RELION® 611 SERIES

Motor Protection and Control REM611

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

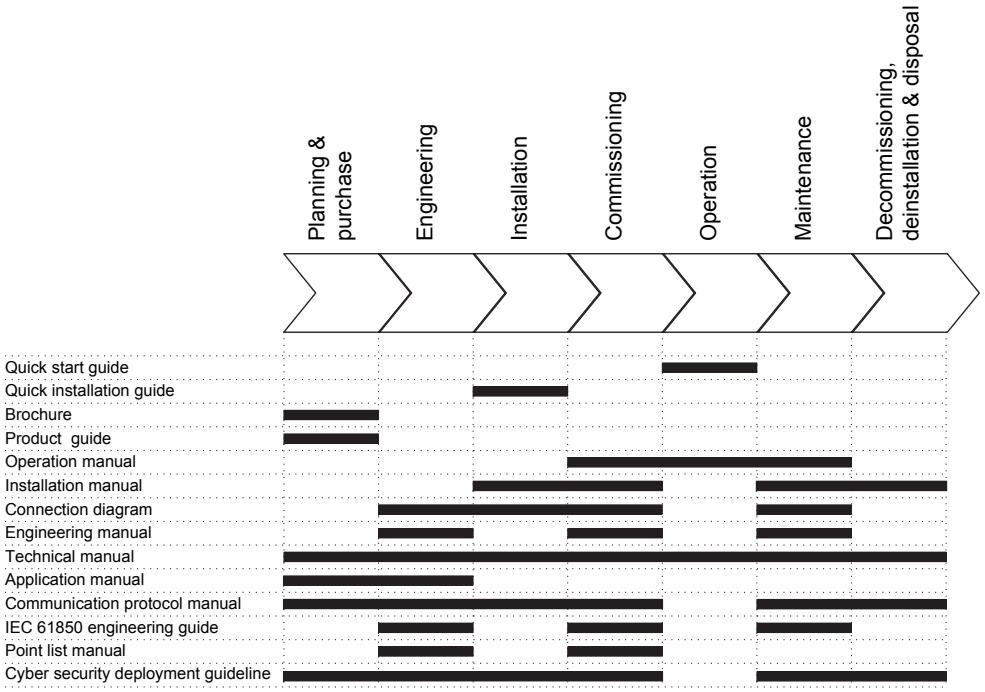


Figure 1: The intended use of manuals in different lifecycles

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			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	3I>>> (1)	50P/51P (1)
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)
Negative-sequence overcurrent protection for machines, instance 1	MNSPTOC1	I2>M (1)	46M (1)
Negative-sequence overcurrent protection for machines, instance 2	MNSPTOC2	I2>M (2)	46M (2)
Loss of load supervision	LOFLPTUC1	3I<	37
Motor load jam protection	JAMPTOC1	Ist>	51LR
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Motor start-up supervision	STTPMSU1	Is2t n<	49,66,48,51LR
Phase reversal protection	PREVPTOC1	I2>>	46R
Thermal overload protection for motors	MPTTR1	3Ith>M	49M
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Other			
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
Minimum pulse timer (2 pcs, second resolution), instance 1	TPSGAPC	TPS (1)	TPS (1)
Move (8 pcs), instance 1	MVGAPC	MV (1)	MV (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Emergency start-up	ESMGAPC1	ESTART	ESTART
Condition monitoring and supervision			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
Runtime counter for machines and devices	MDSOPT1	OPTS	OPTM
Logging			
Disturbance recorder	RDRE1	DR (1)	DFR(1)
Fault recorder	FLTRFRC1	-	FR
Measurement			
Three-phase current measurement, instance 1	CMMXU1	3I	3I
Sequence current measurement	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	Io	In

1) 10 instances
2) 20 instances
3) 6 instances
4) 10 instances

Section 2 REM611 overview

2.1 Overview

REM611 is a dedicated motor protection relay for the protection, control, measurement and supervision of asynchronous motors in manufacturing and process industry. Typically, the relay is used with circuit breaker or contactor-controlled medium-sized or small motors in a variety of drives, such as pumps and conveyors, crushers and choppers, mixers and agitators, and fans and aerators.

REM611 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 filtering 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
- REM611 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 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.

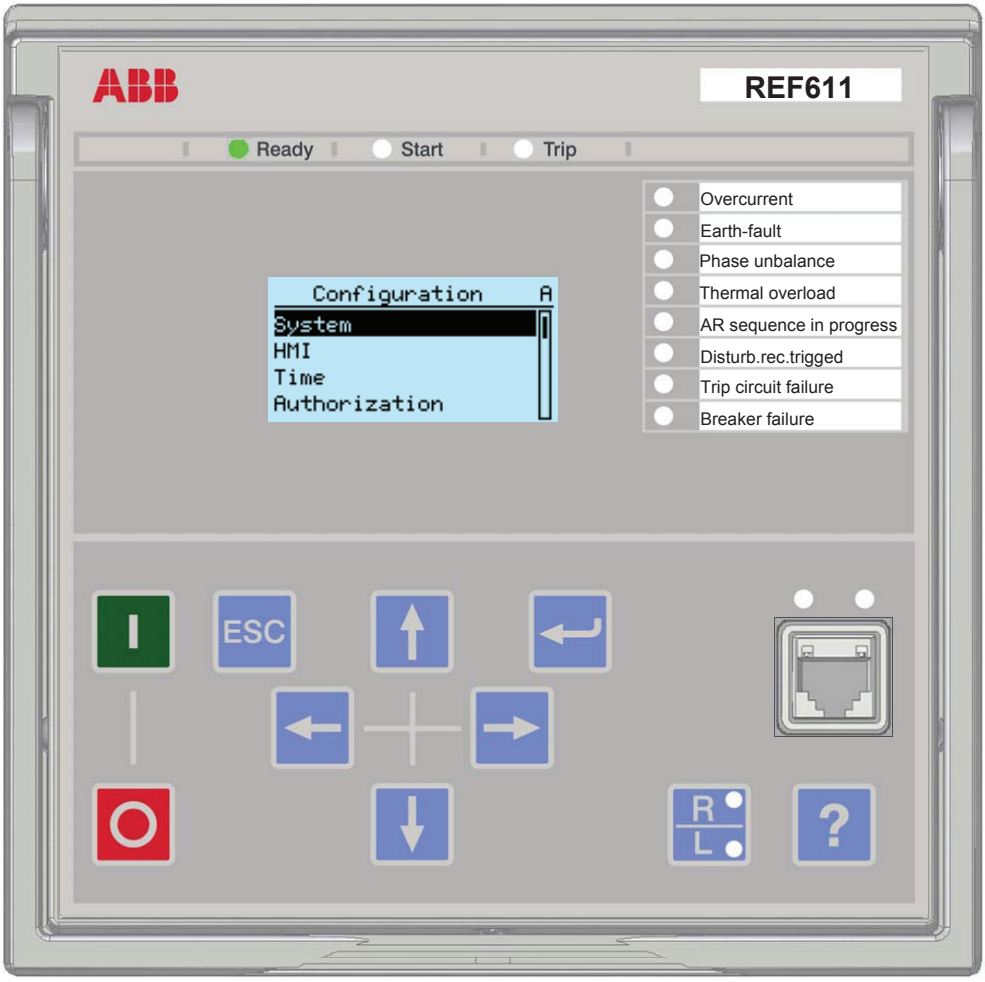


Figure 2: Example of the LHMI

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 size[1)]	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.

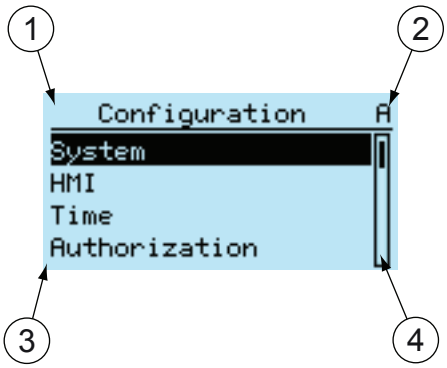


Figure 3: Display layout

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.

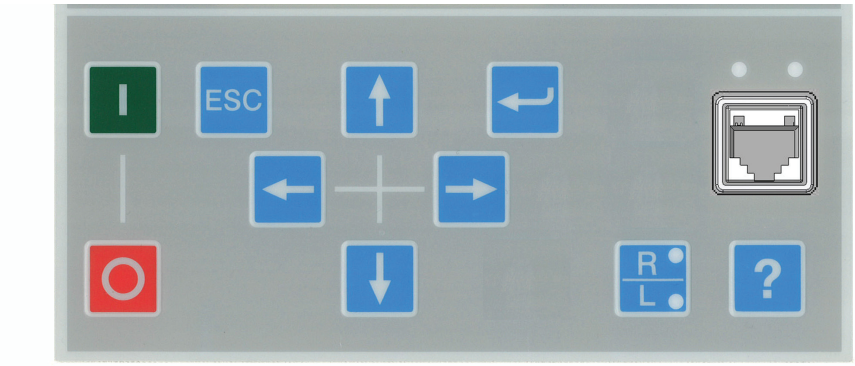


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

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.

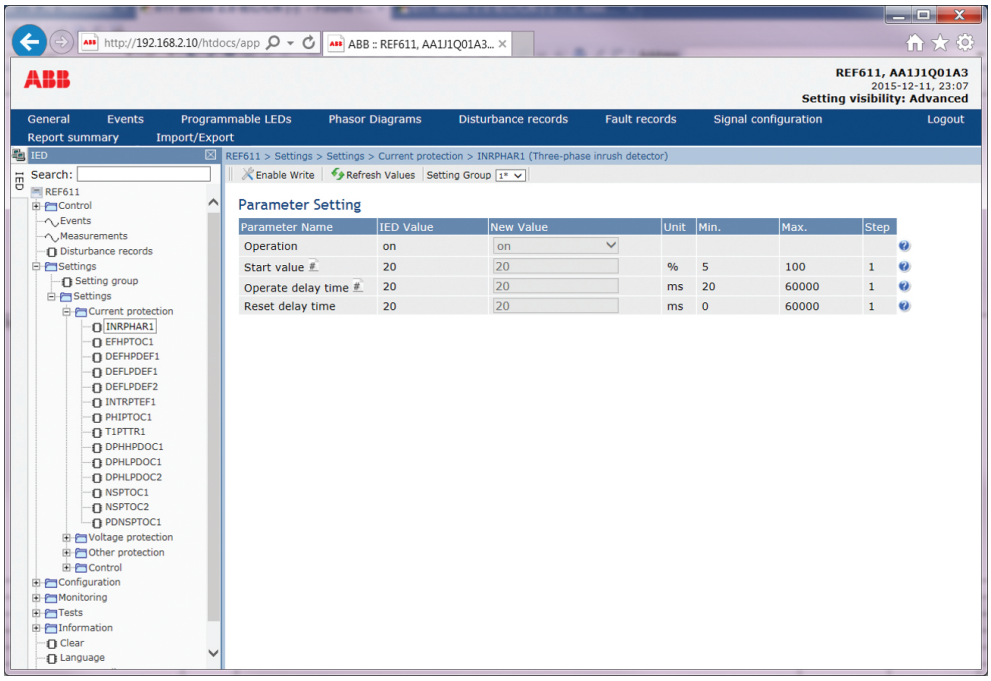


Figure 5: Example view of the WHMI

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

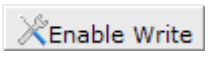
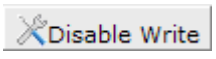
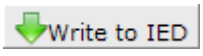
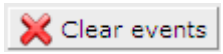
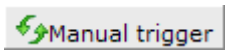
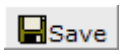
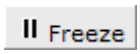
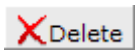
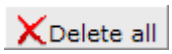
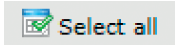
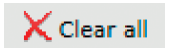
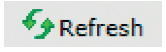
Name	Description
	Enabling parameter editing
	Disabling parameter editing
	Writing parameters to the protection relay
	Refreshing parameter values
	Printing out parameters
	Committing changes to protection relay's nonvolatile flash memory

Table continues on next page

Name	Description
	Rejecting changes
	Showing context sensitive help messages
	Error icon
	Clearing events
	Triggering the disturbance recorder manually
	Saving values to TXT or CSV file format
	Freezing the values so that updates are not displayed
	Receiving continuous updates to the monitoring view
	Deleting the disturbance record
	Deleting all disturbance records
	Saving the disturbance record files
	Viewing all fault records
	Clearing all fault records
	Importing settings
	Exporting settings
	Selecting all
	Clearing all selections
	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.

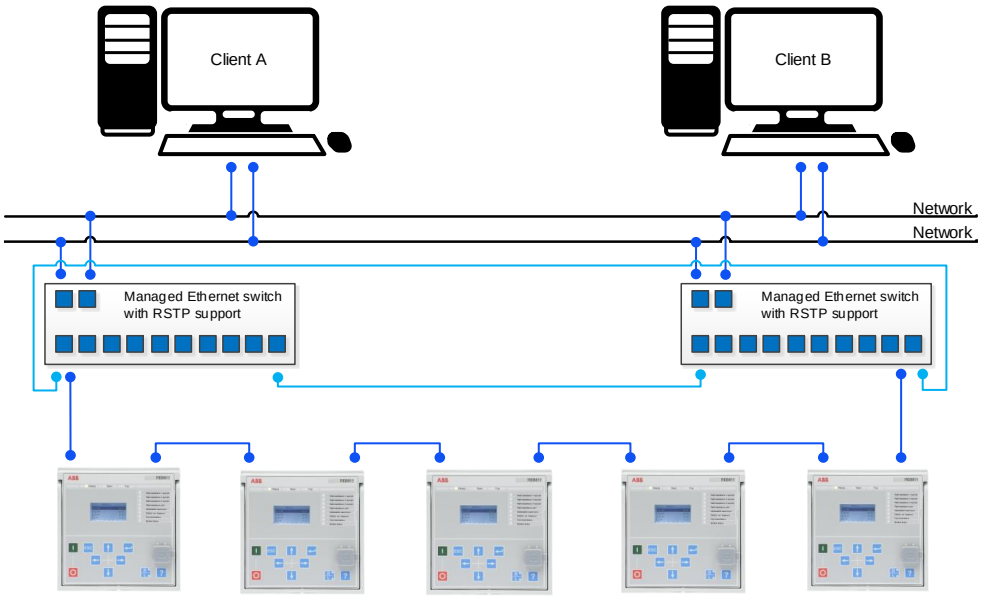


Figure 6: Self-healing Ethernet ring solution

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.

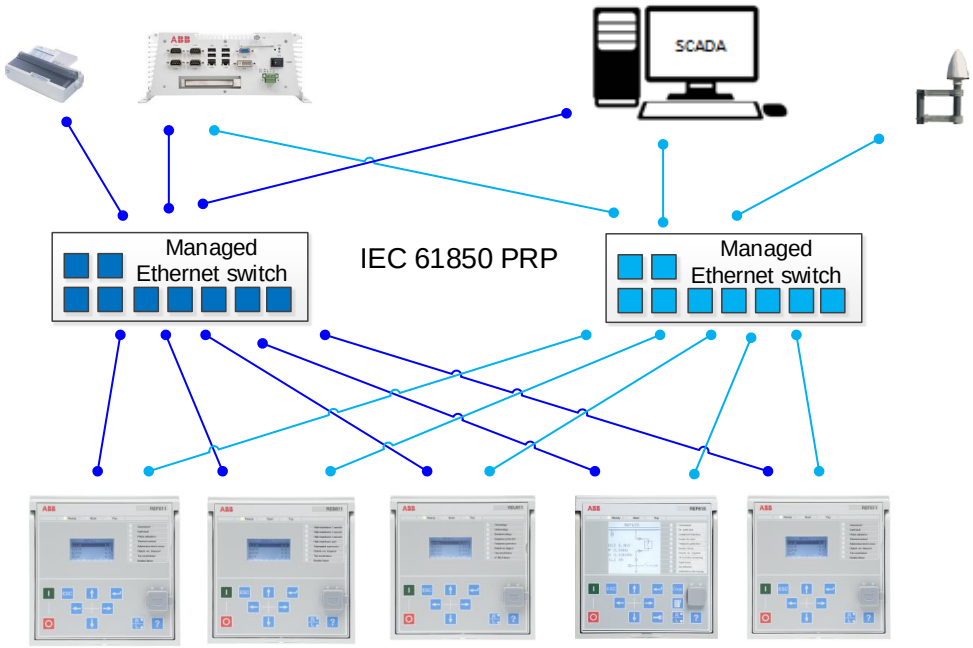


Figure 7: PRP solution

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.

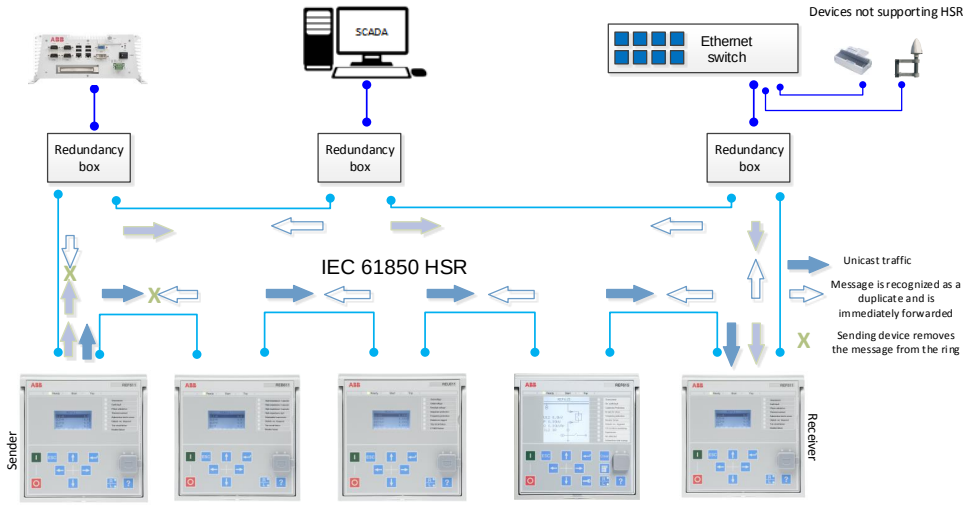


Figure 8: HSR solution

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 REM611 standardized configuration

3.1 Standardized configuration

REM611 is available in one configuration.

To increase the user-friendliness of the configuration and to emphasize the simplicity of usage of the relay, 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.
Motor protection	A

Table 10: Supported functions

Function	IEC 61850	A
Protection		
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1
Non-directional earth-fault protection, low stage	EFLPTOC	1[1)]
Non-directional earth-fault protection, high stage	EFHPTOC	1[1)]
Negative-sequence overcurrent protection for machines	MNSPTOC	2
Loss of load supervision	LOFLPTUC	1
Motor load jam protection	JAMPTOC	1
Motor start-up supervision	STTPMSU	1
Phase reversal protection	PREVPTOC	1
Thermal overload protection for motors	MPTTR	1
Circuit breaker failure protection	CCBRBRF	1
Master trip	TRPPTRC	1
Control		
Circuit-breaker control	CBXCBR	1
Emergency start-up	ESMGAPC	1
Condition monitoring and supervision		
Trip circuit supervision	TCSSCBR	2
Table continues on next page		

Function	IEC 61850	A
Runtime counter for machines and devices	MDSOPT	1
Logging		
Disturbance recorder	RDRE	1
Fault recorder	FLTRFRC	1
Measurement		
Three-phase current measurement	CMMXU	1
Sequence current measurement	CSMSQI	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
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1
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 selectable by parameter and default value is "Io measured"

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.

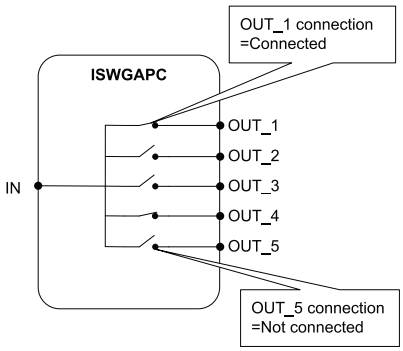


Figure 9: Input switch group ISWGAPC

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.

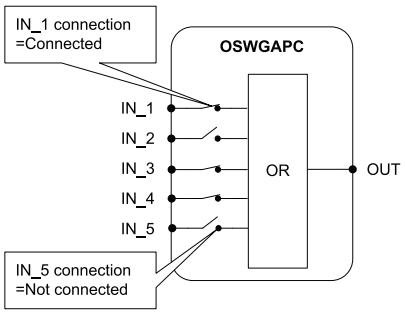


Figure 10: Output switch group OSWGAPC

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.

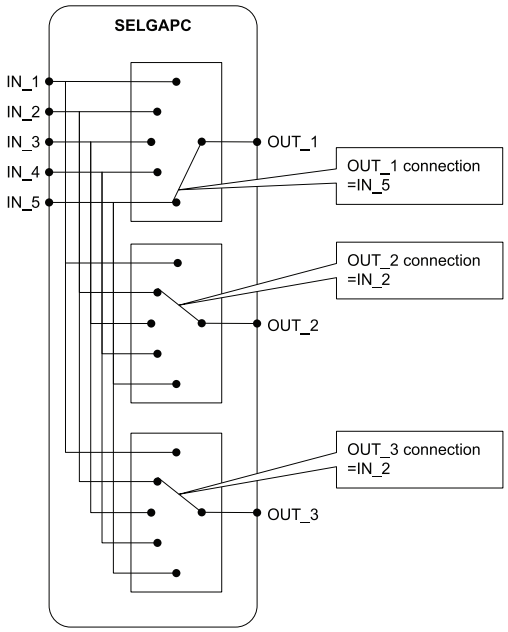


Figure 11: Selector switch group SELGAPC

3.3 Connection diagrams

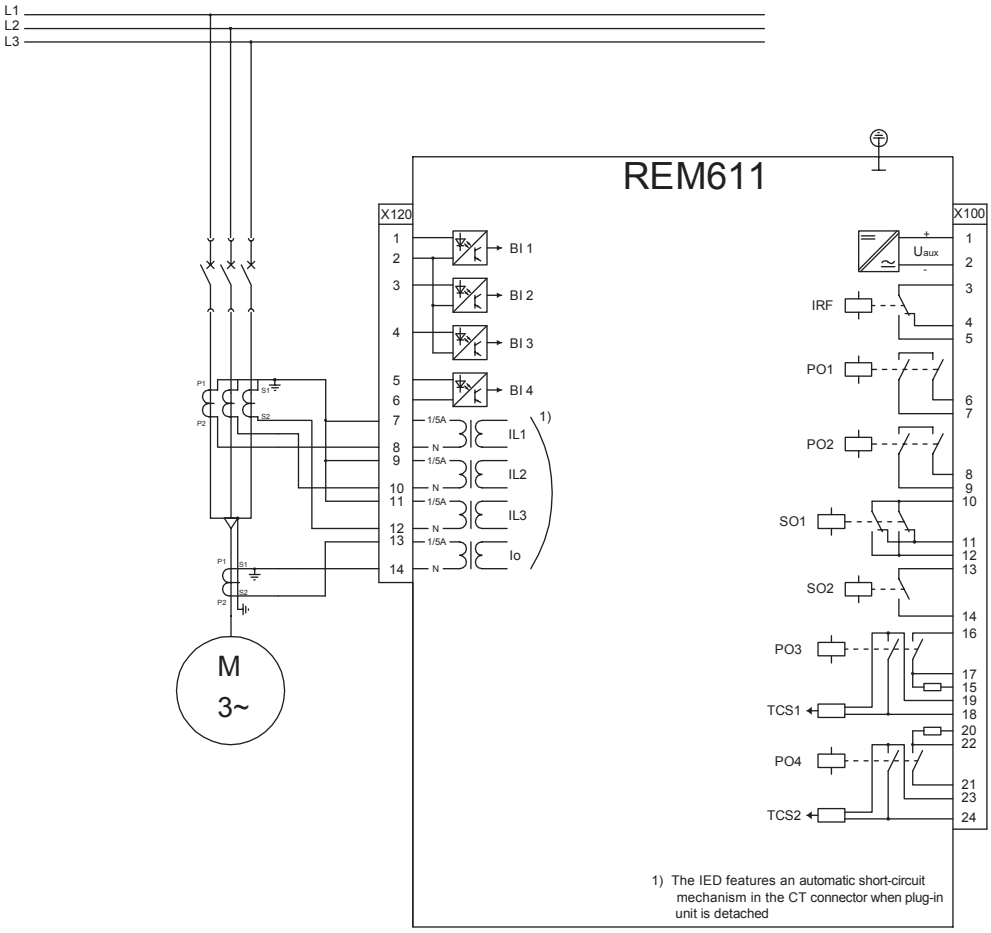


Figure 12: Connection diagram for configuration A when used with a circuit-breaker-controlled motor drive

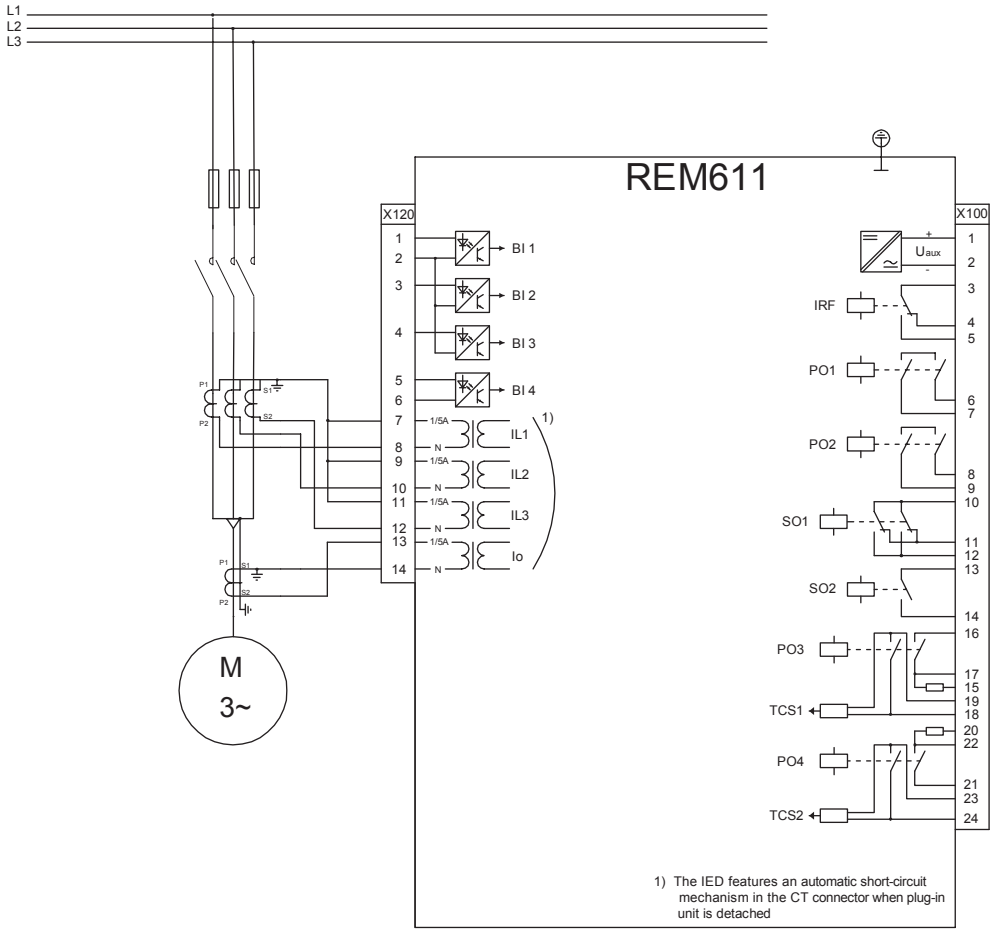


Figure 13: Connection diagram for configuration A when used with a contactor-controlled motor drive

The protection principles are mostly the same for circuit-breaker controlled and contactor controlled motor drives. Because the contactor is not able to break high currents, the relay must be set in such a way that the relay does not open the contactor at faults of high current magnitudes. Faults are cleared with fuses.

3.4 Configuration A

3.4.1 Applications

Configuration A for motor protection and control is mainly intended for the protection, control, measurement and supervision of asynchronous motors and the associated drives in manufacturing and process industry.

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.

3.4.2 Functions

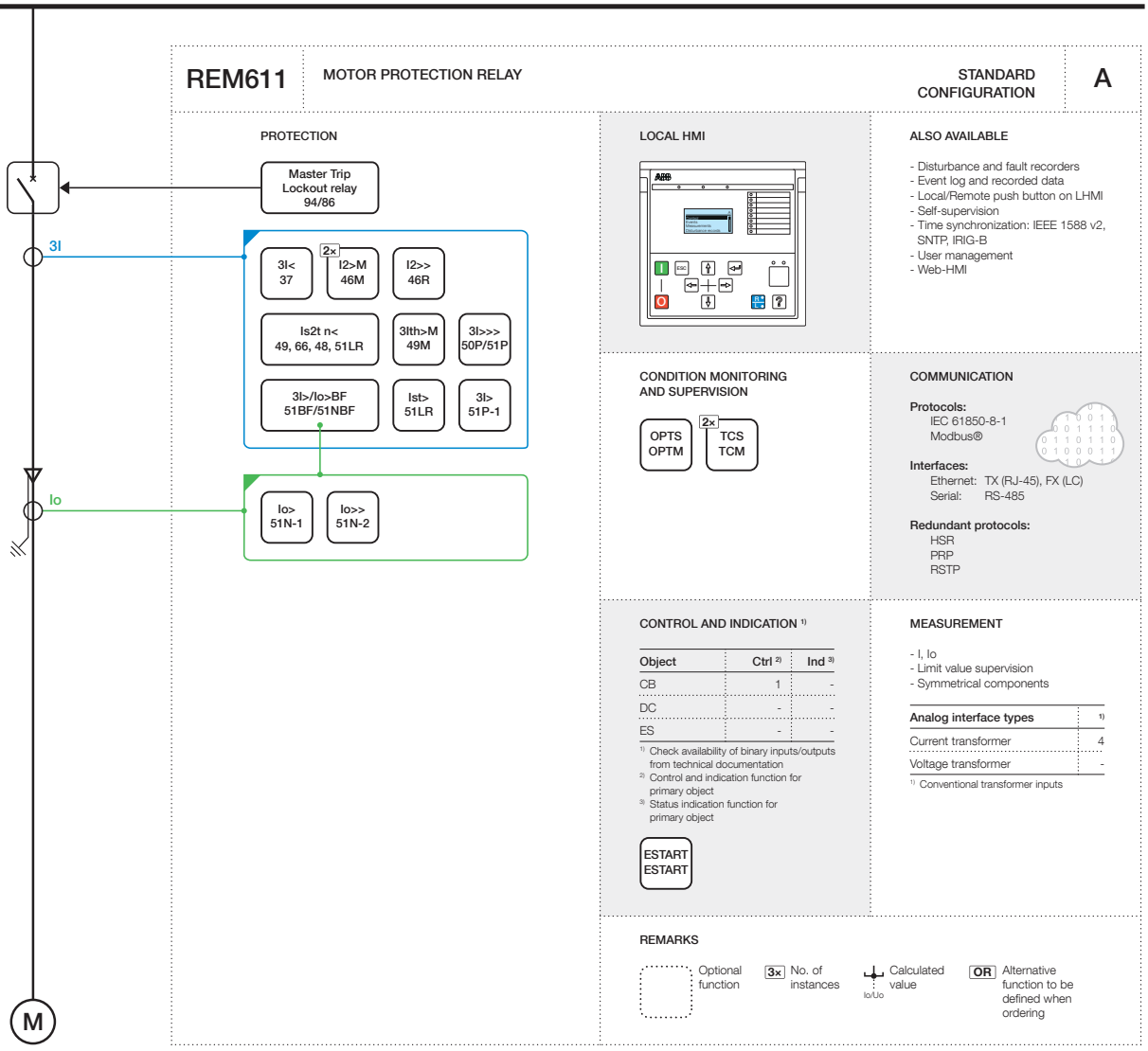


Figure 14: Functionality overview for configuration A

3.4.2.1 Default I/O connections

Table 11: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	Emergency start	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	External restart inhibit	X120:5-6

Table 12: Default connections for binary outputs

Binary input	Description	Connector pins
X100-PO1	Restart enable	X100:6-7
X100-PO2	Breaker failure backup trip to upstream breaker	X100:8-9
X100-SO1	General start indication	X100:10-11,(12)
X100-SO2	General operate indication	X100:13-14
X100-PO3	Open circuit breaker	X100:15,19
X100-PO4	Close circuit breaker	X100:20,24

Table 13: Default connections for LEDs

LED	Description
1	Short circuit protection operate
2	Combined operate indication of the other protection functions
3	Thermal overload protection operate
4	Motor restart inhibit
5	Emergency start enabled
6	Disturbance recorder triggered
7	TCS or runtime counter 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 seven analog channels available for the disturbance recorder function. These channels are freely selectable and a part of the disturbance recorder's parameter settings.

The analog channels are assigned to different functions. The common signal marked with 3I represents the three phase currents. The signal marked with Io represents the measured residual current via a core balance current transformer.

3.4.3.1 Functional diagrams for protection

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

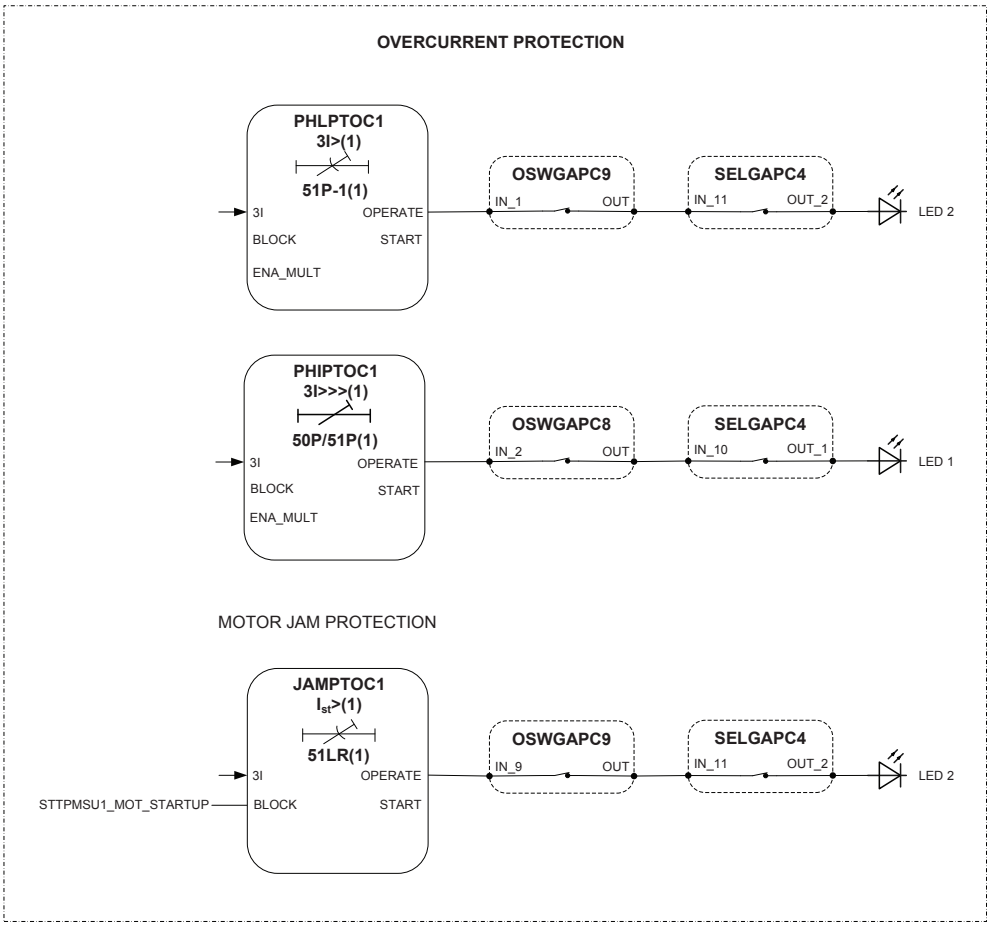


Figure 15: Overcurrent protection

Two overcurrent stages are offered for overcurrent and short-circuit protection. The motor jam protection function JAMPTOC1 is blocked by the motor startup protection function. PHLPTOC1 can be used for overcurrent protection and PHIPTOC1 for the short-circuit protection. The operation of PHIPTOC1 is not blocked by default by any functionality. PHIPTOC1 should be set over the motor start current level to avoid unnecessary operation.

All operate signals are connected to Master Trip. Short-circuit protection PHIPTOC1 operate signal is connected to the alarm LED 1, low stage overcurrent protection PHLPTOC1 and motor jam protection JAMPTOC1 operate signals are connected to the alarm LED 2.

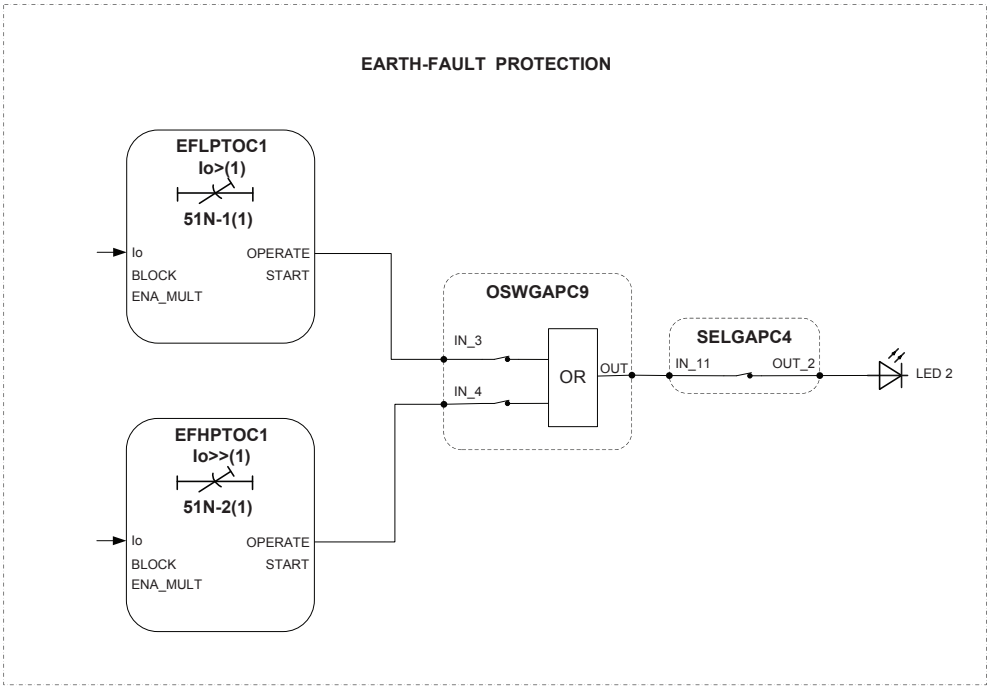


Figure 16: Earth-fault protection

Two non-directional earth-fault stages EFLPTOC1 and EFHPTOC1 are offered to detect phase-to-earth faults that may be a result of, for example, insulation ageing.

The operate signals of the earth-fault protections are connected to Master Trip and also to alarm LED 2.

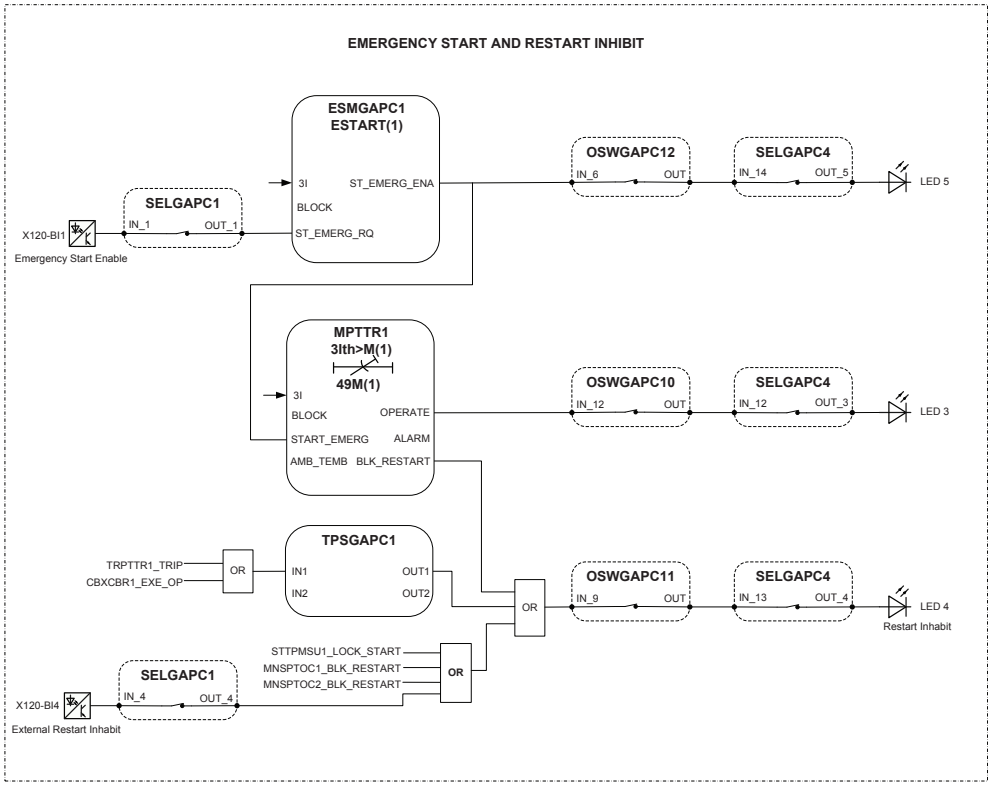


Figure 17: Emergency start and restart inhibit

The emergency start function ESMGAPC1 allows motor start-ups although the restart inhibit is activated. The emergency start is enabled for ten minutes after the selected binary input (X120:BI1) is energized. On the rising edge of the emergency start signal the following takes place.

- Calculated thermal level is set slightly below the restart inhibit level to allow at least one motor startup.
- Value of the cumulative start-up time counter STTPMSU1 is set slightly below the set restart inhibit value to allow at least one motor startup.
- Set operate values of the temperature stages in MPTTR1 function is increased by 10 percent.
- External restart inhibit signal (X100:PO1) is ignored.
- Alarm LED 5 is activated.

The external restart inhibit signal is ignored for as long as the emergency start is activated. A new emergency start cannot be made until the emergency start signal has been reset and the emergency start time of 10 minutes has expired.

The thermal overload protection function MPTTR1 detects short- and long term overloads under varying load conditions. When the emergency start request is issued for the emergency start function, it activates the corresponding input of the thermal overload function. When the thermal overload function has issued a restart blocking, which inhibits the closing of the circuit breaker when the machine is overloaded, the emergency start request removes this blocking and enables the restarting of the motor.

The operate signal of thermal overload protection function MPTTR1 is connected to Master Trip and to alarm LED 3.

The restart inhibit is activated for a set period when a circuit breaker is opened. This is called remanence voltage protection where the motor has damping remanence voltage after circuit breaker opening. Reclosing after a too short period of time can lead to stress for the machine and other apparatuses. The remanence voltage protection waiting time can be set to a timer function TPSGAPC1.

The restart inhibit is also activated when one of the following conditions is met.

- An active trip command or
- Motor startup supervision has issued lockout or
- Motor unbalance function has issued restart blocking or
- An external restart inhibit is activated by a binary input (X120:BI4).

LED 4 is the alarm indication of restart inhibit.

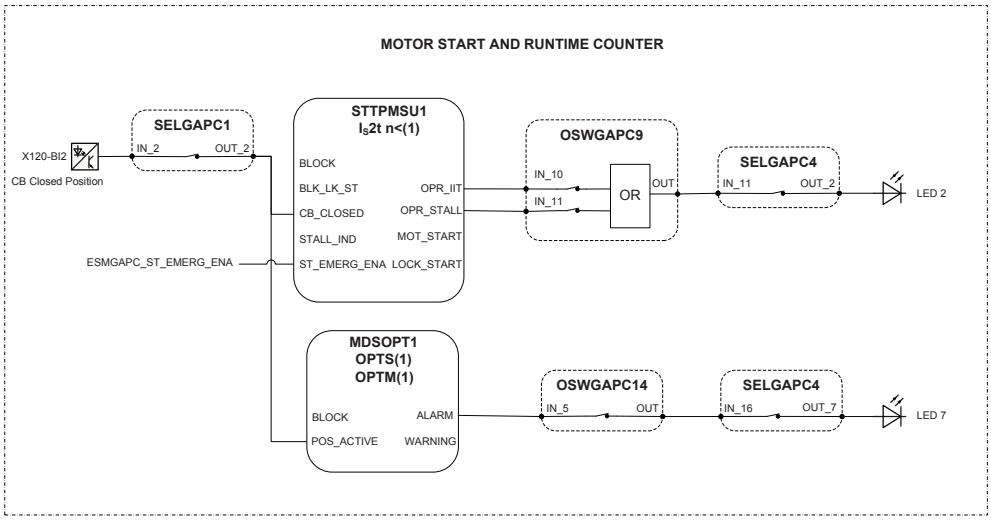


Figure 18: Motor startup supervision

With the motor startup supervision function STTPMSU1 the starting of the motor is supervised by monitoring three-phase currents or the status of the energizing circuit breaker of the motor.

When the emergency start request is activated by ESMCAPC1 and STTPMSU1 is in lockout state, which inhibits motor starting, the lockout is deactivated and emergency starting is available.

The operate signals (OPR_IIT and OPR_STALL) of the motor start-up supervision function STTPMSU1 are connected to Master Trip and to alarm LED 2.

The motor running time counter MDSOPT1 provides history data since the latest commissioning. The counter counts the total number of motor running hours and is

incremented when the energizing circuit breaker is closed. The alarm of the runtime counter is connected to alarm LED 7.

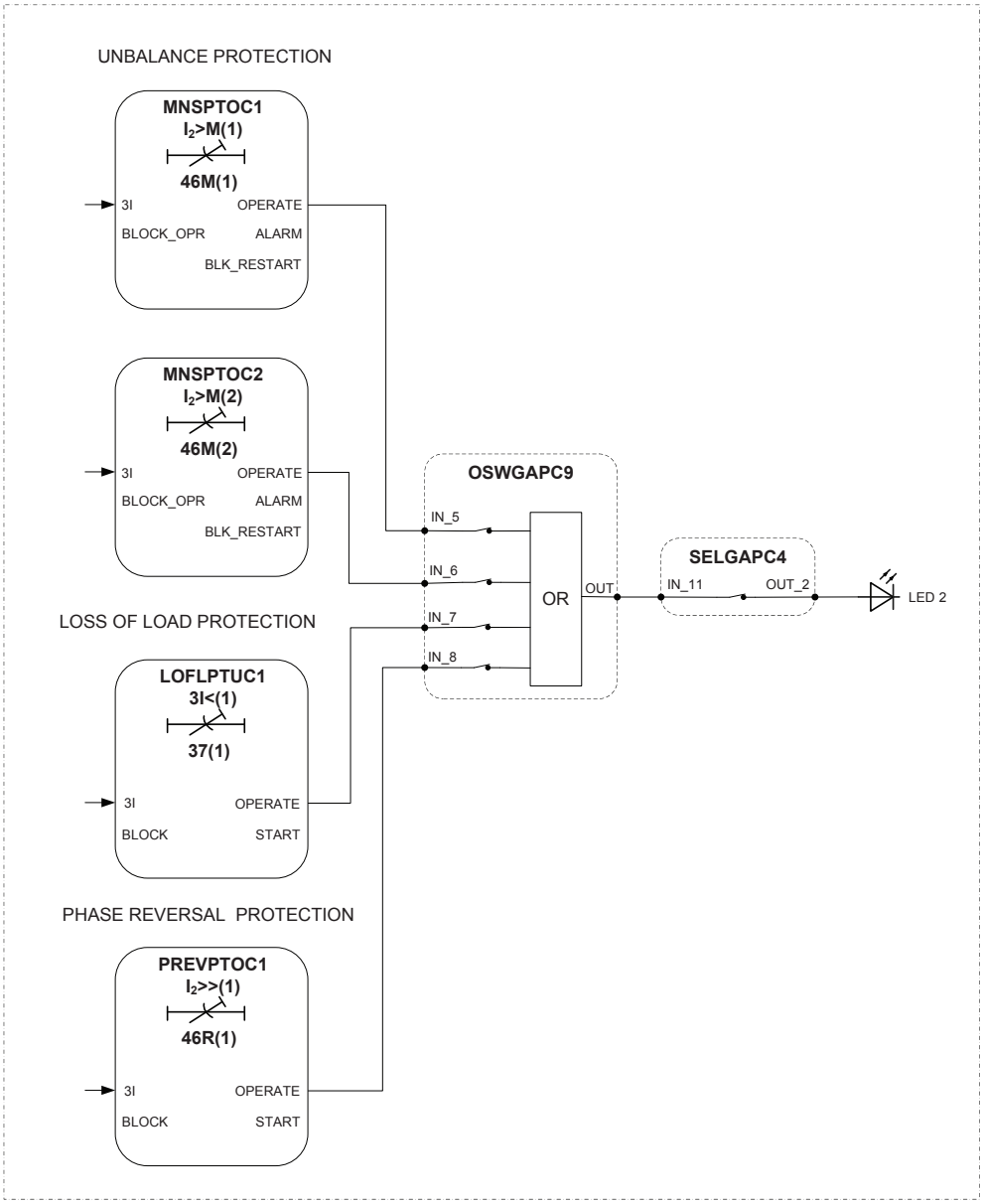


Figure 19: Unbalance, loss of load and phase reversal protection

Two negative-sequence overcurrent stages MNSPTOC1 and MNSPTOC2 are offered for phase unbalance protection. These functions are used to protect the motor against phase unbalance caused by, for example, a broken conductor. Phase unbalance in network feeding of the motor causes overheating of the motor.

The loss of load situation is detected by LOFLPTUC. The loss of load situation can happen, for example, if there is damaged pump or a broken conveyor.

The phase reversal protection PREVPTOC1 is based on the calculated negative phase-sequence current. It detects too high NPS current values during motor start-up, caused by incorrectly connected phases, which in turn causes the motor to rotate in the opposite direction.

All operate signals above are connected to Master Trip and to the alarm LED 2.

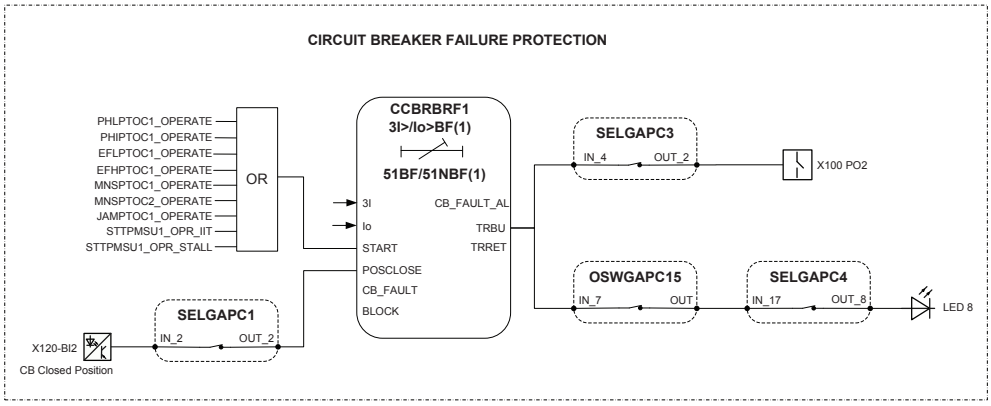


Figure 20: Circuit breaker failure protection

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 the Master Trip 1. 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 and supervision functionsrecorder

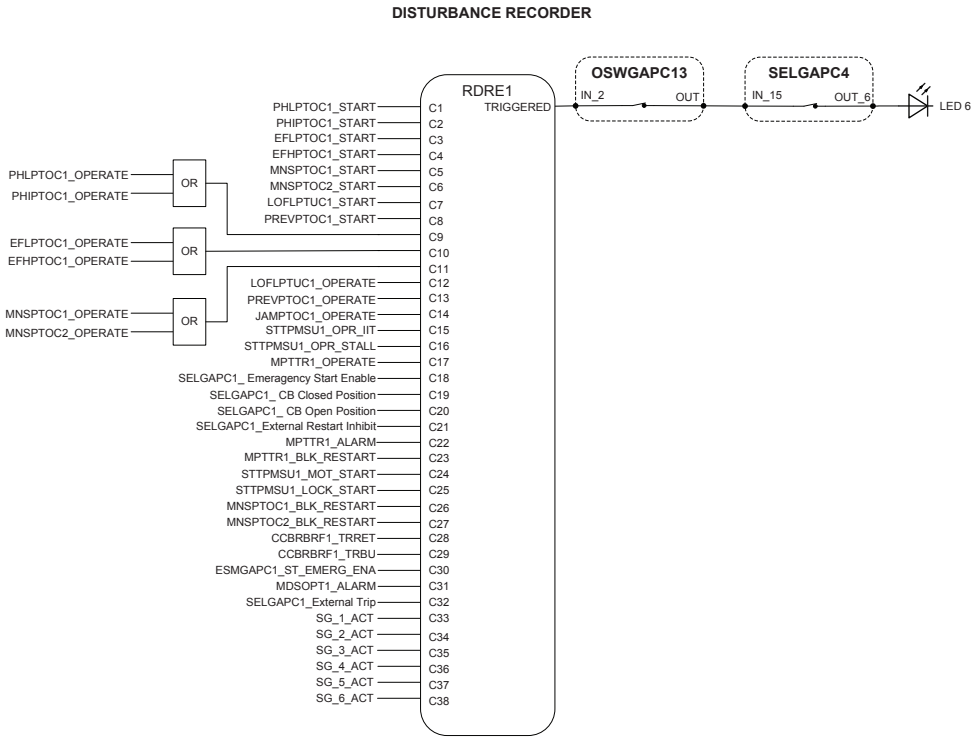


Figure 21: Disturbance recorder

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. 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	PHLPTOC1_START	1=positive or rising
Binary channel 2	PHIPTOC1_START	1=positive or rising
Binary channel 3	EFLPTOC1_START	1=positive or rising
Binary channel 4	EFHPTOC1_START	1=positive or rising
Binary channel 5	MNSPTOC1_START	1=positive or rising
Binary channel 6	MNSPTOC2_START	1=positive or rising
Binary channel 7	LOFLPTUC1_START	1=positive or rising
Binary channel 8	PREVPTOC1_START	1=positive or rising
Binary channel 9	PHLxPTOC1_OPERATE	4=level trigger off
Binary channel 10	EFxPTOC1_OPERATE	4=level trigger off
Binary channel 11	MNSPTOC_OPERATE	4=level trigger off
Table continues on next page		

Channel number	Channel id text	Level trigger mode
Binary channel 12	LOFLPTUC1_OPERATE	4=level trigger off
Binary channel 13	PREVPTOC1_OPERATE	4=level trigger off
Binary channel 14	JAMPOTC1_OPERATE	4=level trigger off
Binary channel 15	STTPMSU1_OPR_IIT	4=level trigger off
Binary channel 16	STPPMSU1_OPR_STALL	1=positive or rising
Binary channel 17	MPTTR1_OPERATE	4=level trigger off
Binary channel 18	SELGAPC1_Emeragecy Start Enable	4=level trigger off
Binary channel 19	SELGAPC1_CB_Closed	4=level trigger off
Binary channel 20	SELGAPC1_CB_Open	4=level trigger off
Binary channel 21	SELGAPC1_External Restart Inhibit	4=level trigger off
Binary channel 22	MPTTR1_ALARM	4=level trigger off
Binary channel 23	MPTTR1_BLK_RESTART	4=level trigger off
Binary channel 24	STTPMSU1_MOT_START	1=positive or rising
Binary channel 25	STTPMSU1_LOCK_START	4=level trigger off
Binary channel 26	MNSPTOC1_BLK_RESTART	4=level trigger off
Binary channel 27	MNSPTOC2_BLK_RESTART	4=level trigger off
Binary channel 28	CCBRBRF1_TRRET	4=level trigger off
Binary channel 29	CCBRBRF1_TRBU	4=level trigger off
Binary channel 30	ESMGAPC1_ST_EMERG_ENA	4=level trigger off
Binary channel 31	MDSOPT1_ALARM	4=level trigger off
Binary channel 32	SELGAPC1_External Trip	4=level trigger off
Binary channel 33	SG_1_ACT	4=level trigger off
Binary channel 34	SG_2_ACT	4=level trigger off
Binary channel 35	SG_3_ACT	4=level trigger off
Binary channel 36	SG_4_ACT	4=level trigger off
Binary channel 37	SG_5_ACT	4=level trigger off
Binary channel 38	SG_6_ACT	4=level trigger off

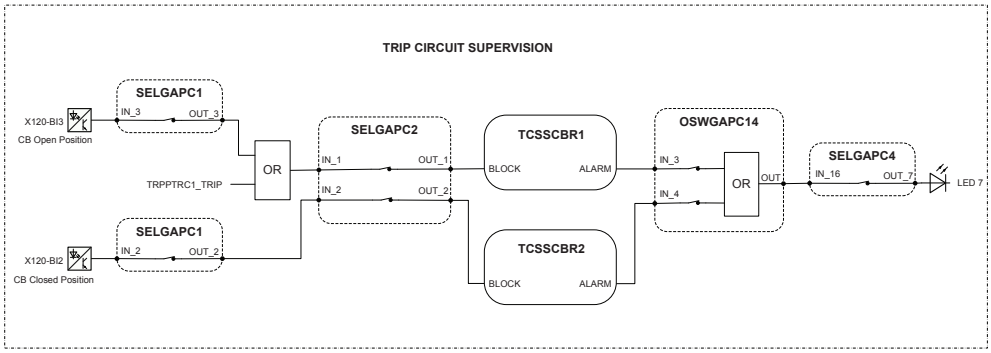


Figure 22: Supervision functions

By default it is expected that there is no external resistor in the circuit breaker tripping/closing coil circuit connected parallel with the circuit breaker normally open/closed auxiliary contact.

3.4.3.3 Functional diagrams for control and interlocking

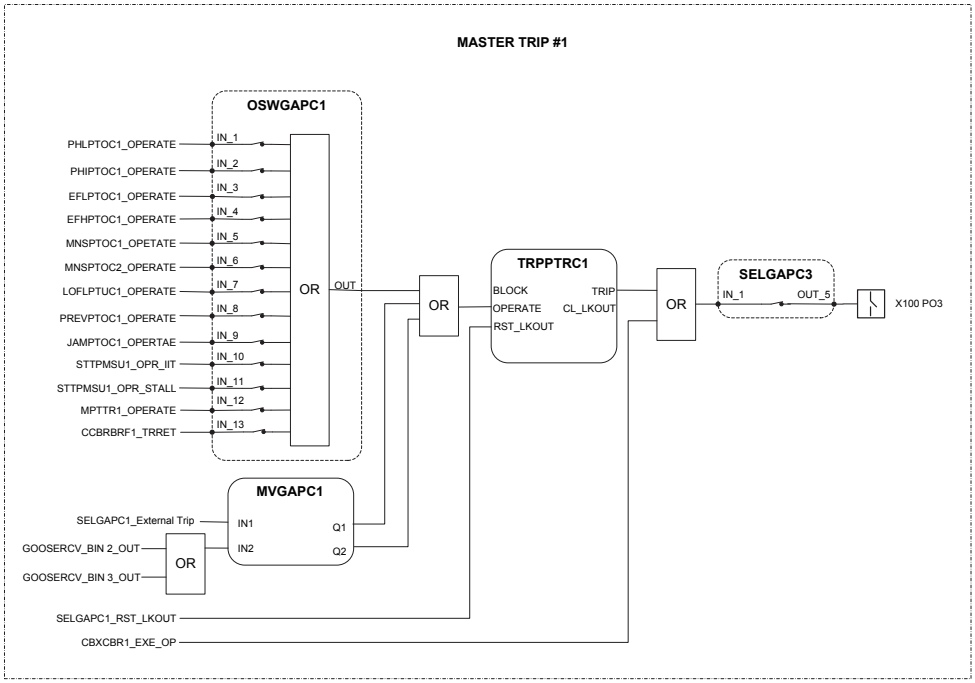


Figure 23: Master trip

The operate signals from the protections and an external trip are connected to the trip output contact PO3 (X100:15-19) via the corresponding Master Trip (TRPPTRC1). Open control commands to the circuit breaker from the local or remote CBXCBR1_EXE_OP are connected directly to the output PO3 (X100:15-19).

TRPPTRC1 provides 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.

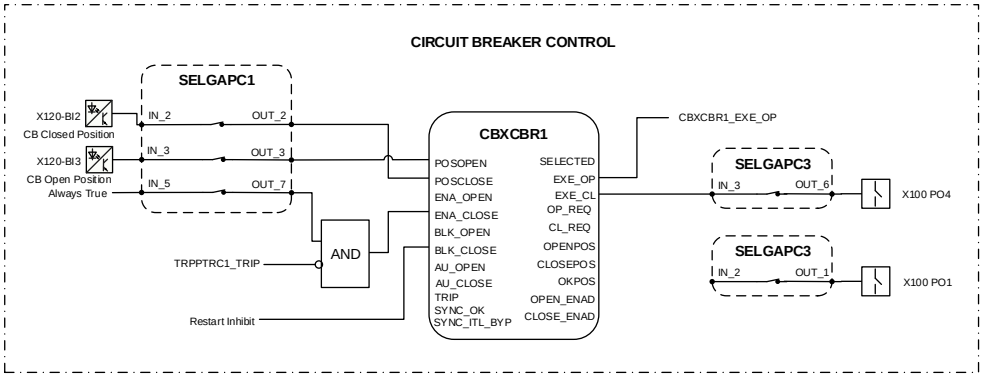


Figure 24: Circuit breaker control

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the master trip logics. An always true signal is also connected to ENA_CLOSE via SELGAPC1 by default. The open operation is always enabled.

When the motor restart is inhibited, the BLK_CLOSE input is activated and closing of the circuit breaker is not possible. When all conditions of the circuit breaker closing are fulfilled, the CLOSE_ENAD output of the CBXCBR1 is activated and PO1 output (X100:6-7) is closed.

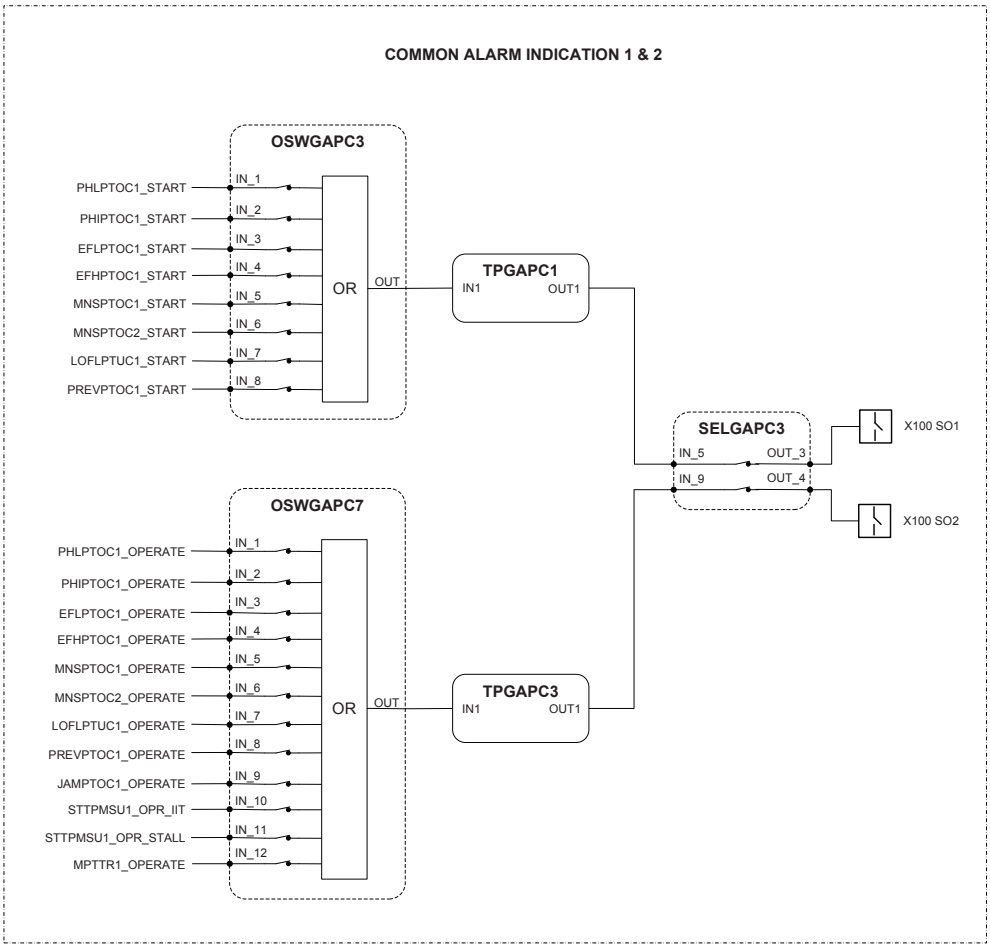


Figure 25: Common alarm indication

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 functions 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.

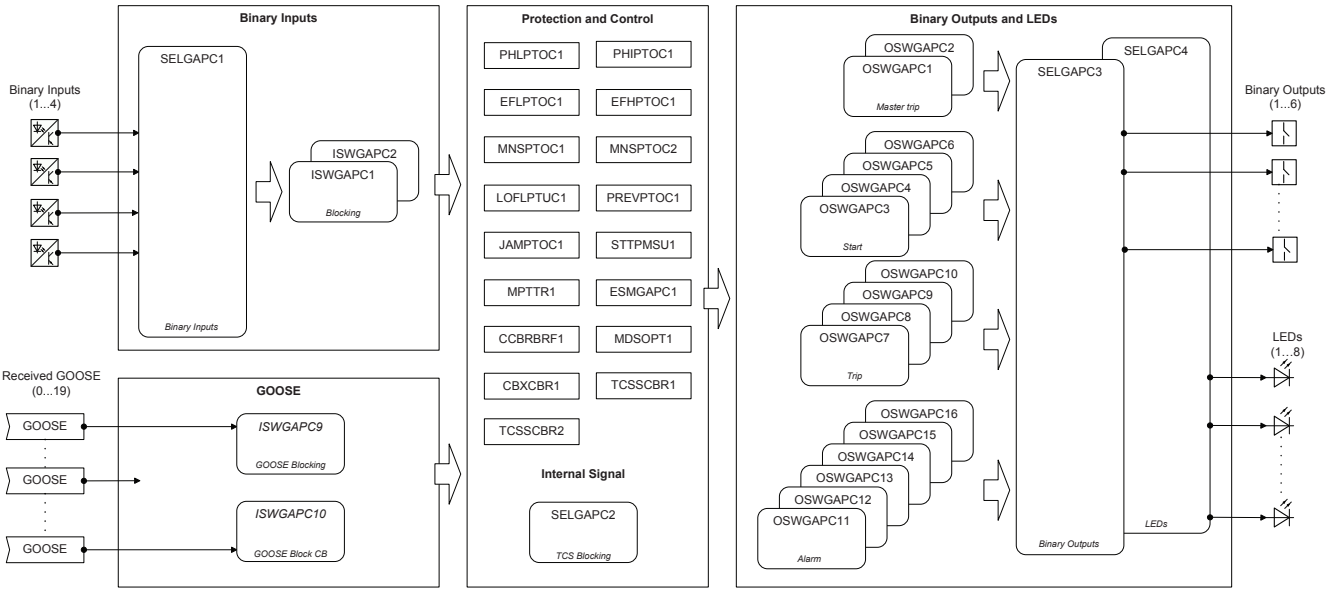


Figure 26: Configuration A switch group overview

3.4.4.1 Binary inputs

The binary inputs group includes one SELGAPC and two ISWGAPCs. SELGAPC1 is used to route binary inputs to ISWGAPC or directly to protection relay functions. ISWGAPC1 and ISWGAPC2 are used to configure the signal to block the protection functions.

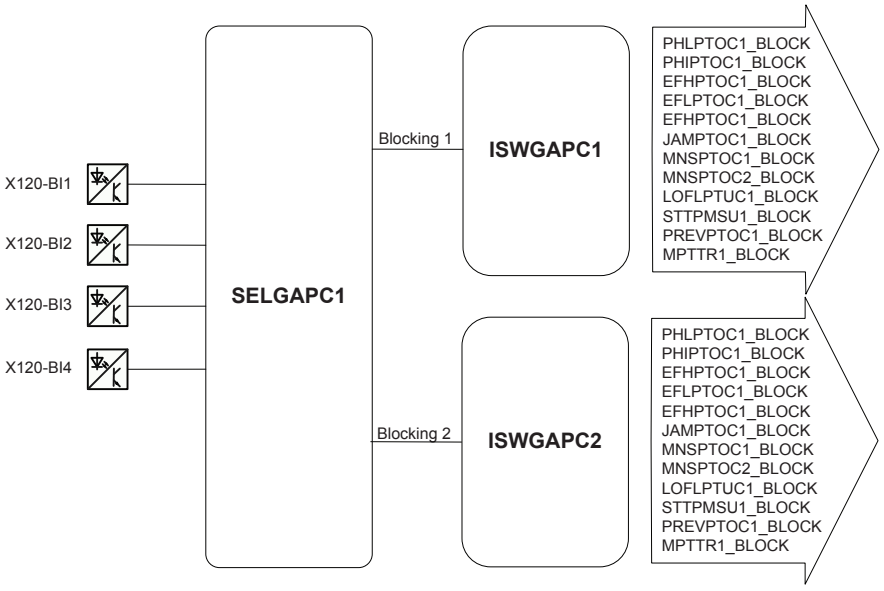


Figure 27: Binary inputs

SELGAPC1

SELGAPC1 has inputs from protection relay binary inputs. IN_1...IN_4 are binary inputs from X100. 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.

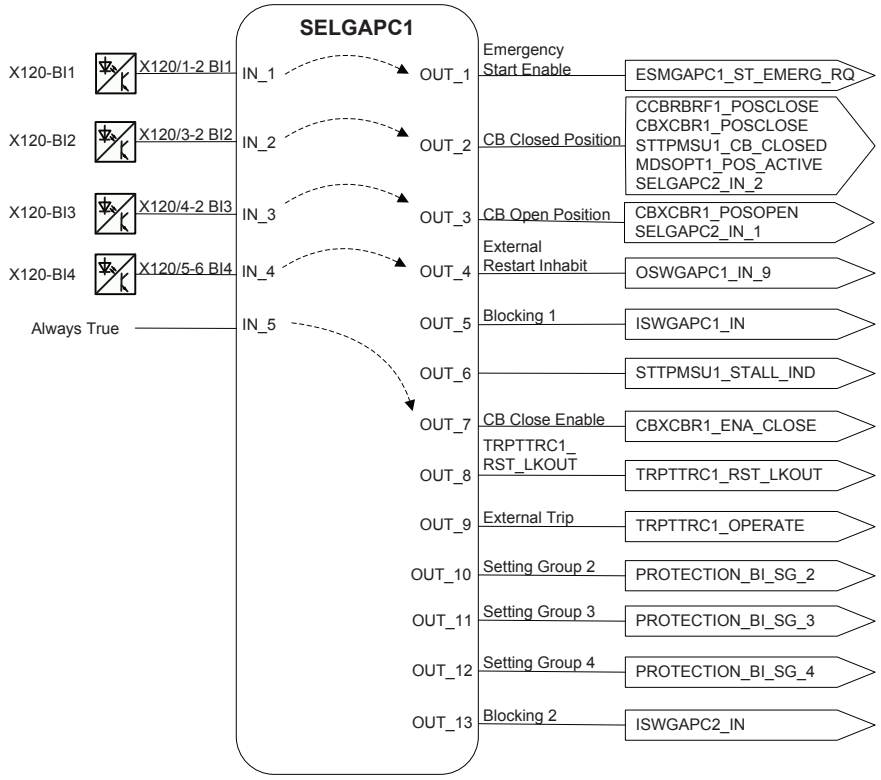


Figure 28: SELGAPC1

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_5 Blocking 1. ISWGAPC1 outputs are connected to the BLOCK inputs of the protection functions.

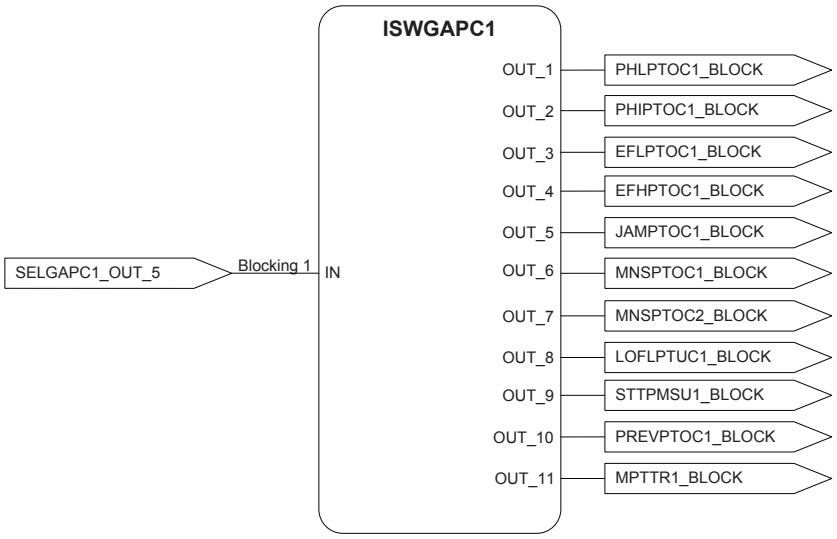


Figure 29: ISWGAPC1

ISWGAPC2

ISWGAPC2 is used to select which protection functions are to be blocked by changing ISWGAPC2 parameters. ISWGAPC2 input is routed from SELGAPC1 output `OUT_13 Blocking 2`. ISWGAPC2 outputs are connected to the `BLOCK` inputs of the protection functions.

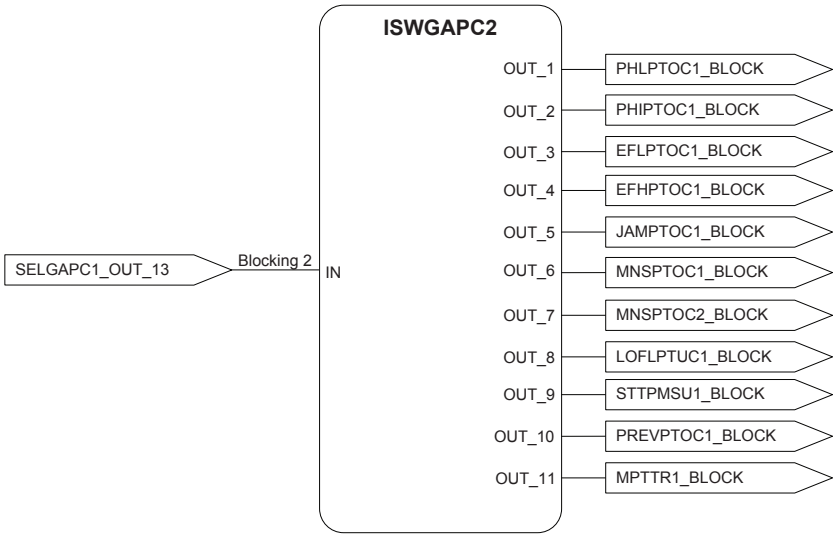


Figure 30: ISWGAPC2

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 circuit breaker open or close position.

Figure 31: 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 is used for the open circuit breaker, X100-PO4 is used for the closing circuit breaker. TCSSCBR1 is blocked by the circuit breaker open position, TCSSCBR2 is blocked by the circuit breaker closed 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_2). If X100-PO4 is used for the open circuit breaker, TCSSCBR2 needs to be blocked by the circuit breaker open position (OUT_2 connection=IN_1).

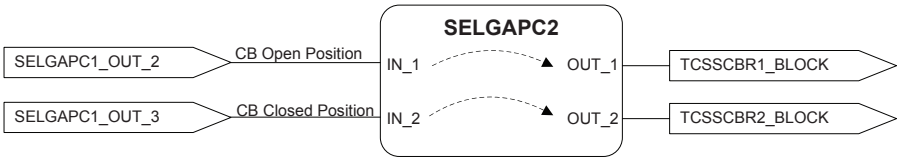


Figure 32: SELGAPC2

3.4.4.3 Binary outputs and LEDs

In standard 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 outputs are connected to binary outputs and LEDs via SELGAPC3 and SELGAPC4.

- SELGAPC3 is used to configure the OSWGAPC signals to the protection relay binary outputs. SELGAPC4 is used to configure the OSWGAPC signals to LEDs.
- OSWGAPC1 is used for Master trip. The inputs are routed from the protection functions operate and circuit-breaker failures re-trip.
- OSWGAPC2 is not 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.

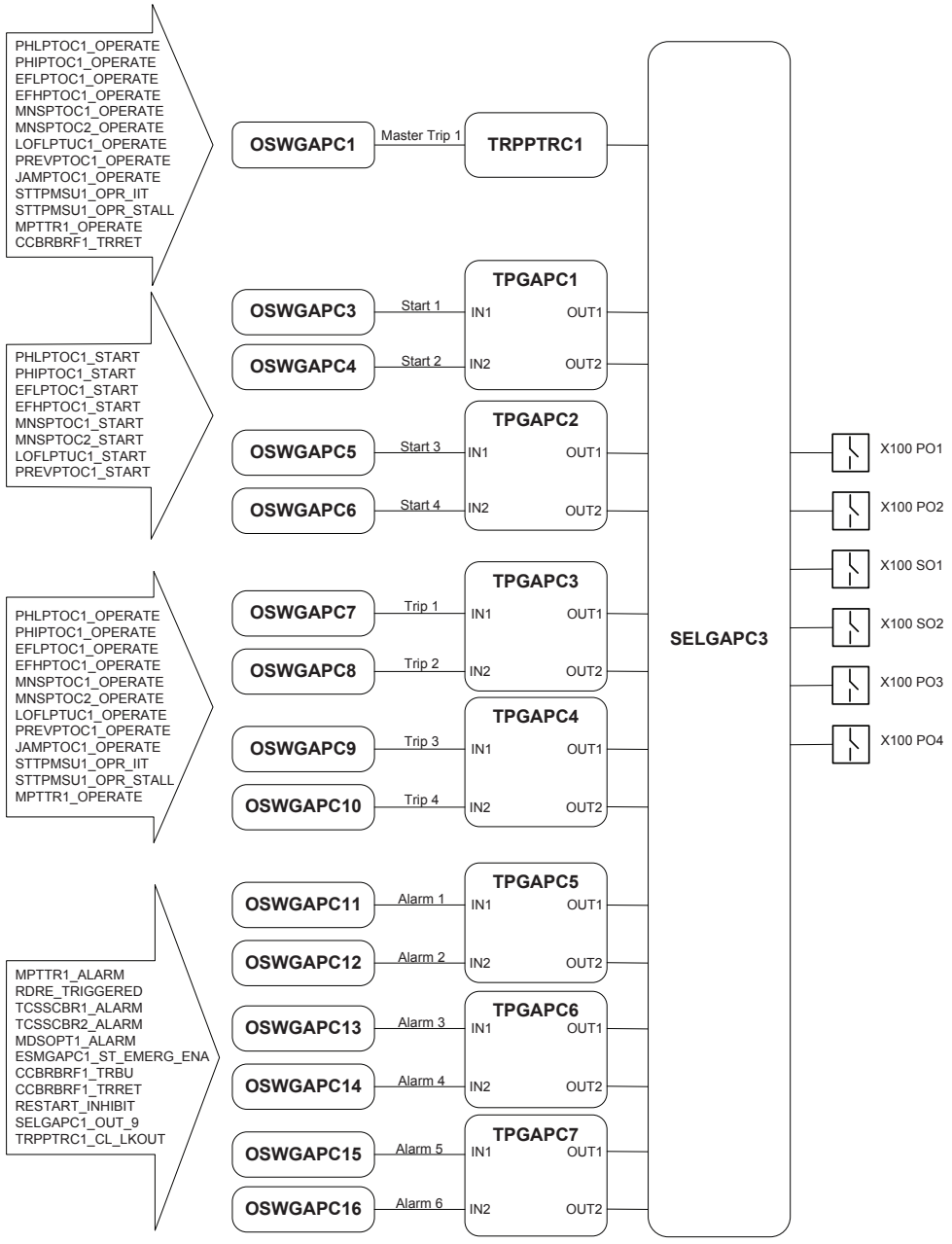


Figure 33: Binary outputs

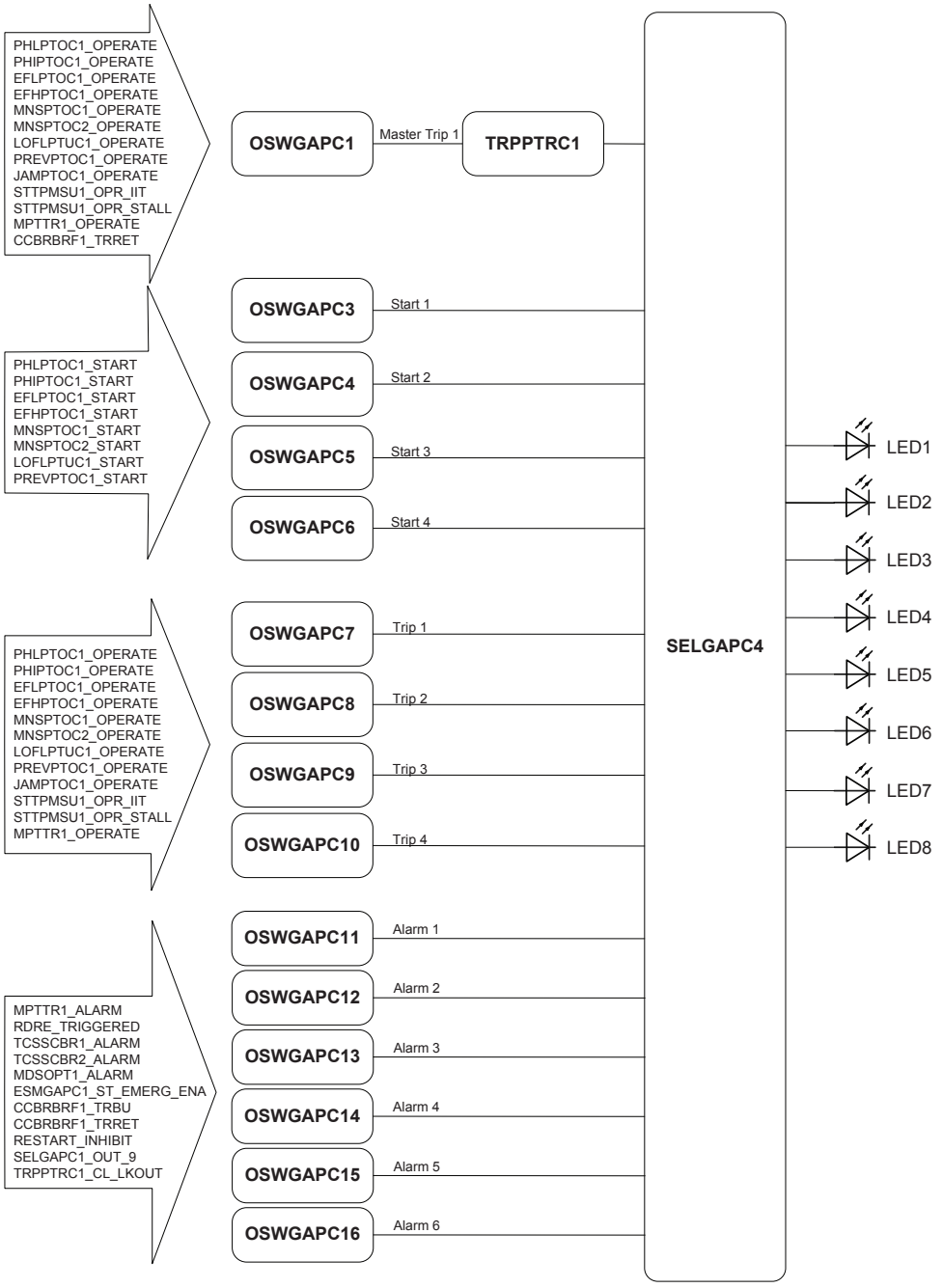


Figure 34: LEDs

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.

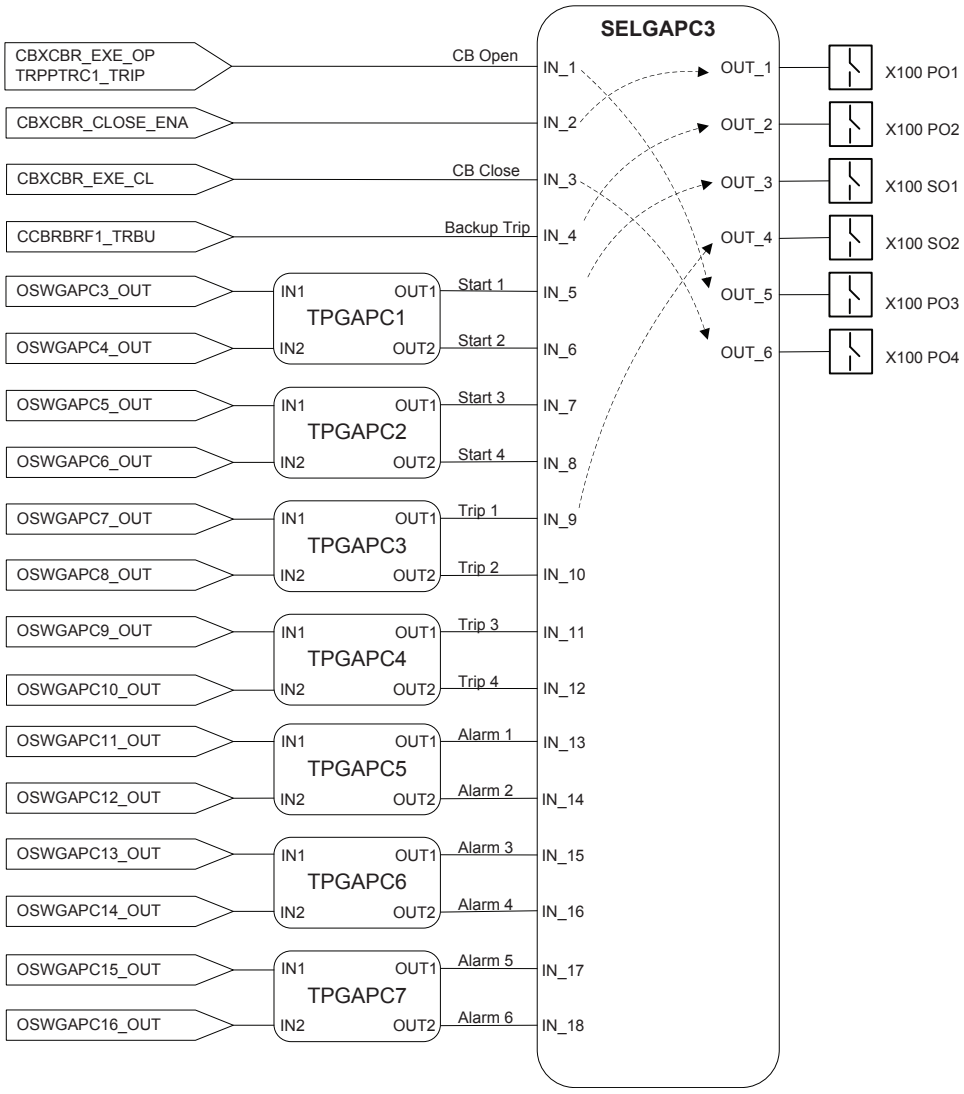


Figure 35: SELGAPC3

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.

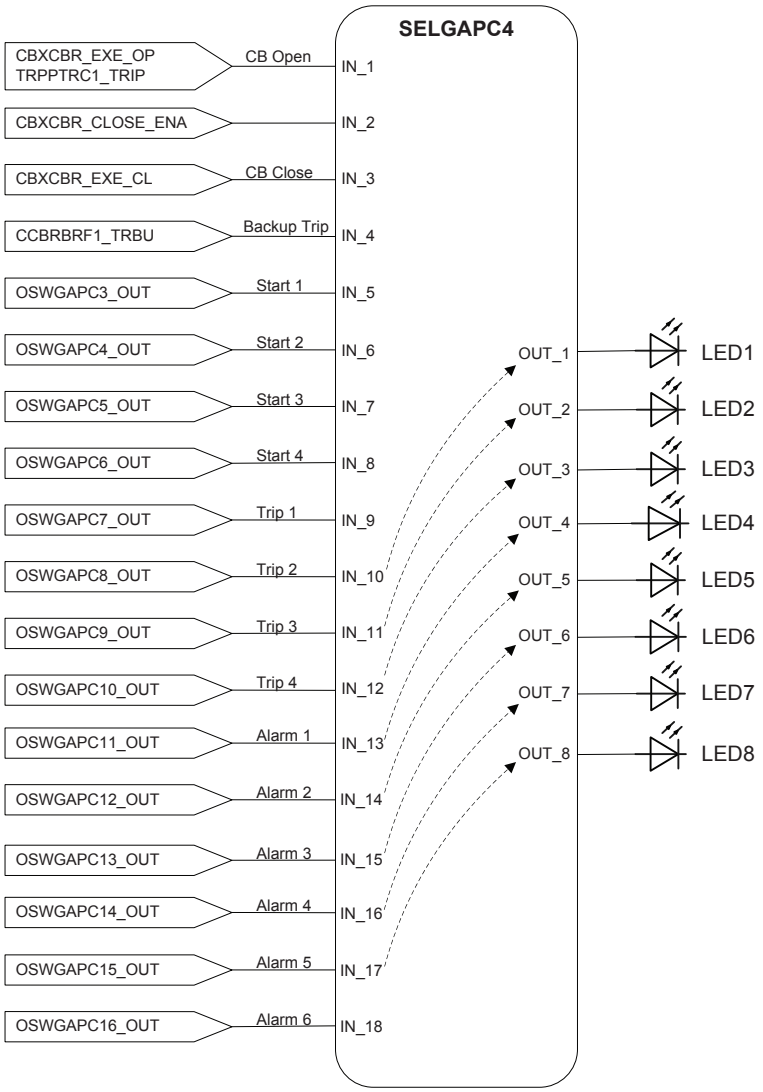


Figure 36: SELGAPC4

Master trip OSWGAPCs

OSWGAPC1 is used to route the protection function operate signals to Master trip. OSWGAPC1 have the same inputs from the protection function operates. The output is connected to the TRPPTRC function.

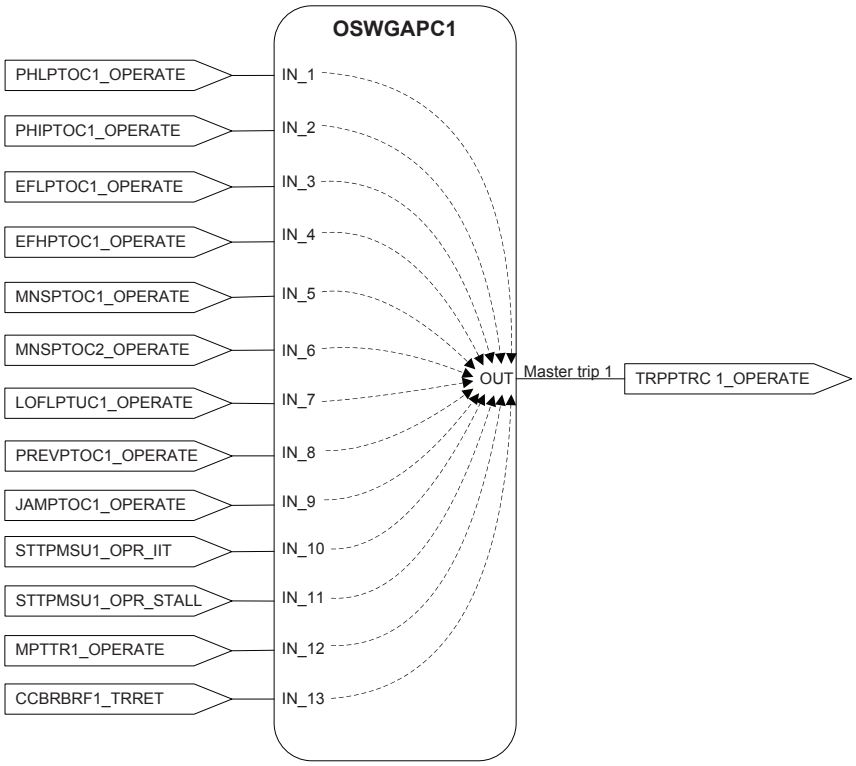


Figure 37: OSWGAPC1

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.

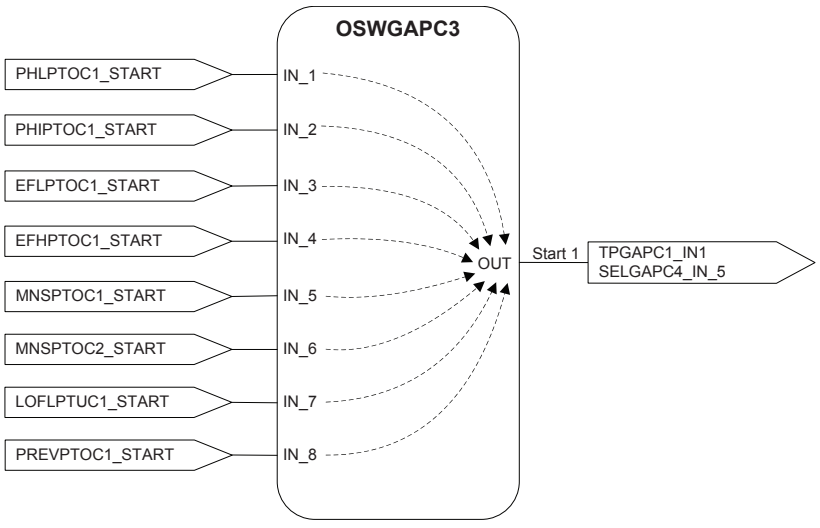


Figure 38: OSWGAPC3

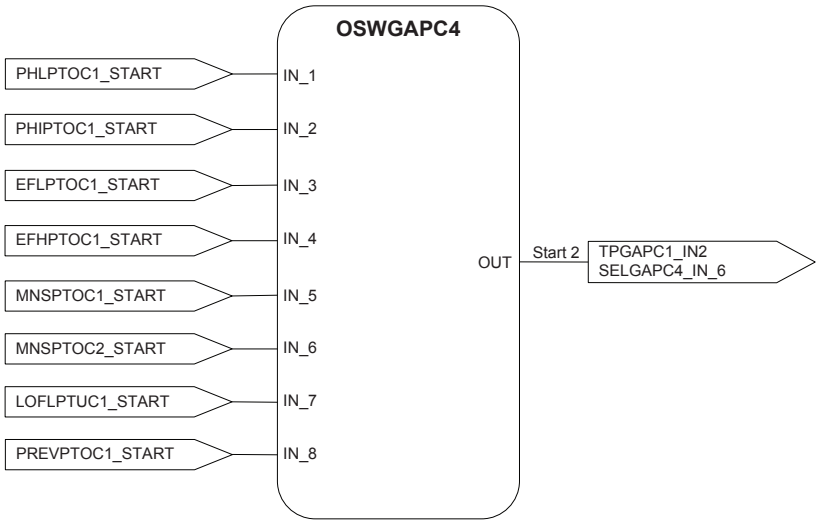


Figure 39: OSWGAPC4

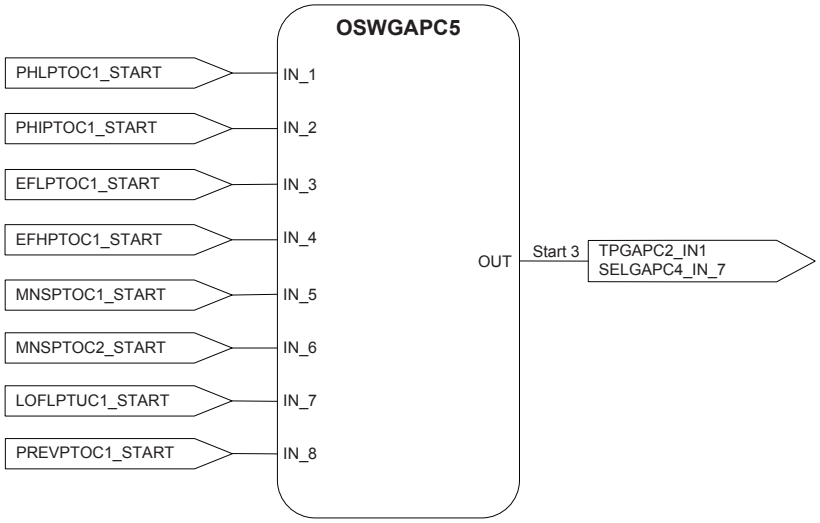


Figure 40: OSWGAPC5

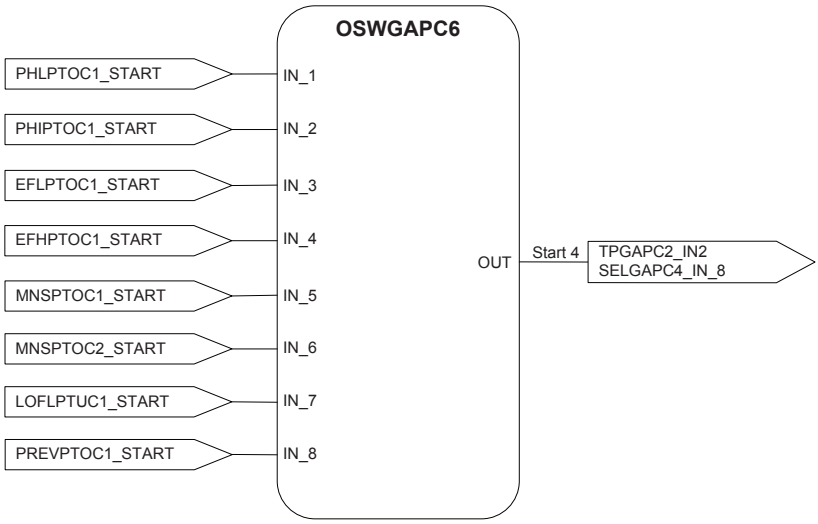


Figure 41: OSWGAPC6

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.

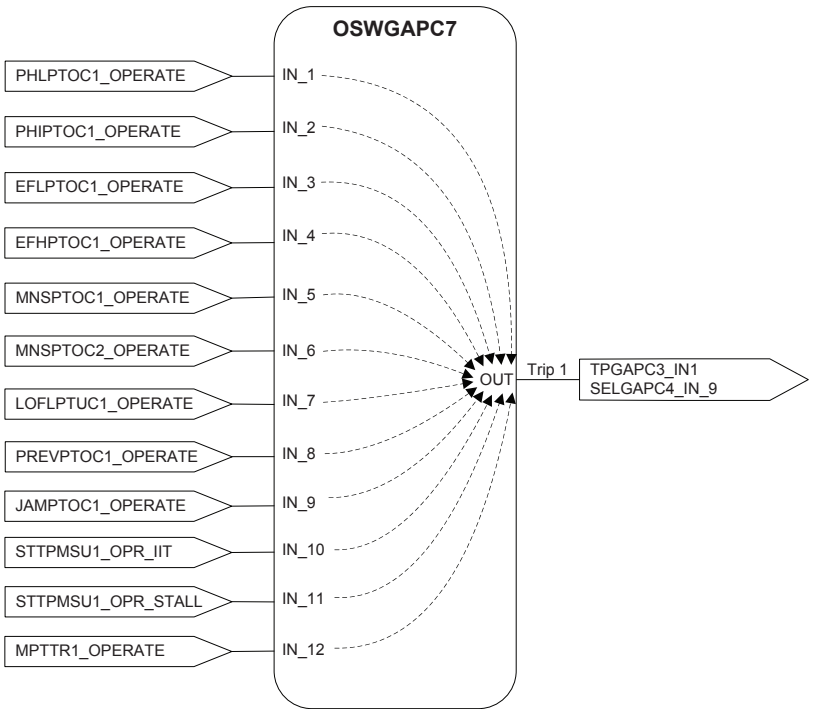


Figure 42: OSWGAPC7

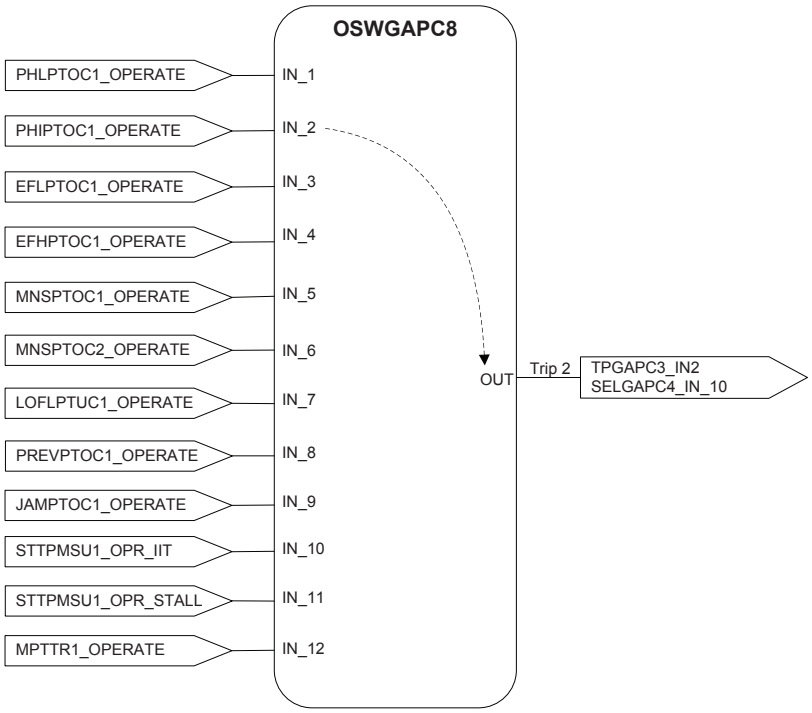


Figure 43: OSWGAPC8

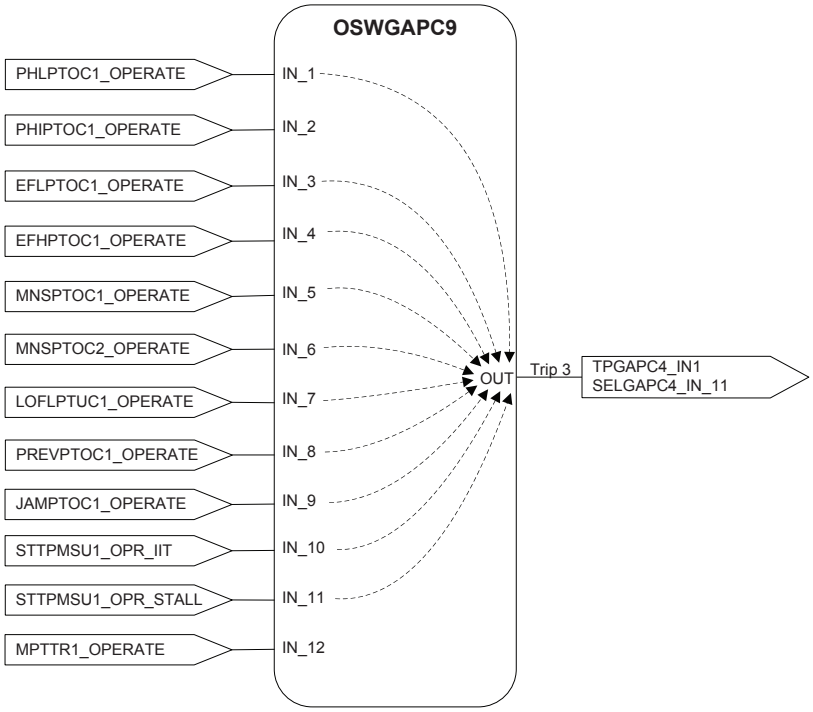


Figure 44: OSWGAPC9

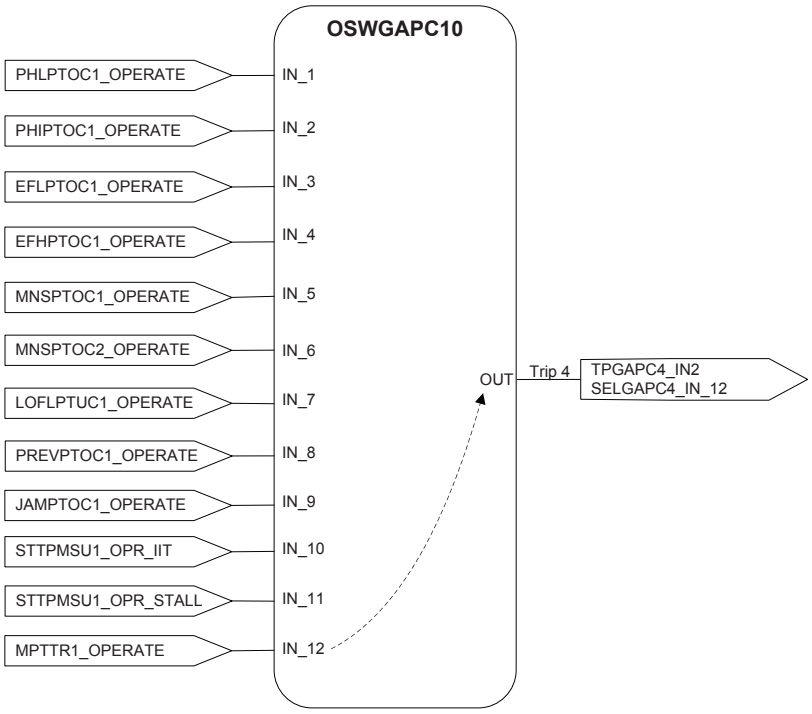


Figure 45: OSWGAPC10

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.

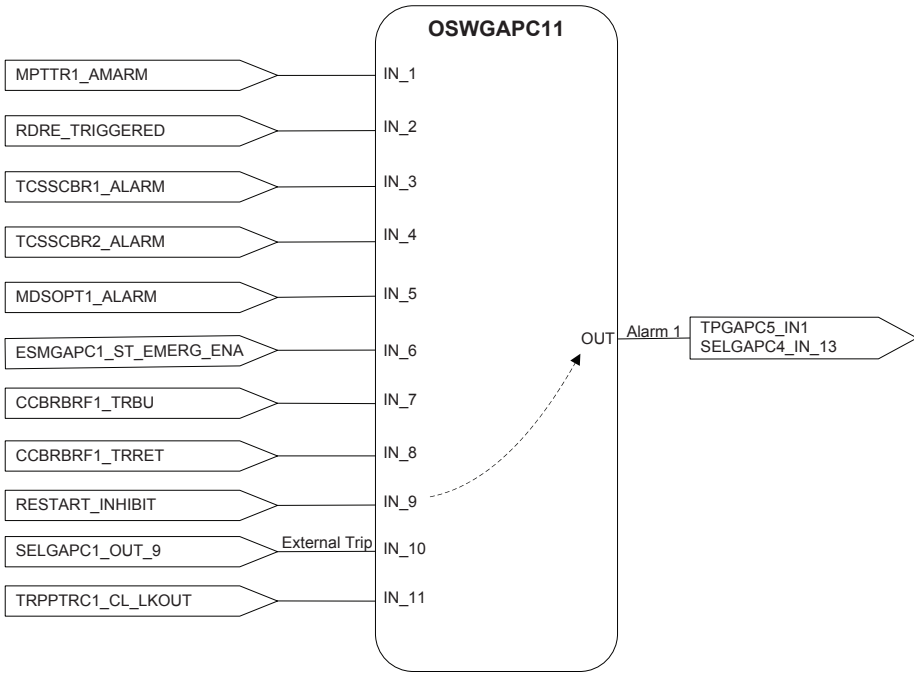


Figure 46: OSWGAPC11

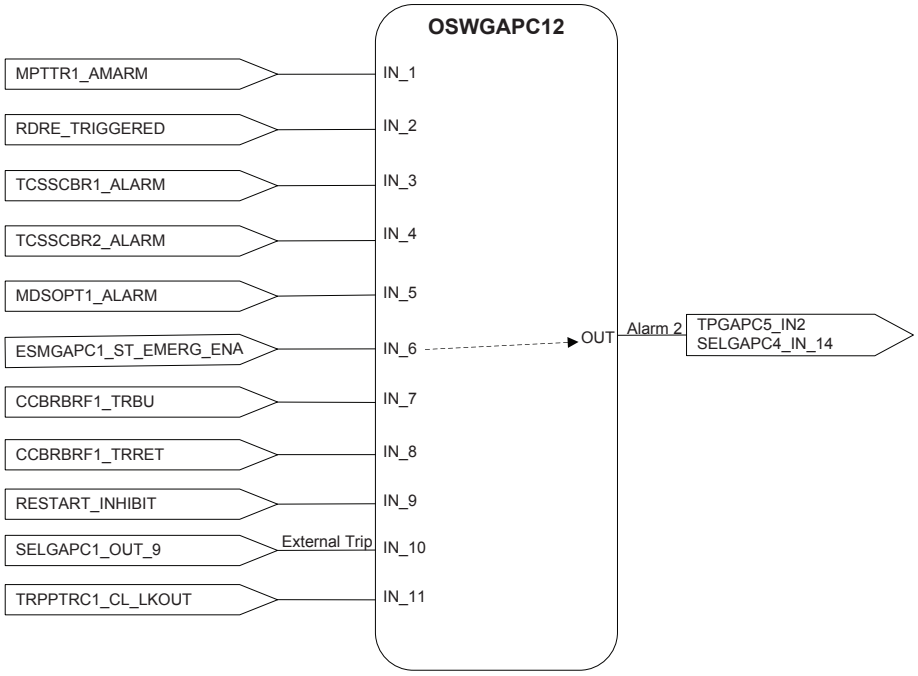


Figure 47: OSWGAPC12

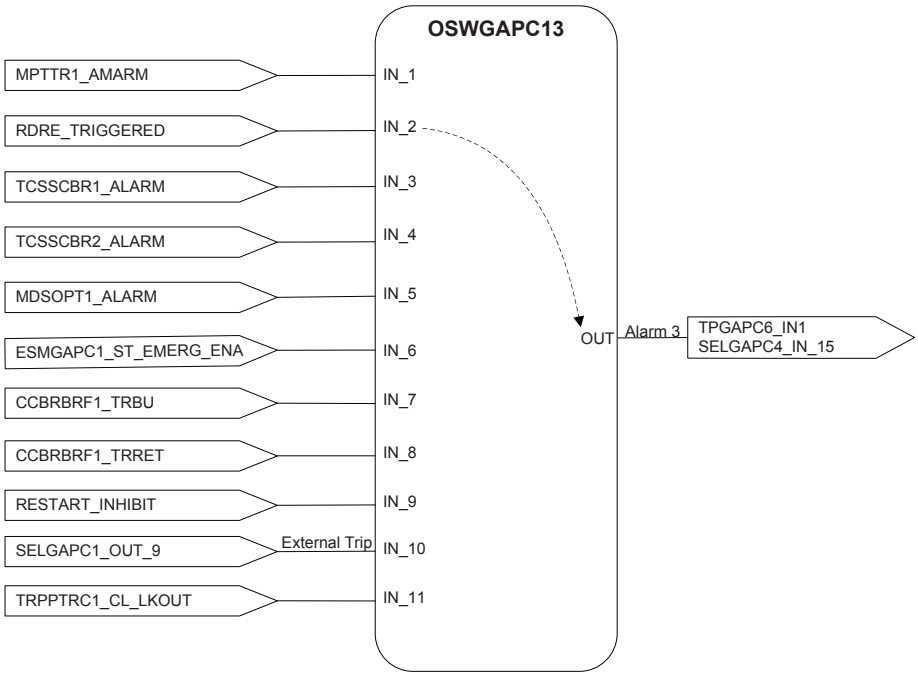


Figure 48: OSWGAPC13

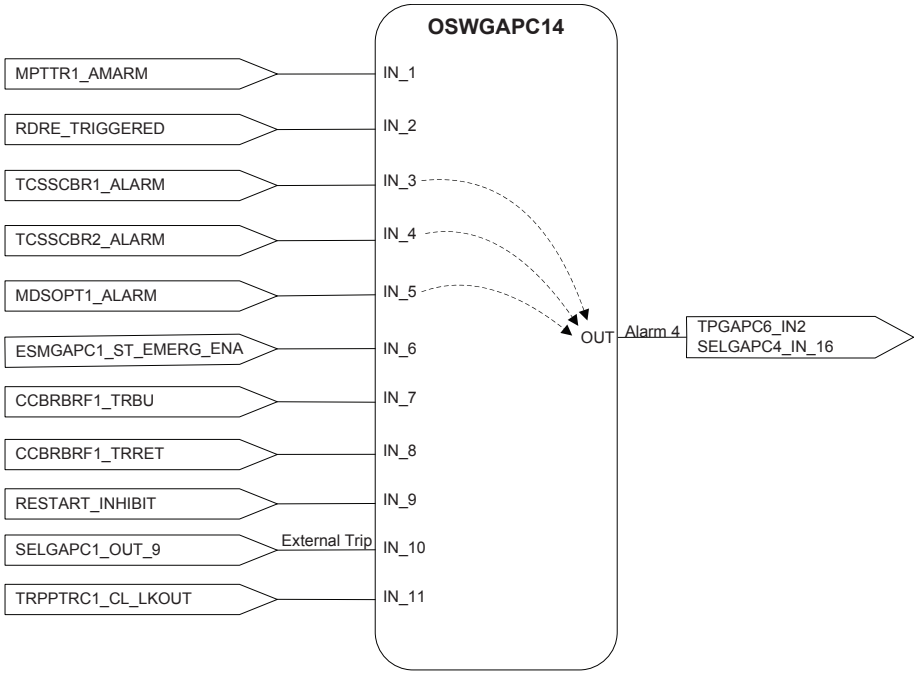


Figure 49: OSWGAPC14

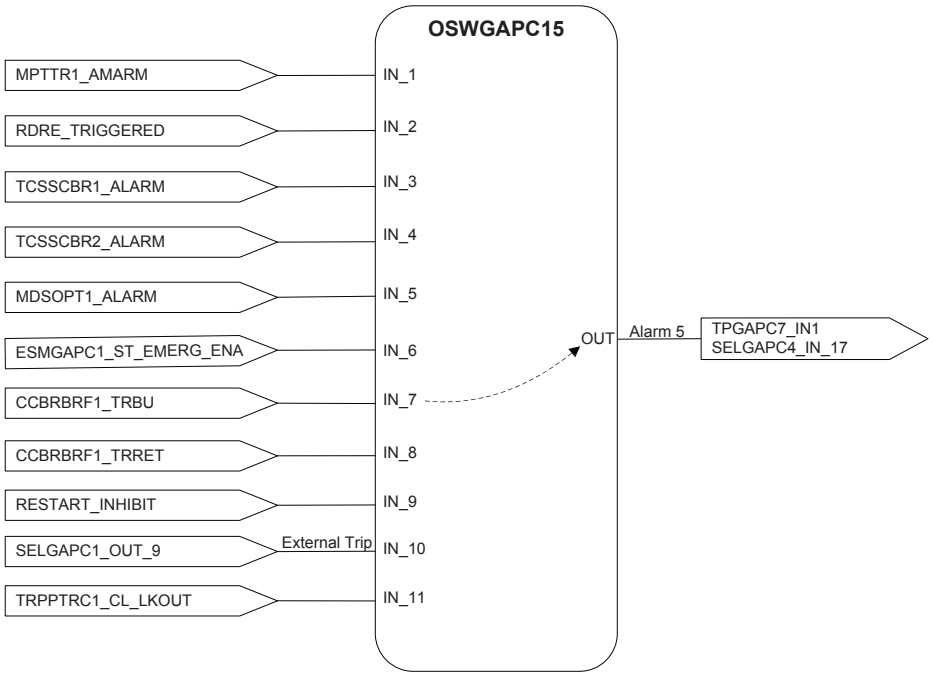


Figure 50: OSWGAPC15

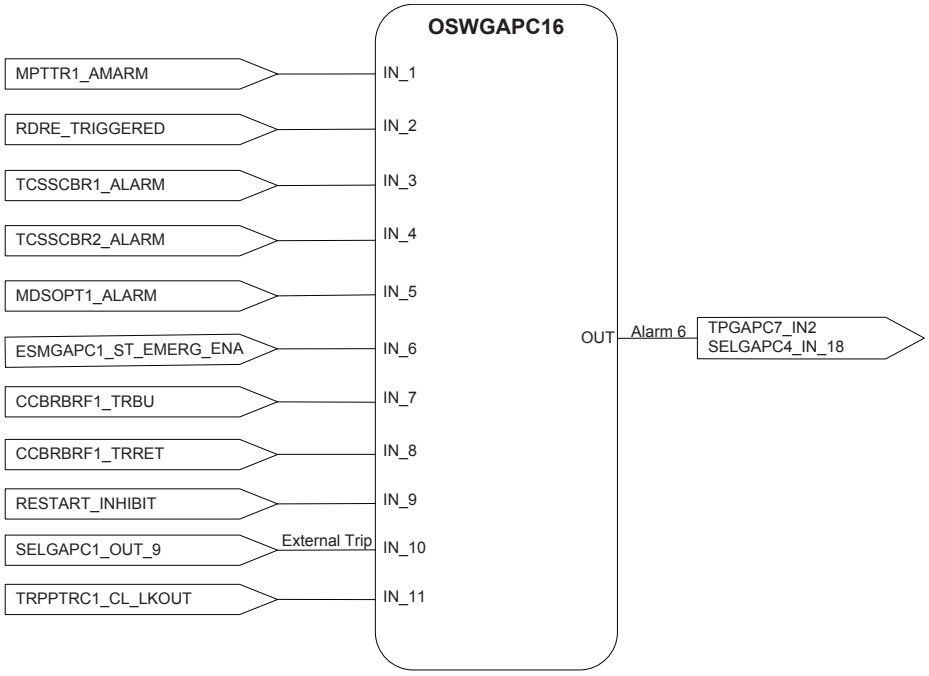


Figure 51: OSWGAPC16

3.4.4.4 GOOSE

In the configuration, there are 20 GOOSERCV_BIN functions and 1 GOOSERCV_MV function. Each GOOSERVC_BIN function can be connected to one received binary GOOSE signal and the GOOSERVC_MV function can be connected to one received analog 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 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.
- GOOSERCV_MV instance 1 is used for ambient temperature measurement from GOOSE. Signal from this GOOSERCV_MV is connected to the input `AMB_TEMP` of MPTTR1.

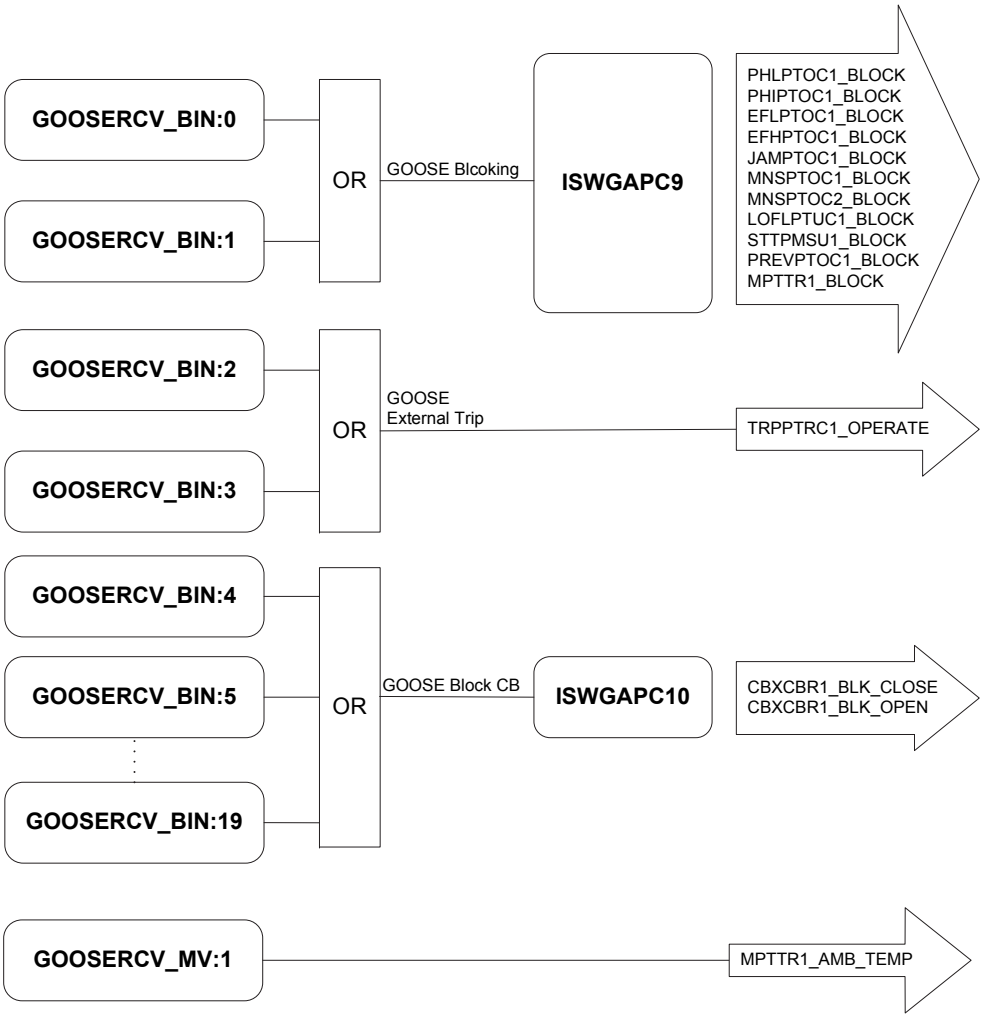


Figure 52: GOOSE overview

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.

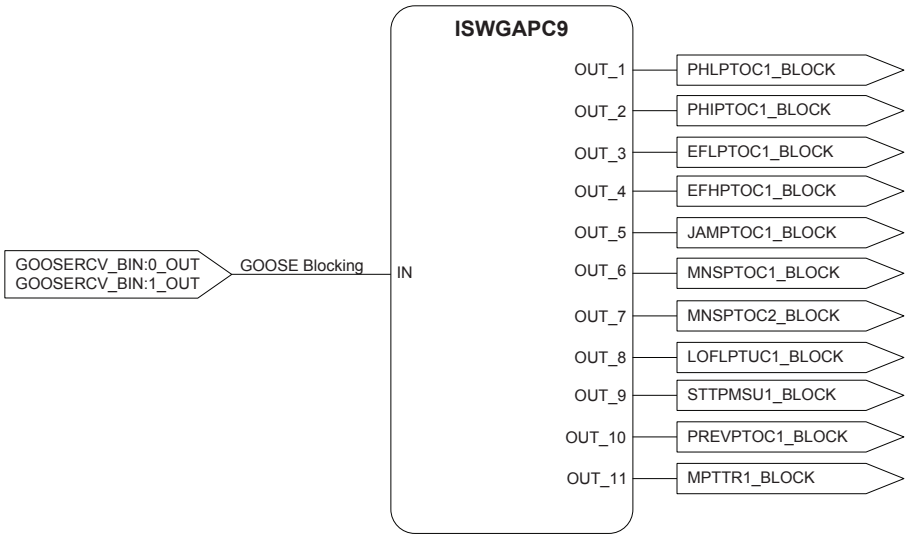


Figure 53: ISWGAPC9

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.

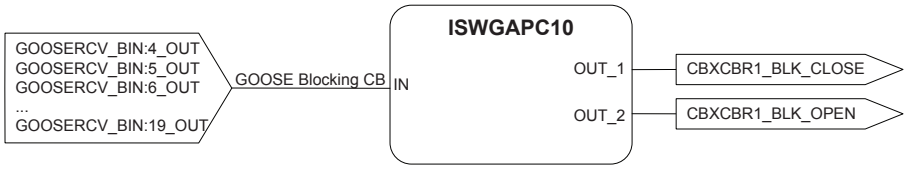


Figure 54: ISWGAPC10

Section 4 Requirements for measurement transformers

4.1 Current transformers

4.1.1 Current transformer requirements for overcurrent protection

For reliable and correct operation of the overcurrent protection, the CT has to be chosen carefully. The distortion of the secondary current of a saturated CT may endanger the operation, selectivity, and co-ordination of protection. However, when the CT is correctly selected, a fast and reliable short circuit protection can be enabled.

The selection of a CT depends not only on the CT specifications but also on the network fault current magnitude, desired protection objectives, and the actual CT burden.

4.1.1.1 Current transformer accuracy class and accuracy limit factor

The rated accuracy limit factor (F_n) is the ratio of the rated accuracy limit primary current to the rated primary current. For example, a protective current transformer of type 5P10 has the accuracy class 5P and the accuracy limit factor 10. For protective current transformers, the accuracy class is designed by the highest permissible percentage composite error at the rated accuracy limit primary current prescribed for the accuracy class concerned, followed by the letter "P" (meaning protection).

Table 16: Limits of errors according to IEC 60044-1 for protective current transformers

Accuracy class	Current error at rated primary current (%)	Phase displacement at rated primary current		Composite error at rated accuracy limit primary current (%)
		minutes	centiradians	
5P	±1	±60	±1.8	5
10P	±3	-	-	10

The accuracy classes 5P and 10P are both suitable for non-directional overcurrent protection. The 5P class provides a better accuracy.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy.

In practise, the actual accuracy limit factor (F_a) differs from the rated accuracy limit factor (F_n) and is proportional to the ratio of the rated CT burden and the actual CT burden.

The actual accuracy limit factor is calculated using the formula:

$$F_a \approx F_n \times \frac{|S_{in} + S_n|}{|S_{in} + S|}$$

F_n	the accuracy limit factor with the nominal external burden S_n
S_{in}	the internal secondary burden of the CT
S	the actual external burden

4.1.1.2 Non-directional overcurrent protection

The current transformer selection

Non-directional overcurrent protection does not set high requirements on the accuracy class or on the actual accuracy limit factor (F_a) of the CTs. It is, however, recommended to select a CT with F_a of at least 20.

The nominal primary current I_{1n} should be chosen in such a way that the thermal and dynamic strength of the current measuring input of the protection relay is not exceeded. This is always fulfilled when

$I_{1n} > I_{kmax} / 100$,

I_{kmax} is the highest fault current.

The saturation of the CT protects the measuring circuit and the current input of the protection relay. For that reason, in practice, even a few times smaller nominal primary current can be used than given by the formula.

Recommended start current settings

If I_{kmin} is the lowest primary current at which the highest set overcurrent stage is to operate, the start current should be set using the formula:

Current start value < $0.7 \times (I_{kmin} / I_{1n})$

I_{1n} is the nominal primary current of the CT.

The factor 0.7 takes into account the protection relay inaccuracy, current transformer errors, and imperfections of the short circuit calculations.

The adequate performance of the CT should be checked when the setting of the high set stage overcurrent protection is defined. The operate time delay caused by the CT saturation is typically small enough when the overcurrent setting is noticeably lower than F_a.

When defining the setting values for the low set stages, the saturation of the CT does not need to be taken into account and the start current setting is simply according to the formula.

Delay in operation caused by saturation of current transformers

The saturation of CT may cause a delayed protection relay operation. To ensure the time selectivity, the delay must be taken into account when setting the operate times of successive protection relays.

With definite time mode of operation, the saturation of CT may cause a delay that is as long as the time constant of the DC component of the fault current, when the current is only slightly higher than the starting current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the operate time setting.

With inverse time mode of operation, the delay should always be considered as being as long as the time constant of the DC component.

With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen using the formula:

$F_a > 20 \times$ *Current start value* / I_{1n}

The *Current start value* is the primary start current setting of the protection relay.

4.1.1.3 Example for non-directional overcurrent protection

The following figure describes a typical medium voltage feeder. The protection is implemented as three-stage definite time non-directional overcurrent protection.

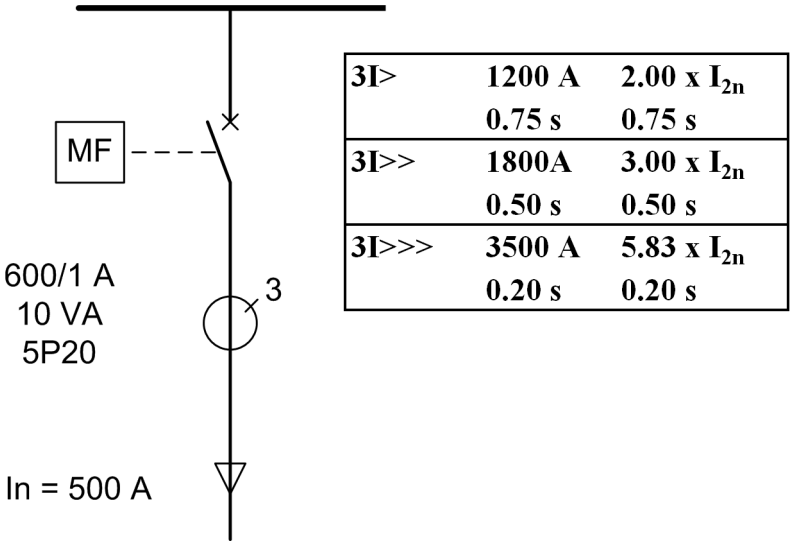


Figure 55: Example of three-stage overcurrent protection

The maximum three-phase fault current is 41.7 kA and the minimum three-phase short circuit current is 22.8 kA. The actual accuracy limit factor of the CT is calculated to be 59.

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 55). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 55.

For the application point of view, the suitable setting for instantaneous stage (I>>>) in this example is 3 500 A (5.83 × I_{2n}). I_{2n} is the 1.2 multiple with nominal primary current of the CT. For the CT characteristics point of view, the criteria given by the current transformer selection formula is fulfilled and also the protection relay setting is considerably below the F_a. In this application, the CT rated burden could have been selected much lower than 10 VA for economical reasons.

Section 5 Protection relay's physical connections

5.1 Inputs

5.1.1 Energizing inputs

5.1.1.1 Phase 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 17: Phase 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 18: 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 19: 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 20: 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 21: 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 22: 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 23: 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
CT	Current transformer
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
HMI	Human-machine interface
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
IED	Intelligent electronic device

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.
NPS	Negative phase sequence
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
REM611	Motor 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
WAN	Wide area network
WHMI	Web human-machine interface

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