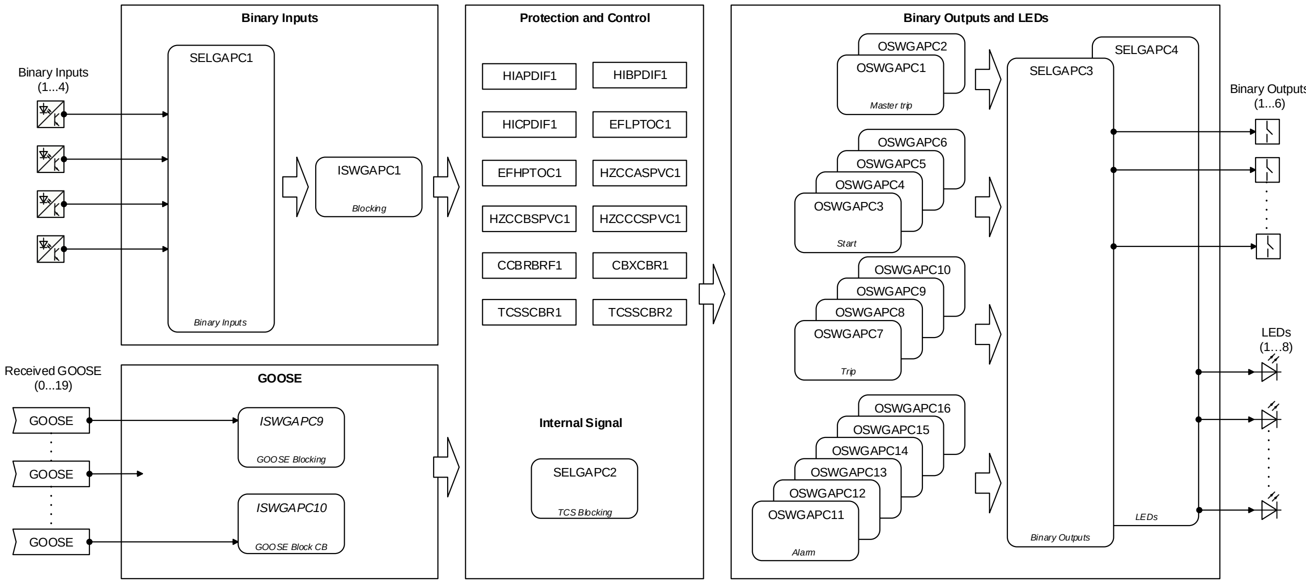

Figure 25: Configuration A switch group overview

3.4.4.1 Binary inputs

The binary inputs group includes one SELGAPC and one ISWGAPC. SELGAPC1 is used to route binary inputs to ISWGAPC or directly to protection relay functions. ISWGAPC1 is used to configure the signal to block the protection functions.

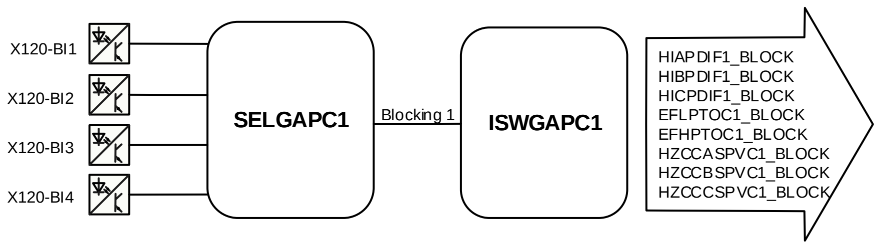

Figure 26: Binary inputs

SELGAPC1

SELGAPC1 has inputs from protection relay binary inputs. `IN_1` to `IN_4` are binary inputs from X120. An always true signal is connected to `IN_5`. SELGAPC1 outputs are used to route inputs to different functions. By setting SELGAPC1, binary inputs can be configured for different purposes.

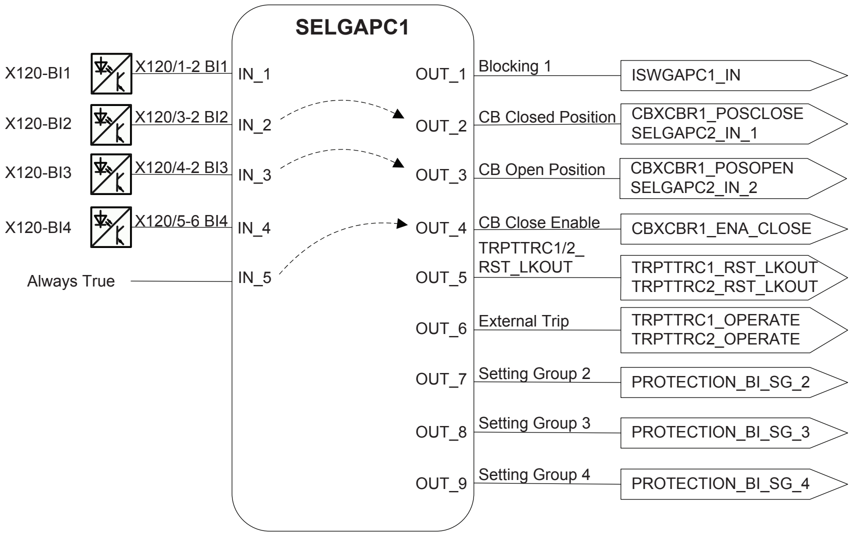

Figure 27: SELGAPC1

ISWGAPC1

ISWGAPC1 is used to select which protection functions are to be blocked by changing ISWGAPC1 parameters. ISWGAPC1 input is routed from SELGAPC1 output `OUT_1 Blocking 1`. ISWGAPC1 outputs are connected to the `BLOCK` inputs of the protection functions.

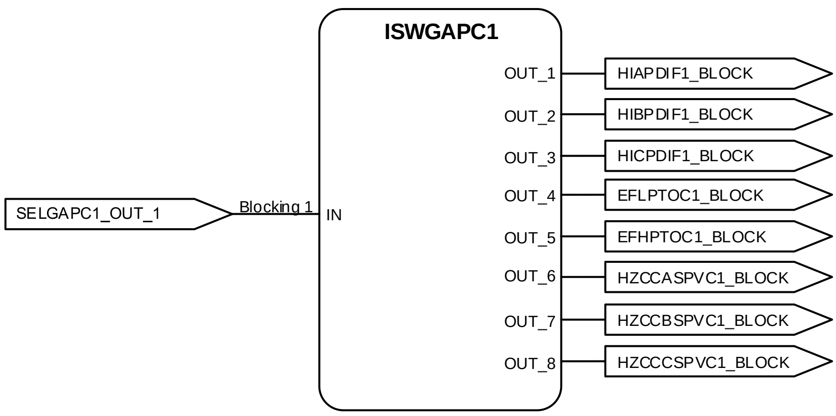

Figure 28: ISWGAPC1

3.4.4.2 Internal signal

The internal signal group is used to configure the logic connections between function blocks. There is one SELGAPC in this group.

SELGAPC2 is used to configure trip circuit supervision blocking from the circuit breaker open or close position.

Figure 29: Internal signal

SELGAPC2

SELGAPC2 inputs are circuit breaker closed and open positions from SELGACP1. SELGAPC2 outputs are routed to the `BLOCK` input of the trip circuit supervision TCSSCBR1 and TCSSCBR2.

By default, X100-PO3 and PO4 are both used for the open circuit breaker. TCSSCBR1 and TCSSCBR2 are both blocked by the circuit breaker open position. If X100-PO3 is used for closing the circuit breaker, TCSSCBR1 needs to be blocked by the circuit breaker close position (`OUT_1` connection=`IN_1`). If X100-PO4 is used for closing the circuit breaker, TCSSCBR2 needs to be blocked by the circuit breaker close position (`OUT_2` connection=`IN_1`).

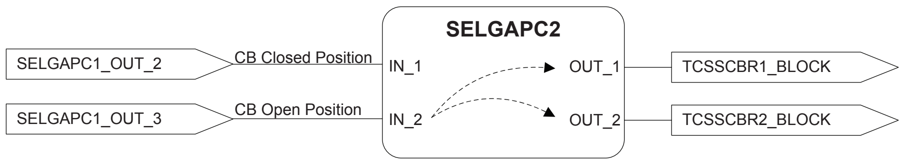

Figure 30: SELGAPC2

3.4.4.3 Binary outputs and LEDs

In configuration A, the signals route to binary outputs and LEDs are configured by OSWGAPCs. There are totally 15 OSWGAPC instances. They can be categorized to four groups, including one master trip, four start, four trip and six alarm signals. The OSWGAPC output is connected to binary outputs and LEDs via SELGAPC3 and SELGAPC4.

- SELGAPC3 is used to configure OSWGAPC signals to protection relay binary outputs. SELGAPC4 is used to configure OSWGAPC signals to LEDs.
- OSWGAPC1 is used for master trip. The inputs are the operate and re-trip signals from protection and breaker failure functions respectively.
- OSWGAPC2 is not in used.

- OSWGAPC3 to OSWGAPC6 are used for the start signal. The inputs are start signals from the protection functions.
- OSWGAPC7 to OSWGAPC10 are used for the trip signal. The inputs are operation signals from the protection functions.
- OSWGAPC11 to OSWGAPC16 are used for the alarm signal. The inputs are alarm signals from the protection and monitoring functions.

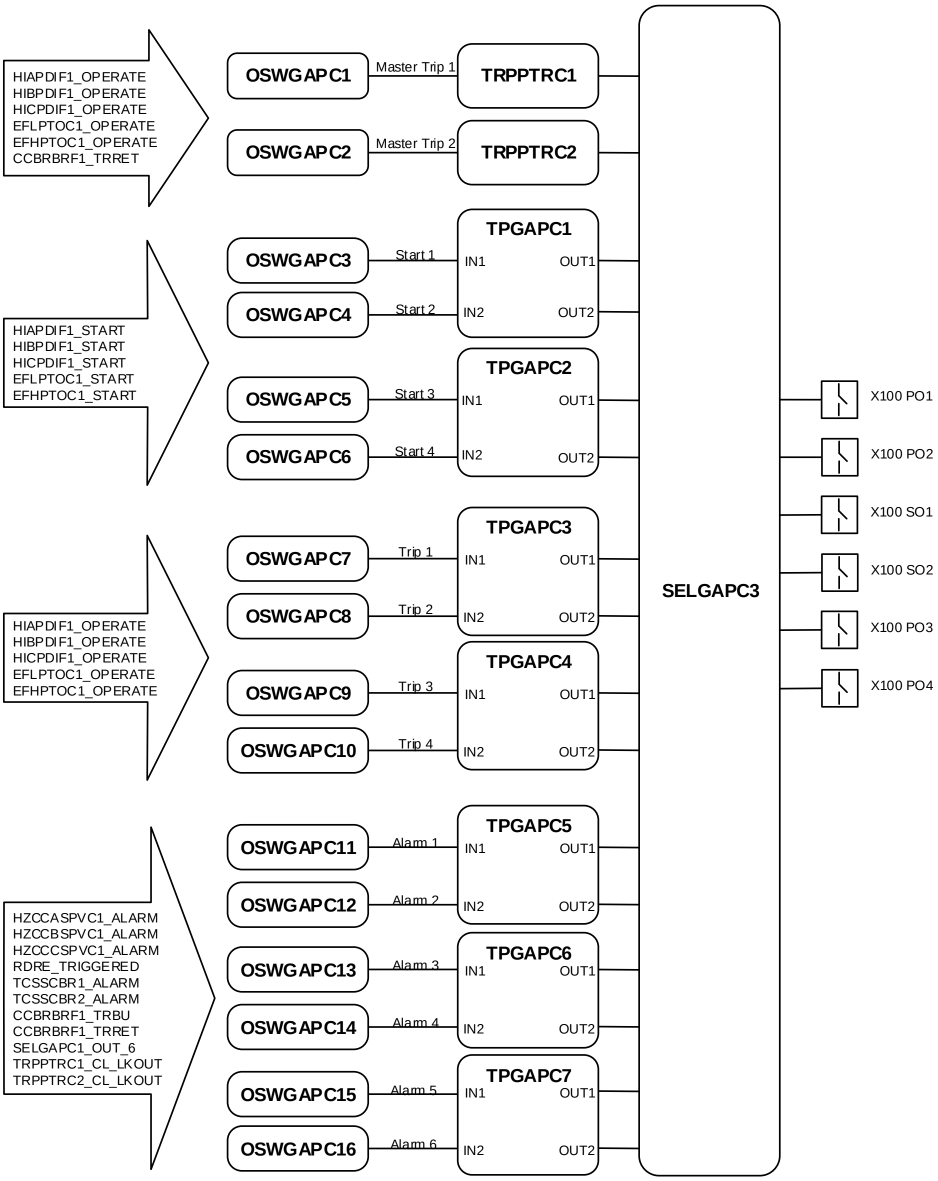

Figure 31: Binary outputs

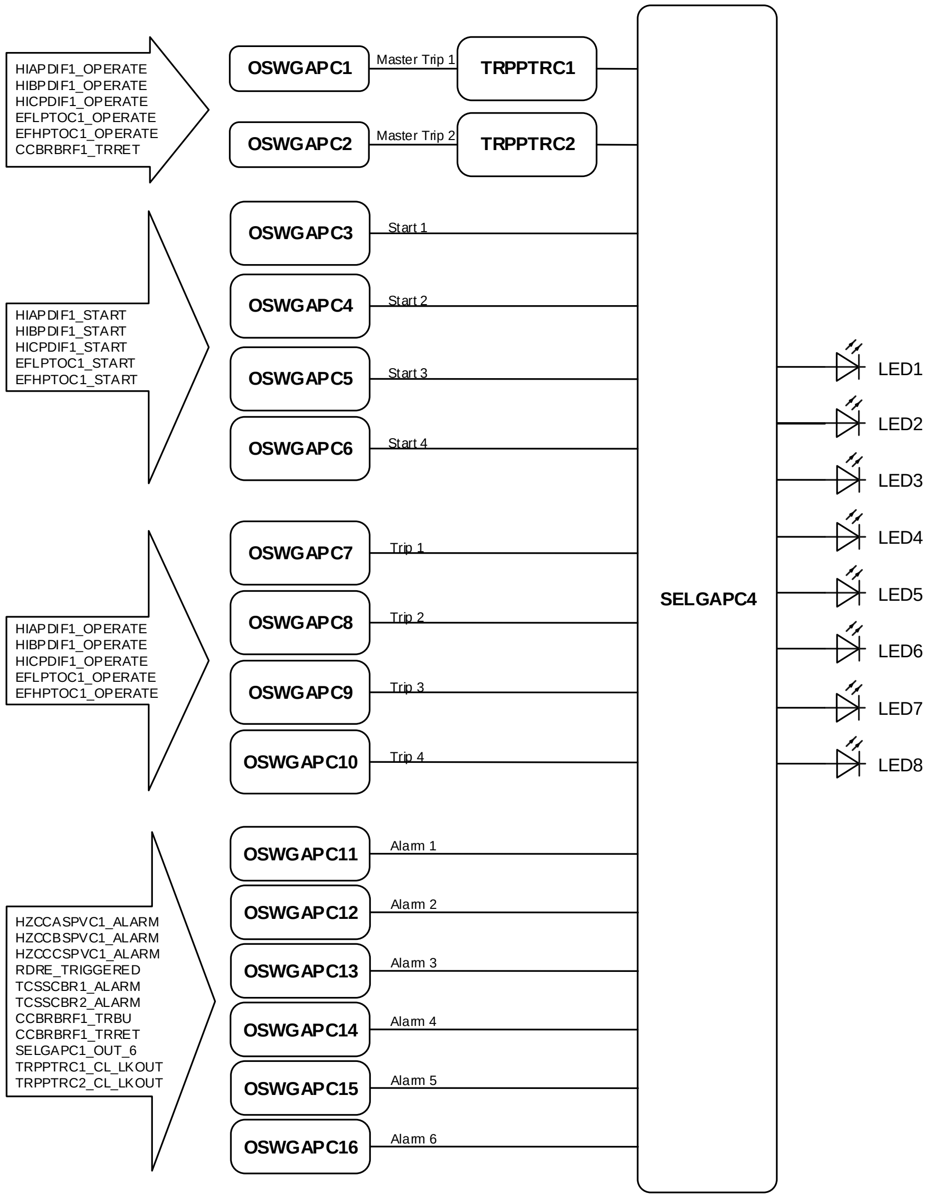

Figure 32: LEDs

SELGAPC3

SELGAPC3 is used to configure the OSWGAPC outputs to the protection relay binary outputs. The master trip signals are connected to SELGAPC3 via TRPPTRC. Start, trip and alarm signals are connected to SELGAPC3 via TPGAPC. TPGAPC are timers and used for setting the minimum pulse length for the outputs.

SELGAPC3 outputs are connected with X100 binary outputs.

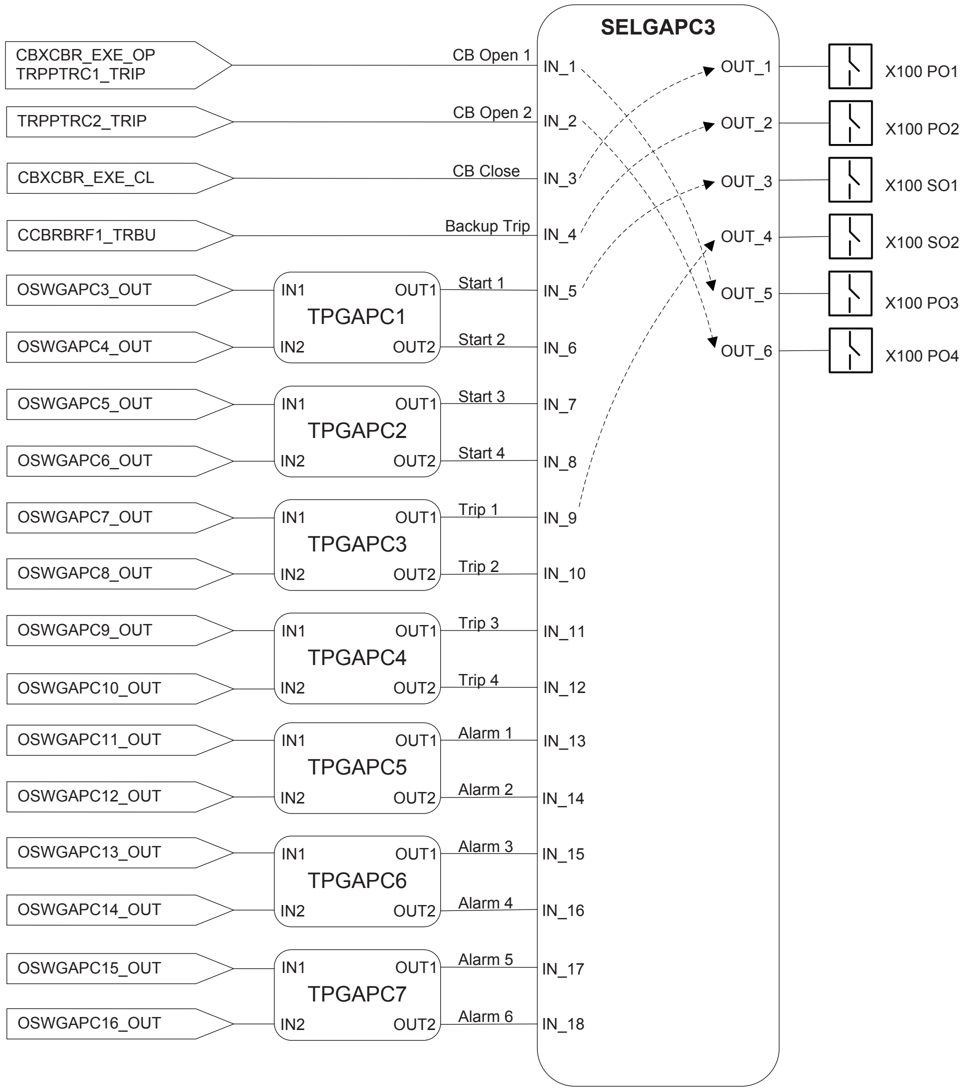

Figure 33: SELGAPC3

SELGAPC4

SELGAPC4 is used to configure the OSWGAPC outputs to LEDs. Master trip signals are connected to SELGAPC4 via TRPPTRC. Start, trip and alarm signals are connected to SELGAPC4 directly. SELGAPC4 outputs are connected to programmable LED1 to LED8.

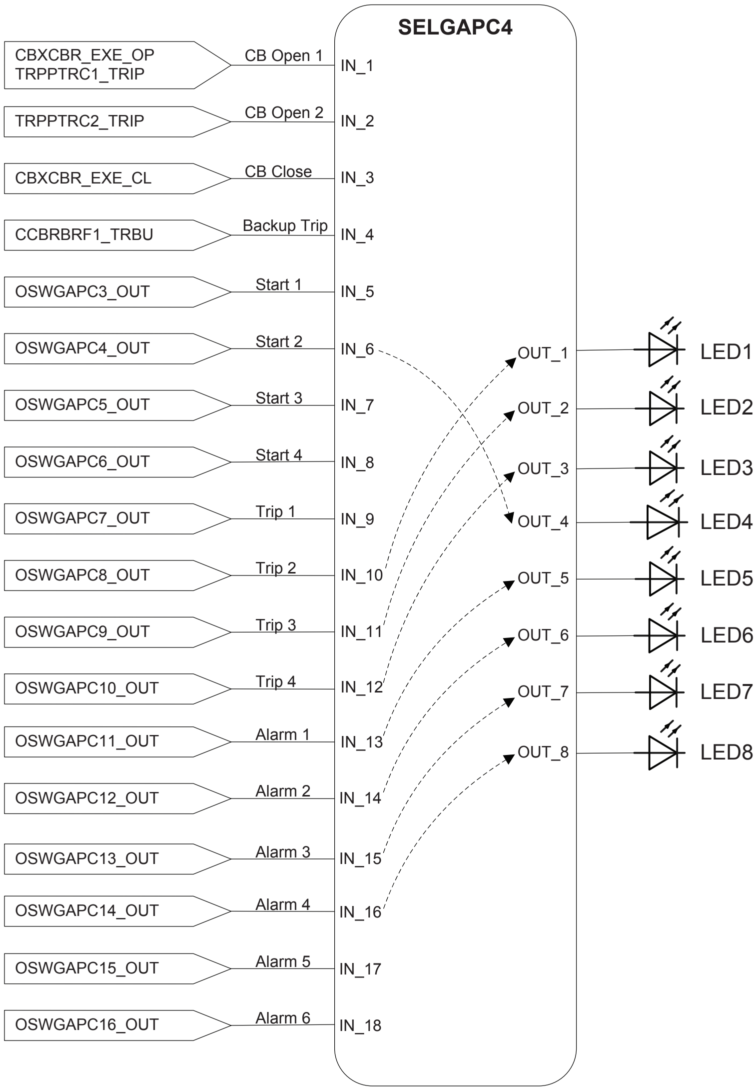

Figure 34: SELGAPC4

Master trip OSWGAPCs

OSWGAPC1 and OSWGAPC2 are used to route the protection function operate signals to master trip. OSWGAPC1 and OSWGAPC2 have the same inputs from the protection function operates. The output is connected to the TRPPTRC function. The default connections for OSWGAPC1 and OSWGAPC2 are different.

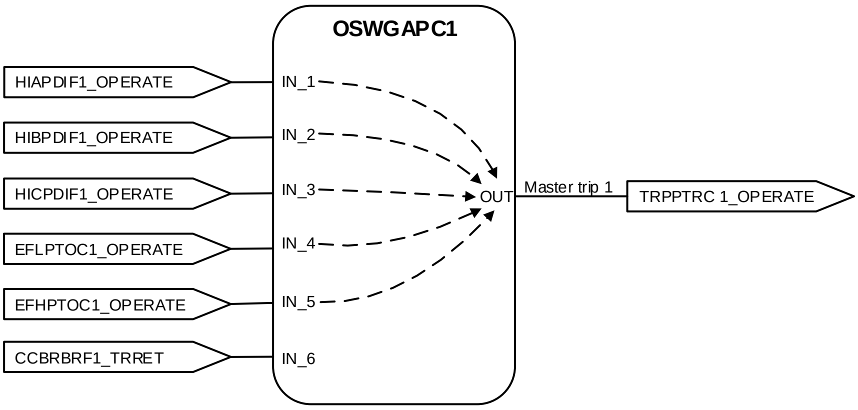

Figure 35: OSWGAPC1

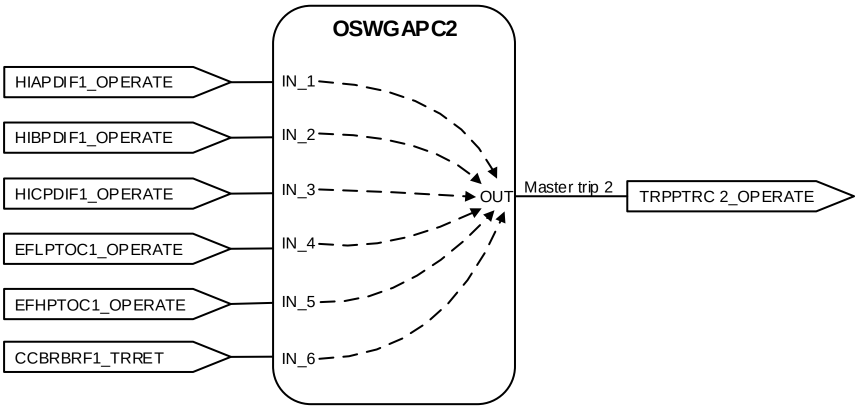

Figure 36: OSWGAPC2

Start OSWGAPCs

OSWGAPC instances 3...6 are used to configure the protection start signals. These four OSWGAPCs have the same inputs from the protection function start signals. The output is routed to SELGAPC3 via TPGAPC timer and to SELGAPC4 directly.

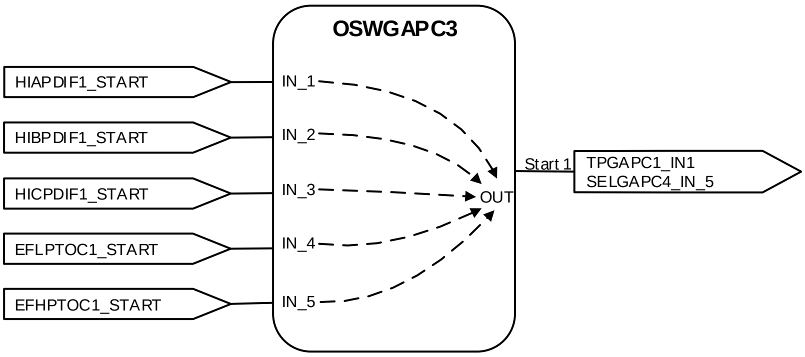

Figure 37: OSWGAPC3

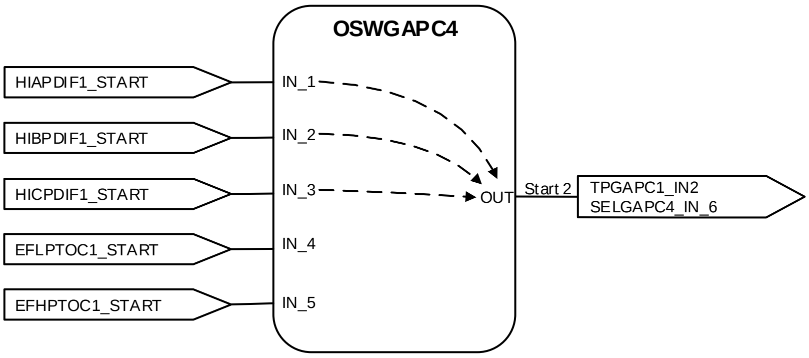

Figure 38: OSWGAPC4

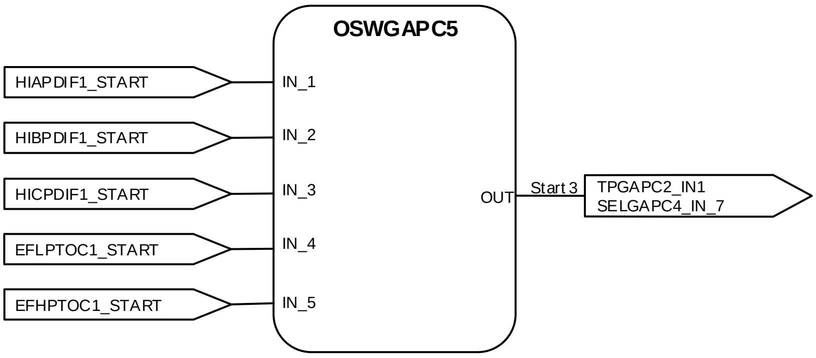

Figure 39: OSWGAPC5

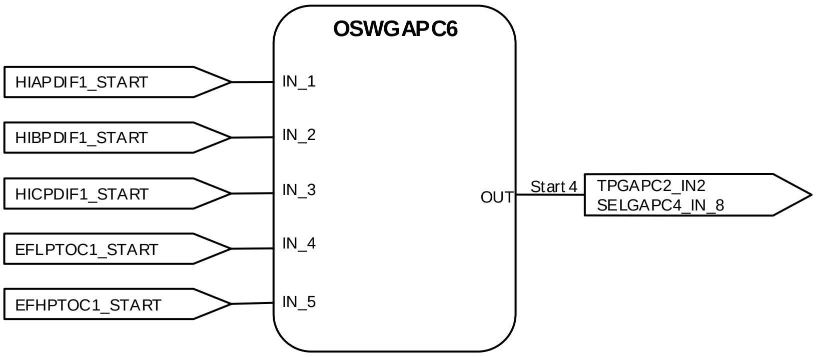

Figure 40: OSWGAPC6

Trip OSWGAPCs

OSWGAPC instances 7...10 are used to configure the protection operate signals that belong to the trip group. These four OSWGAPCs have the same inputs from the operate signals of the protection functions. The output is routed to SELGAPC3 via TPGAPC timer and to SELGAPC4 directly.

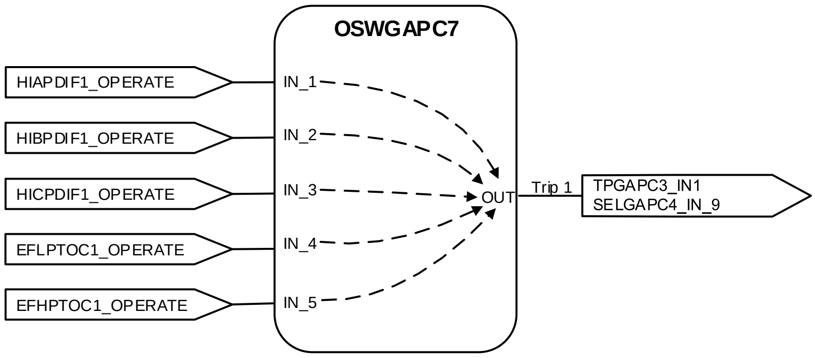

Figure 41: OSWGAPC7

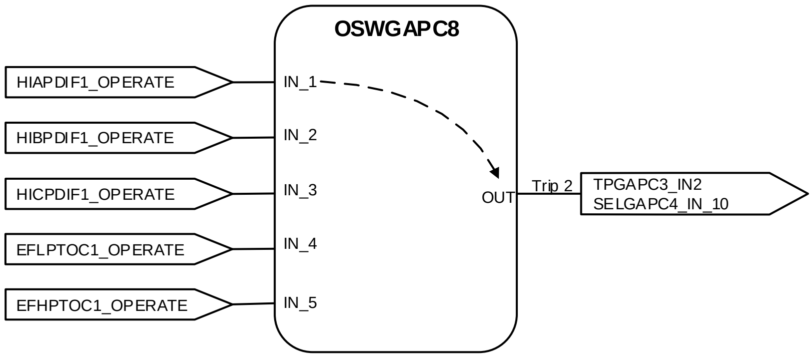

Figure 42: OSWGAPC8

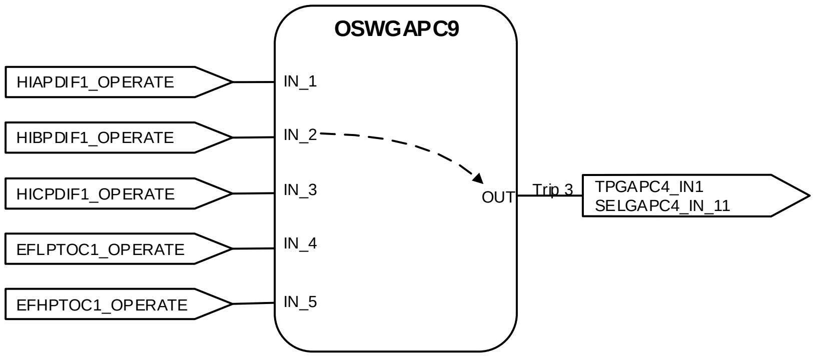

Figure 43: OSWGAPC9

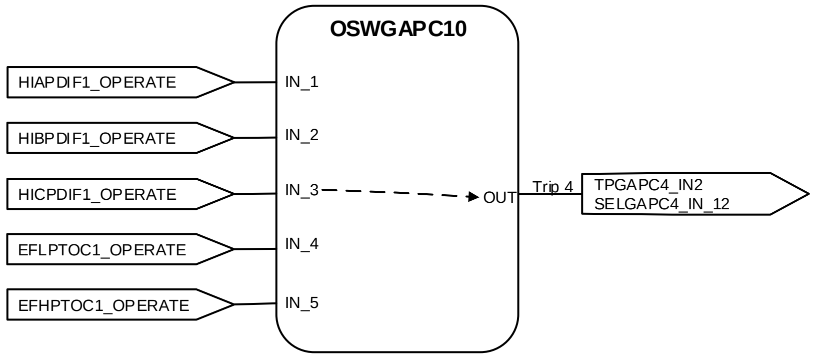

Figure 44: OSWGAPC10

Alarm OSWGAPCs

OSWGAPC instances 11...16 are used to configure the alarm signals that belong to the alarm group. These six OSWGAPCs have the same inputs from the alarm signals. The output is routed to SELGAPC3 via TPGAPC timer and to SELGAPC4 directly.

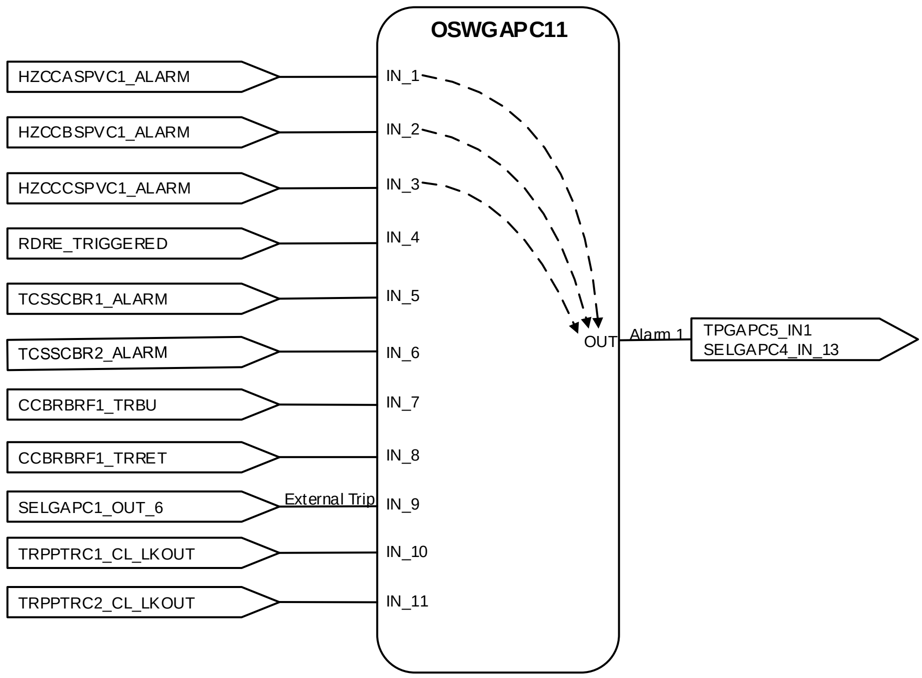

Figure 45: OSWGAPC11

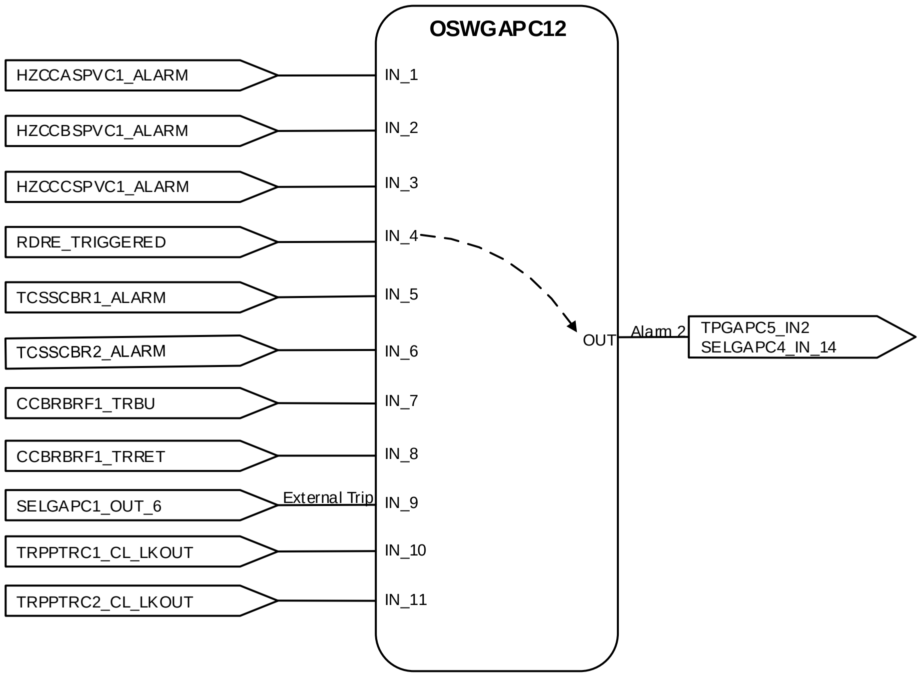

Figure 46: OSWGAPC12

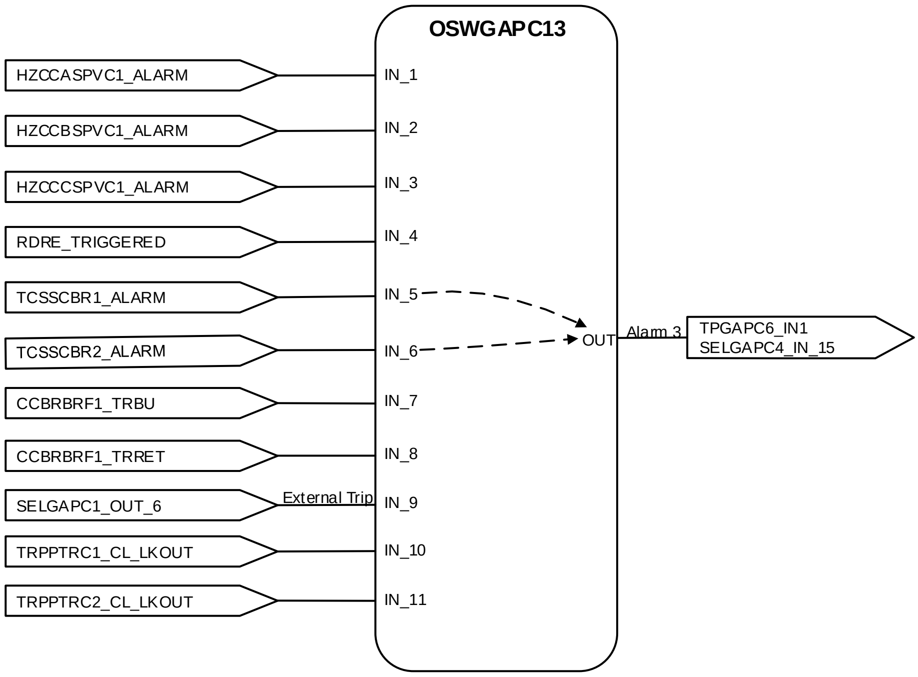

Figure 47: OSWGAPC13

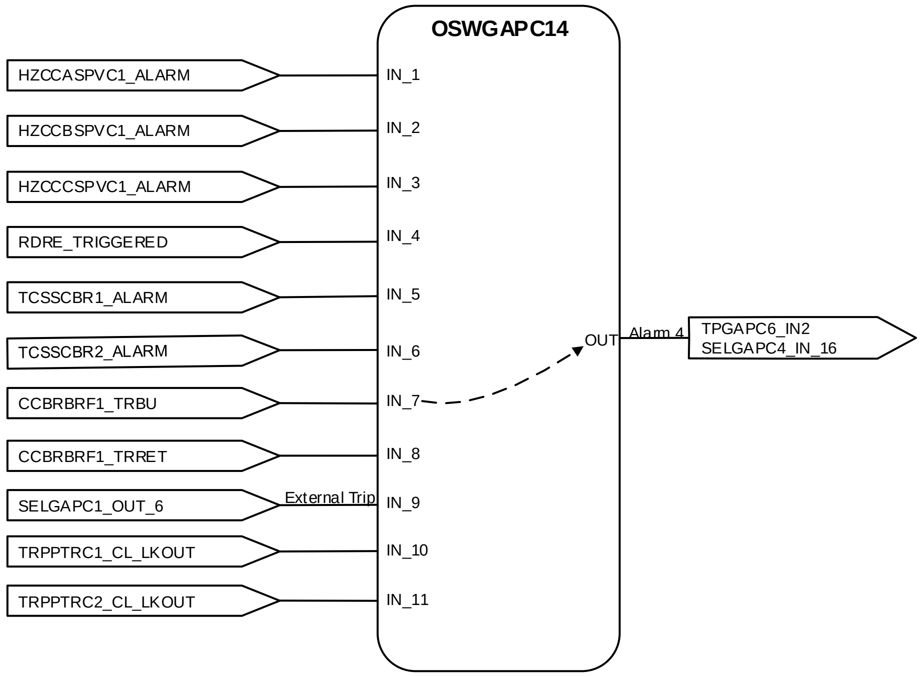

Figure 48: OSWGAPC14

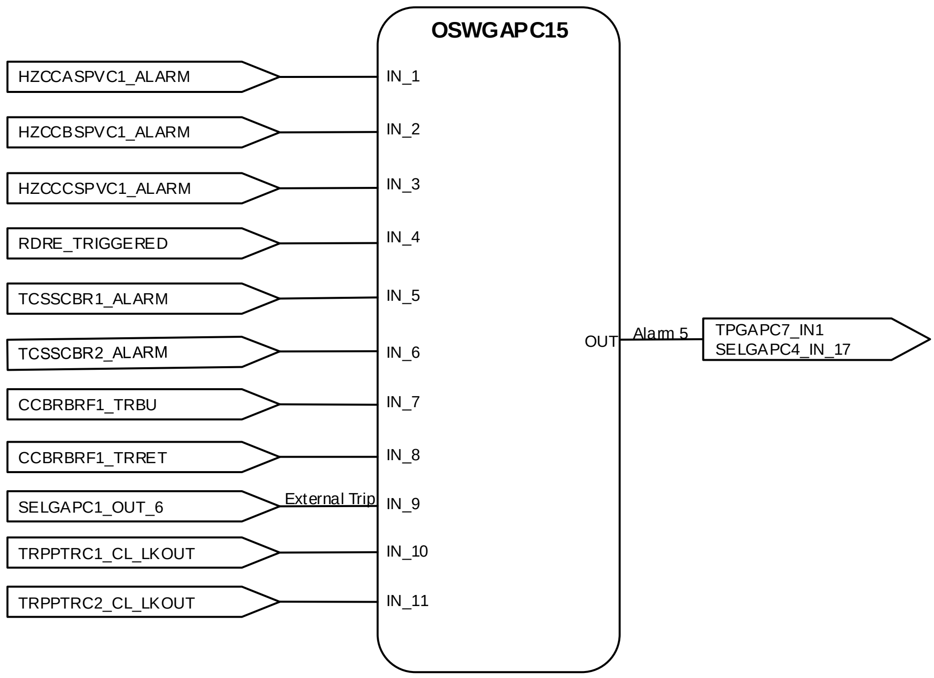

Figure 49: OSWGAPC15

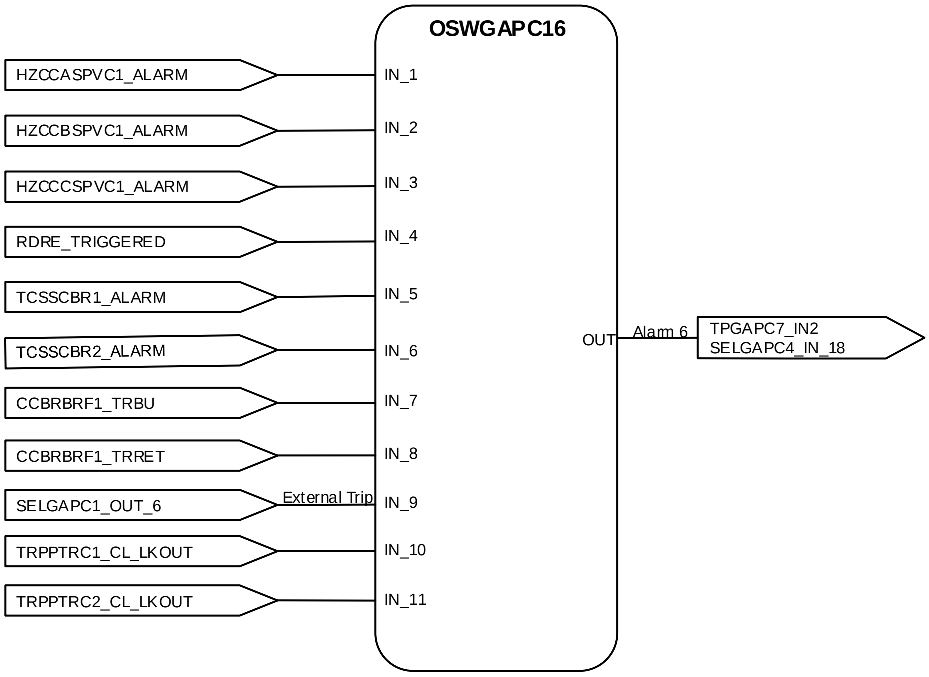

Figure 50: OSWGAPC16

3.4.4.4 GOOSE

In the configuration, there are 20 GOOSERCV_BIN functions. Each GOOSERVC_BIN function can be connected to one received binary GOOSE signal. The signal connection can be configured in PCM600.

- GOOSERCV_BIN instances 0 and 1 are used for blocking protection functions. Signals from these two GOOSERCV_BINs are connected to ISWGAPC9. ISWGAPC9 is used to configure which protection function block is blocked.
- GOOSERCV_BIN instances 2 and 3 are used for tripping from GOOSE. Signals from these two GOOSERCV_BINs are connected to TRPPTRC1 and TRPPTRC2 trip.
- GOOSERCV_BIN instances 4 to 19 are used for blocking the circuit breaker operation. Signals from these 16 GOOSERCV_BINs are connected to ISWGAPC10. ISWGAPC10 is used to configure the GOOSE input signal to block the circuit breaker open or close operation.

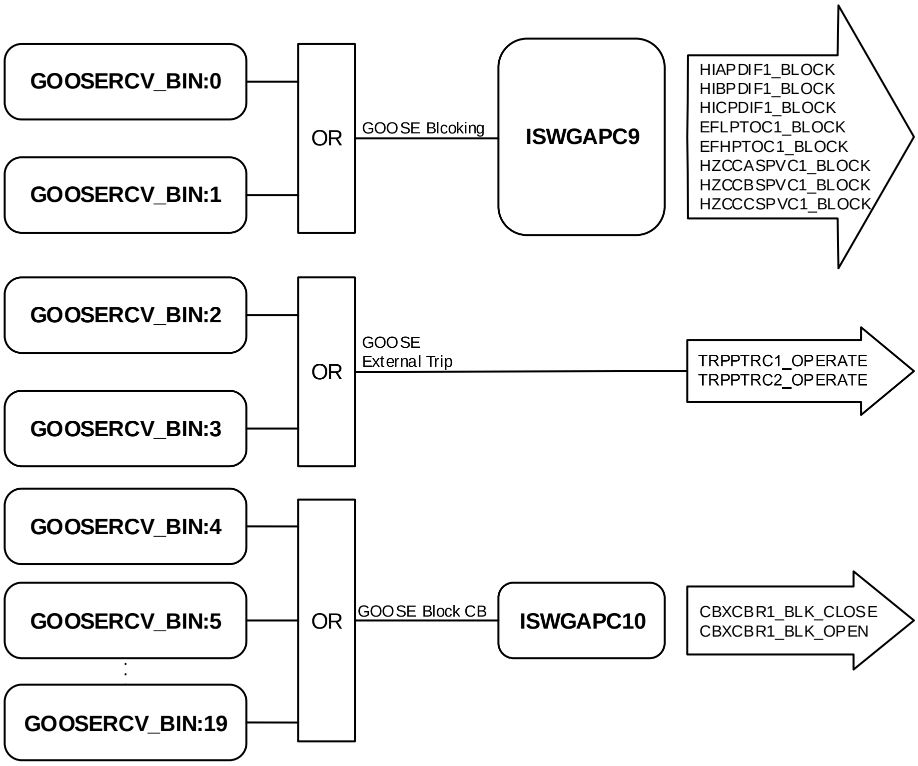

Figure 51: GOOSE overview

ISWGAPC9

ISWGAPC9 is used to configure which protection functions can be blocked by the received GOOSE signals. ISWGAPC9 inputs are received GOOSE signals from GOOSERCV_BIN:0 and GOOSERCV_BIN:1. The outputs are connected to the block inputs of the protection functions.

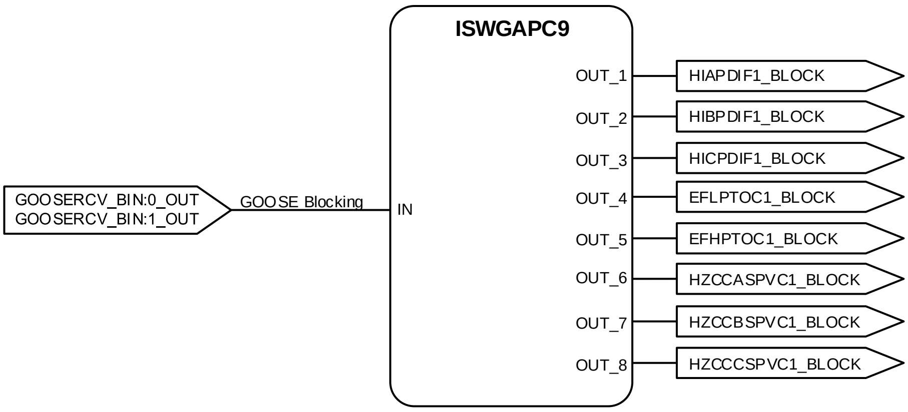

Figure 52: ISWGAPC9

ISWGAPC10

ISWGAPC10 is used to block the circuit breaker operation from the received GOOSE signals. ISWGAPC10 inputs are received GOOSE signals from GOOSERCV_BIN: 4 to GOOSERCV_BIN:19. The outputs are connected to block the circuit breaker close and open operation.

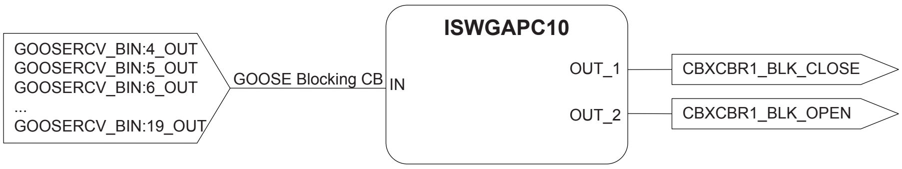

Figure 53: ISWGAPC10

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for differential protection

The sensitivity and the reliability of the protection depends on the characteristics of the current transformers. The CTs must have an identical transformation ratio. It is recommended that all the CTs have an identical constructions, that is, they have an equal burden and characteristics and are of the same type, preferably from the same manufacturing batch. If the CT characteristics and burden values are not equal, calculations for each branch in the scheme should be performed separately and the worst-case results should be used. In Figure 54, the CT winding resistance and the burden of the branches are not equal, and hence, the maximum burden equal to 3.2 Ω should be used for calculating the stabilized voltage.

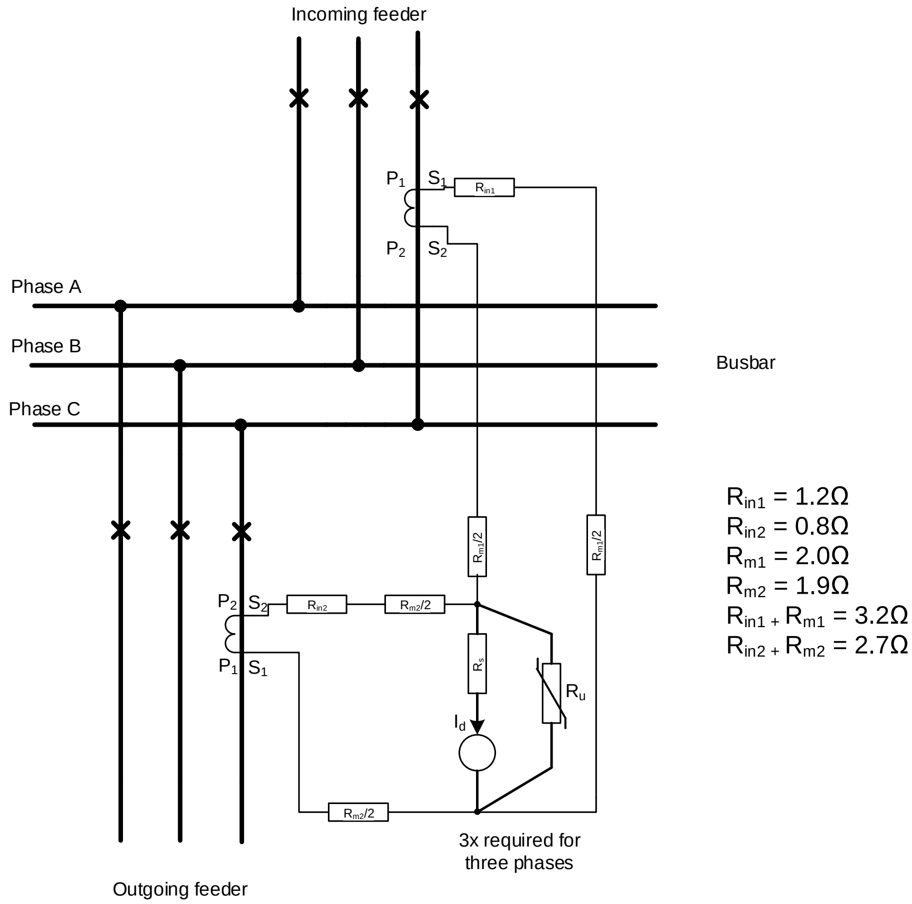

Figure 54: High-impedance busbar differential protection with different CT burden value on each feeder

First, the stabilizing voltage, that is, the voltage appearing across the measuring branch during the out-of-zone fault, is calculated assuming that one of the CTs connected in parallel is fully saturated. The stabilizing voltage can be calculated using the formula:

$$U_s = \frac{I_{k\max}}{n}(R_{in} + R_m)$$

(Equation 1)

I_{kmax}	the highest through-fault current in primary amps. The highest earth-fault or short circuit current during the out-of-zone fault.
n	the turns ratio of the CT
R_{in}	the secondary winding resistance of the CT in ohms
R_m	the total resistance of the secondary circuit wires in ohms

The current transformers must be able to force enough current to operate the protection relay through the differential circuit during a fault condition inside the protection zone. To ensure this, the knee point voltage U_{kn} must be at least two times higher than the stabilizing voltage U_s.

The required knee point voltage U_{kn} of the current transformer is calculated using the formula

$$U_{kn} \geq 2 \times U_s$$

(Equation 2)

U_{kn} the knee point voltage

U_s the stabilizing voltage

The factor two is used when a delay in the operating time of the protection is not acceptable. To prevent the knee point voltage from rising too high, CTs with the secondary winding resistance same as the resistance of the measuring loop should be used.

As the impedance of the protection relay is low, a stabilizing resistor is needed. The value of the stabilizing resistor is calculated using the formula:

$$R_s = \frac{U_s}{I_{rs}}$$

(Equation 3)

R_s the resistance of the stabilizing resistor

U_s the stabilizing voltage of the protection relay

I_{rs} the value of the *Operate value* setting in secondary amps

The stabilizing resistor should be capable to dissipate high energy within a very short time; therefore, a wire wound-type resistor must be used. The minimum rated power should be a few tens of watts because of the possible CT inaccuracy which might cause some current through the stabilizing resistor in a normal load situation.

If U_{kn} is high or U_s is low, a resistor with a higher power rating is needed. Often the resistor manufacturers allow 10 times the rated power for 5 seconds. Thus, the power of the resistor can be calculated using the formula:

$$\frac{U_{kn}^2}{R_s \times 10}$$

(Equation 4)

The actual sensitivity of the protection is affected by the protection relay setting, the magnetizing currents of the CTs connected in parallel and the shunting effect of the voltage-dependent resistor (VDR). The value of the primary current I_{prim} at which the protection relay operates at a certain setting can be calculated using the formula

$$I_{prim} = n \times (I_{rs} + I_u + m \times I_m)$$

(Equation 5)

I_{prim}	the primary current at which the protection is to start
n	the turn ratio of the current transformer
I_{rs}	the value of the *Operate value* setting
I_u	the leakage current flowing through the VDR at the U_s voltage
m	the number of current transformers included in the protection per phase
I_m	the magnetizing current per current transformer at the U_s voltage

The I_e value given in many catalogs is the excitation current at the knee point voltage. Assuming $U_{kn} \approx 2 \times U_s$, the value of $I_m \approx \frac{I_e}{2}$ gives an approximate value for Equation 5.

The selection of current transformers can be divided into procedures:

1. The rated current I_n of the feeder should be known. The value of I_n also affects how high I_{kmax} is.
2. The rated primary current I_{1n} of the CT must be higher than the rated current of the feeder.
   The choice of the CT also specifies R_{in}.
3. The required U_{kn} is calculated using Equation 2. If U_{kn} of the CT is not high enough, enough, another CT has to be selected. The value of U_{kn} is given by the manufacturer in the case of Class X current transformers or it can be estimated using Equation 6.
4. The sensitivity I_{prim} is calculated using Equation 5. If the achieved sensitivity is sufficient, the present CT is chosen. If a better sensitivity is needed, a CT with a bigger core is chosen.

If other than Class X CTs are used, an estimate for U_{kn} is calculated using the equation:

$$U_{kn} = 0.8 \times F_n \times I_{2n} \times \left(R_{in} + \frac{S_n}{I_{2n}^2} \right)$$

(Equation 6)

F_n the rated accuracy limit factor corresponding to the rated burden S_n

I_{2n} the rated secondary current of the CT

R_{in} the secondary internal resistance of the CT

S_n the volt-amp rating of the CT

The formulas are based on selecting the CTs according to Equation 2, results in an absolutely stable scheme. In some cases, it is possible to achieve stability with the knee point voltages lower than stated in the formulas. The conditions in the network, however, must be known well enough to ensure the stability.

1. If $U_{kn} \geq 2 \times U_s$, faster protection relay operations are secure.
2. If $U_{kn} \geq 1.5 \times U_s$ and $< 2 \times U_s$, protection relay operation can be slightly prolonged and should be studied case by case.
   If $U_{kn} < 1.5 \times U_s$, the protection relay operation is jeopardized. Another CT has to be chosen.

The need for the VDR depends on certain conditions.

First, voltage U_{max}, ignoring the CT saturation during the fault, is calculated using the formula

$$U_{max} = \frac{I_{kmaxin}}{n} \times (R_{in} + R_m + R_s) \approx \frac{I_{kmaxin}}{n} \times R_s$$

(Equation 7)

I_{kmaxin} the maximum fault current inside the zone in primary amps

n the turns ratio of the CT

R_{in} the internal resistance of the CT in ohms

R_m the resistance of the longest loop of the CT secondary circuit in ohms

R_s the resistance of the stabilized resistor in ohms

Next, the peak voltage û, which includes the CT saturation, is calculated using the formula (given by P.Mathews, 1955):

$$\hat{u} = 2\sqrt{2U_{kn}(U_{max} - U_{kn})}$$

(Equation 8)

U_{kn} the knee point voltage of the CT

The VDR is recommended when the peak voltage û ≥ 2kV, which is the insulation level for which the protection relay is tested.

The maximum fault current in case of a fault inside the zone is considered to be 12.6 kA in primary, CT is of 1250/5 A (ratio n = 240), knee point voltage is 81 V and the stabilizing resistor is 330 Ohms.

$$U_{max} = \frac{12600A}{240} \times 330\ \Omega = 17325\ V$$

(Equation 9)

$$\hat{u} = 2\sqrt{2 \times 81 \times (17325 - 81)} \approx 3.34kV$$

(Equation 10)

As the peak voltage û is 3.2 kV, VDR must be used. If the $R_s$is smaller, VDR could be avoided. However, the value of R_s depends on the operation current and stabilizing voltage of the protection relay. Thus, either a higher setting should be used or the stabilizing voltage should be lowered.

As the peak voltage û = 3.2 kV, VDR must be used. If the R_s is smaller, VDR can be avoided.

The value of R_s depends on the protection relay operating current and the stabilizing voltage. Therefore, either a higher setting in the protection relay or a lower stabilizing voltage must be used.

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Differential currents

The protection relay can also be used in single or two-phase applications by leaving one or two energizing inputs unoccupied. However, at least terminals X120:7-8 must be connected.

Table 16: Differential current inputs included in configuration A

Terminal	Description
X120:7-8	IL1
X120:9-10	IL2
X120:11-12	IL3

5.1.1.2 Residual current

Table 17: Residual current input included in configuration A

Terminal	Description
X120:13-14	Io

5.1.2 Auxiliary supply voltage input

The auxiliary voltage of the protection relay is connected to terminals X100:1-2. At DC supply, the positive lead is connected to terminal X100:1. The permitted auxiliary voltage range (AC/DC or DC) is marked on the top of the LHMI of the protection relay.

Table 18: Auxiliary voltage supply

Terminal	Description
X100:1	+ Input
X100:2	- Input

5.1.3 Binary inputs

The binary inputs can be used, for example, to generate a blocking signal, to unlatch output contacts, to trigger the disturbance recorder or for remote control of protection relay settings.

Binary inputs of slot X120 are available with configuration A.

Table 19: Binary input terminals X120-1...6

Terminal	Description
X120:1	BI1, +
X120:2	BI1, -
X120:3	BI2, +
X120:2	BI2, -
X120:4	BI3, +
X120:2	BI3, -
X120:5	BI4, +
X120:6	BI4, -

5.2 Outputs

5.2.1 Outputs for tripping and controlling

Output contacts PO1, PO2, PO3 and PO4 are heavy-duty trip contacts capable of controlling most circuit breakers. In the factory default configuration, the trip signals from all the protection stages are routed to PO3 and PO4.

Table 20: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCS resistor)
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCS1 input), NO
X100:19	PO3 (TCS1 input), NO
X100:20	PO4, NO (TCS resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCS2 input), NO
X100:24	PO4 (TCS2 input), NO

5.2.2 Outputs for signalling

Output contacts SO1 and SO2 in slot X100 can be used for signalling on start and tripping of the protection relay. On delivery from the factory, the start and alarm signals from all the protection stages are routed to signalling outputs.

Table 21: Output contacts X100:10...14

Terminal	Description
X100:10	SO1, common
X100:11	SO1, NC
X100:12	SO1, NO
X100:13	SO2, NO
X100:14	SO2, NO

5.2.3 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection relay. Under normal operating conditions, the protection relay is energized and the contact is closed (X100:3-5). When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the contact X100:3-5 drops off and the contact X100:3-4 closes.

Table 22: IRF contact

Terminal	Description
X100:3	IRF, common
X100:4	Closed; IRF, or U_{aux} disconnected
X100:5	Closed; no IRF, and U_{aux} connected

Section 6 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
100BASE-TX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
611 series	Series of numerical protection and control relays for low-end protection and supervision applications of utility substations, and industrial switchgear and equipment
CB	Circuit breaker
CSV	Comma-separated values
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DPC	Double-point control
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FIFO	First in, first out
FTP	File transfer protocol
FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
IEC	International Electrotechnical Commission
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IEEE 1686	Standard for Substation Intelligent Electronic Devices' (IEDs') Cyber Security Capabilities
IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a

	unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MMS	1. Manufacturing message specification 2. Metering management system
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
REB611	Busbar and multipurpose differential protection and control relay
RJ-45	Galvanic connector type
RS-485	Serial link according to EIA standard RS485
RSTP	Rapid spanning tree protocol
SAN	Single attached node
SNTP	Simple Network Time Protocol
SO	Signal output
VDR	Voltage-depended resistor
WAN	Wide area network
WHMI	Web human-machine interface

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