RELION® 611 SERIES

Feedder Protection and Control REF611

Application Manual

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Warranty

Please inquire about the terms of warranty from your nearest ABB representative.

www.abb.com/relion

Disclaimer

Conformity

This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2014/30/EU) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2014/35/EU). This conformity is the result of tests conducted by ABB in accordance with the product standard EN 60255-26 for the EMC directive, and with the product standards EN 60255-1 and EN 60255-27 for the low voltage directive. The product is designed in accordance with the international standards of the IEC 60255 series.

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

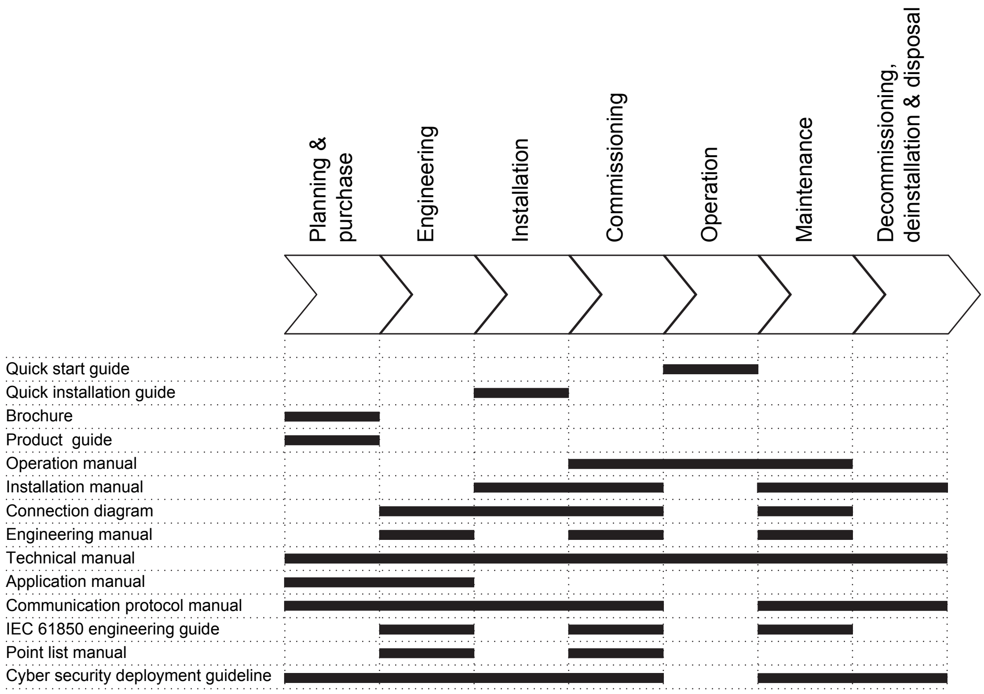


Figure 1: The intended use of manuals in different lifecycles

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, high stage, instance 1	PHHPTOC1	3I>> (1)	51P-2 (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	3I>> (2)	51P-2 (2)
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, low stage, instance 2	EFLPTOC2	Io> (2)	51N-1 (2)
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Non-directional earth-fault protection, high stage, instance 1	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>>	50N/51N
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	3I> -> (1)	67-1(1)
Three-phase directional overcurrent protection, low stage, instance 2	DPHLPDOC2	3I> -> (2)	67-1(2)
Three-phase directional overcurrent protection, high stage, instance 1	DPHHPDOC1	3I>> -> (1)	67-2(1)
Directional earth-fault protection, low stage, instance 1	DEFLPDEF1	Io> -> (1)	67N-1 (1)
Directional earth-fault protection, low stage, instance 2	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> ->	67N-2
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF	67NIEF
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	I2> (1)	46 (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1>	46PD
Residual overvoltage protection, instance 1	ROVPTOV1	Uo> (1)	59G (1)
Residual overvoltage protection, instance 2	ROVPTOV2	Uo> (2)	59G (2)
Residual overvoltage protection, instance 3	ROVPTOV3	Uo> (3)	59G (3)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F	49F
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF	51BF/51NBF
Three-phase inrush detector	INRPHAR1	3I2f>	68
Master trip, instance 1	TRPPTRC1	Master Trip (1)	94/86 (1)
Master trip, instance 2	TRPPTRC2	Master Trip (2)	94/86 (2)
Switch onto fault	CBPSOF1	SOTF	SOTF
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
Move (8 pcs), instance 1	MVGAPC	MV (1)	MV (1)
Control			
Table continues on next page			

Function	IEC 61850	IEC 60617	IEC-ANSI
Circuit-breaker control	CBXCBR1	I <-> O CB	I <-> O CB
Autoreclosing	DARREC1	O -> I	79
Condition monitoring and supervision			
Trip circuit supervision, instance 1	TCSSCBR1	TCS (1)	TCM (1)
Trip circuit supervision, instance 2	TCSSCBR2	TCS (2)	TCM (2)
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
Three-phase voltage measurement, instance 1	VMMXU1	3U	3U
Sequence voltage measurement, instance 1	VSMSQI1	U1, U2, U0	U1, U2, U0
Residual voltage measurement	RESVMMXU1	Uo	Vn
Frequency measurement, instance 1	FMMXU1	f	f
Three-phase power and energy measurement, instance 1	PEMMXU1	P, E	P, E

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

Section 2 REF611 overview

2.1 Overview

REF611 is a dedicated feeder relay for the protection, control, measurement and supervision of utility substations and industrial power systems including radial, looped and meshed distribution networks with or without distributed power generation.

REF611 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	• New configuration C • Additions/changes for configuration A and B • 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 • Switch onto fault

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 Ver.2.7 or later
- REF611 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

- Autoreclosing
- 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 contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X120	AI/BI module	Only with configuration A: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1] 1 residual voltage input (60...120 V) 3 binary inputs
			Only with configurations B and C: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A or 0.2/1 A)[1] 4 binary inputs
Case	X130	Optional BI/O module	Optional for configurations B and C: 6 binary inputs 3 SO contacts
		AI/BI module	Only with configuration C: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs
	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 configurations

Conf.	Analog channels		Binary channels	
	CT	VT	BI	BO
A	4	1	3(9)[1)]	6(9)[1)]
B	4	-	4(10)[1)]	6(9)[1)]
C	4	4	8	6

1) With optional BIO module

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.

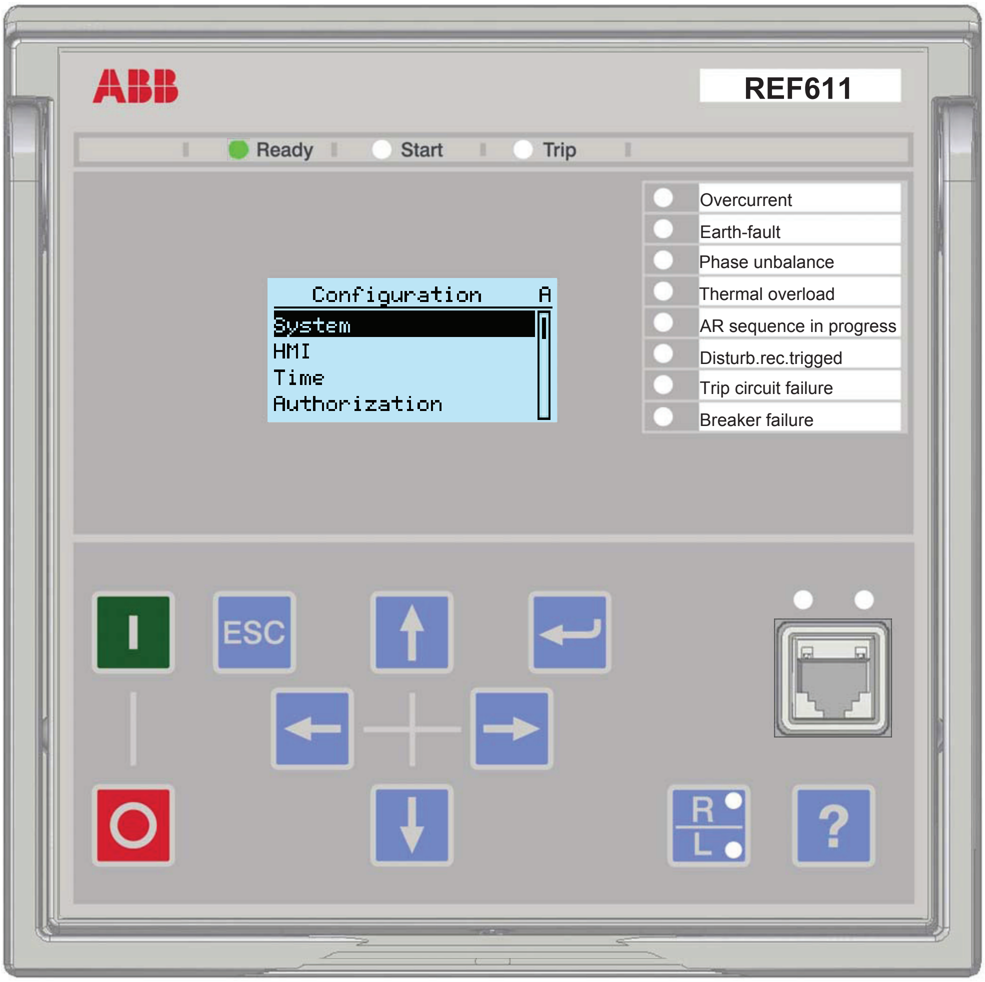


Figure 2: Example of the LHMI

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.

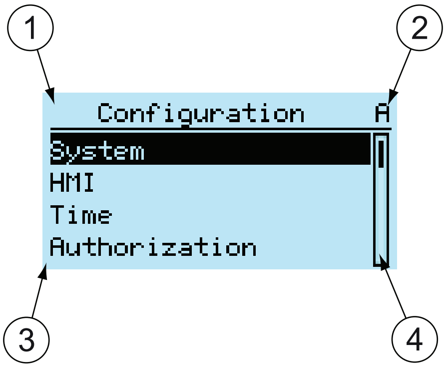


Figure 3: Display layout

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.

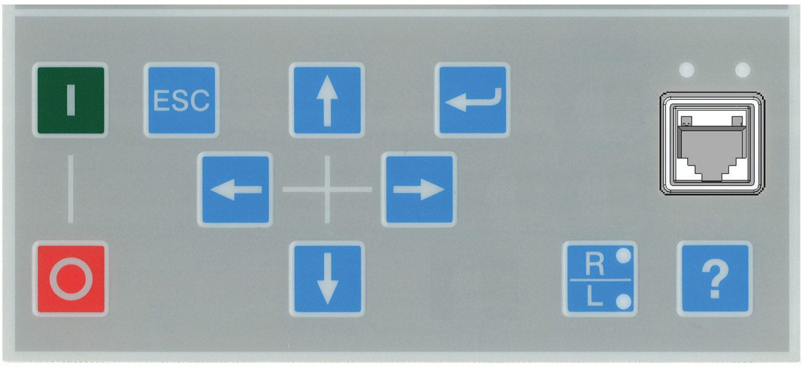


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

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.

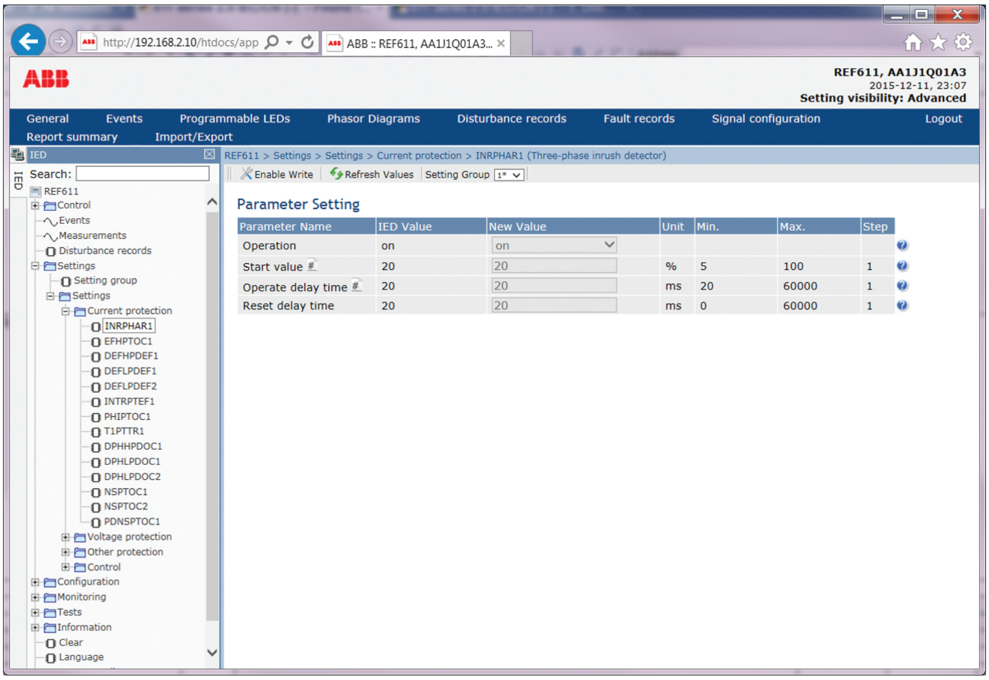


Figure 5: Example view of the WHMI

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.

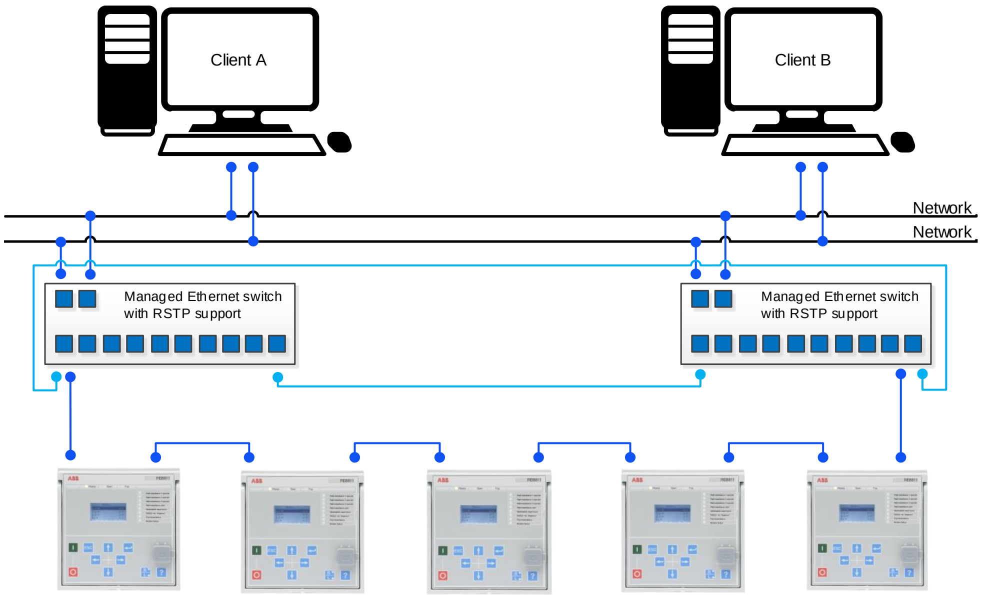


Figure 6: Self-healing Ethernet ring solution

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.

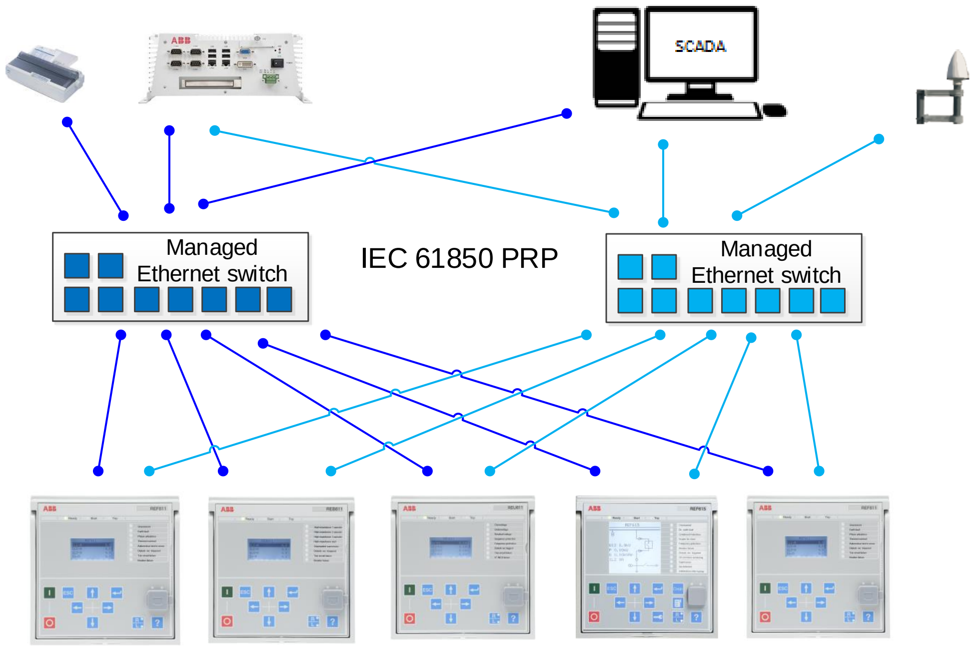


Figure 7: PRP solution

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.

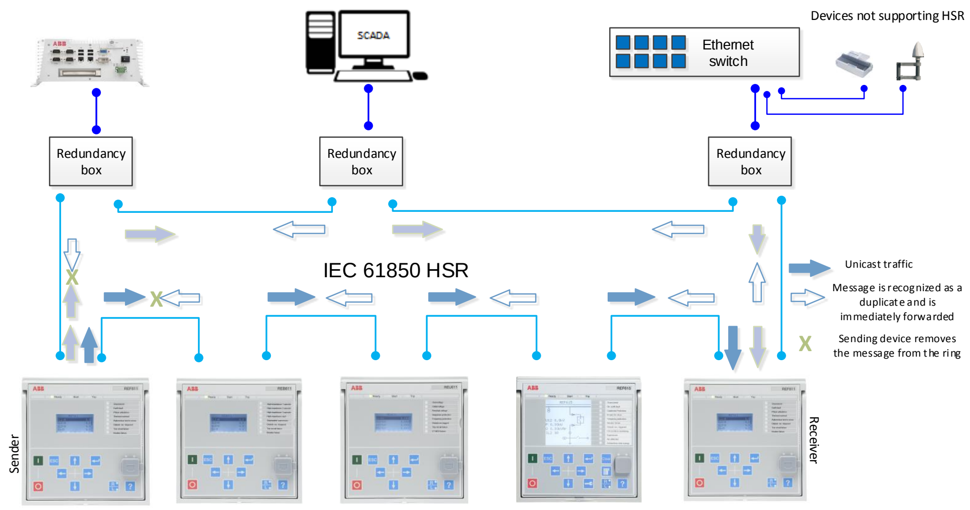


Figure 8: HSR solution

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 REF611 standardized configurations

3.1 Standardized configurations

REF611 is available in three alternative configurations.

To increase the user-friendliness of the configurations 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 configurations

Description	Conf.
Non-directional overcurrent and directional earth-fault protection	A
Non-directional overcurrent and earth-fault protection	B
Directional overcurrent and earth-fault protection	C

Table 10: Supported functions

Function	IEC 61850	A	B	C
Protection				
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1	
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2	
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1
Non-directional earth-fault protection, low stage	EFLPTOC		2[1)]	
Non-directional earth-fault protection, high stage	EFHPTOC		1[1)]	
Non-directional earth-fault protection, instantaneous stage	EFIPTOC		1[1)]	
Three-phase directional overcurrent protection, low stage	DPHLPDOC			2
Three-phase directional overcurrent protection, high stage	DPHHPDOC			1
Directional earth-fault protection, low stage	DEFLPDEF	2[1)2)]		2[1)2)]
Directional earth-fault protection, high stage	DEFHPDEF	1[1)2)]		1[1)2)]
Transient/intermittent earth-fault protection	INTRPTEF	1		1
Non-directional (cross-country) earth fault protection, using calculated Io	EFHPTOC	1[3)]		1[3)]
Negative-sequence overcurrent protection	NSPTOC	2	2	2
Phase discontinuity protection	PDNSPTOC	1	1	1
Residual overvoltage protection	ROVPTOV	3[2)]		3[2)]
Table continues on next page				

Function	IEC 61850	A	B	C
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	1	1	1
Circuit breaker failure protection	CCBRBRF	1	1	1
Three-phase inrush detector	INRPHAR	1	1	1
Master trip	TRPPTRC	2	2	2
Switch onto fault	CBPSOF	1	1	1
Control				
Circuit-breaker control	CBXCBR	1	1	1
Autoreclosing	DARREC	(1)	(1)	(1)
Condition monitoring and supervision				
Trip circuit supervision	TCSSCBR	2	2	2
Logging				
Disturbance recorder	RDRE	1	1	1
Fault recorder	FLTRFRC	1	1	1
Measurement				
Three-phase current measurement	CMMXU	1	1	1
Sequence current measurement	CSMSQI	1	1	1
Residual current measurement	RESCMMXU	1	1	1
Three-phase voltage measurement	VMMXU			1
Sequence voltage measurement	VSMSQI			1
Residual voltage measurement	RESVMMXU	1		1
Frequency measurement	FMMXU			1
Three-phase power and energy measurement	PEMMXU			1
Other				
Input switch group	ISWGAPC	10	10	10
Output switch group	OSWGAPC	21	21	21
Selector	SELGAPC	6	6	6
Minimum pulse timer (2 pcs)	TPGAPC	10	10	10
Move (8 pcs)	MVGAPC	1	1	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"
2) "Uo measured" is always used
3) Io selectable by parameter and default value is "Io calculated"

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.

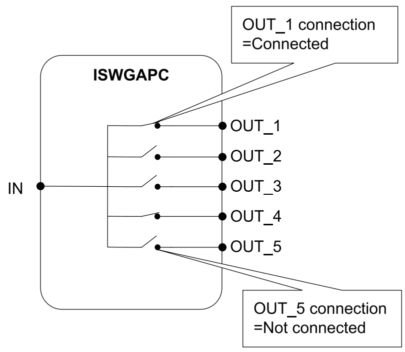


Figure 9: Input switch group ISWGAPC

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.

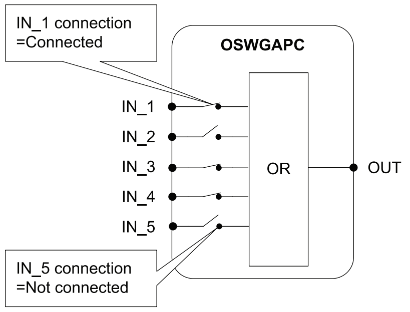


Figure 10: Output switch group OSWGAPC

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.

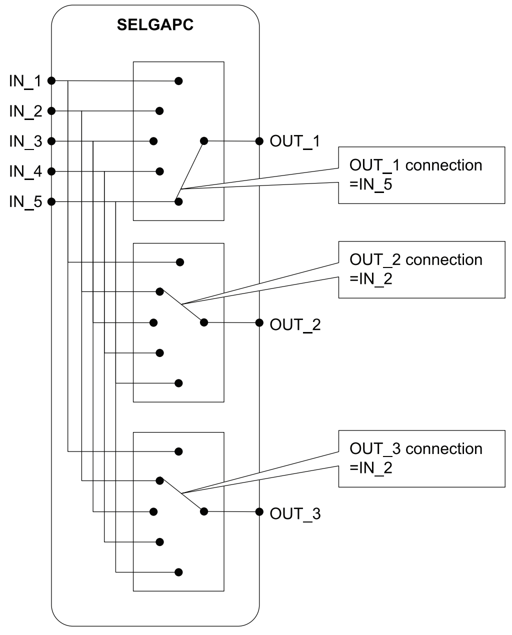


Figure 11: Selector switch group SELGAPC

3.3 Connection diagrams

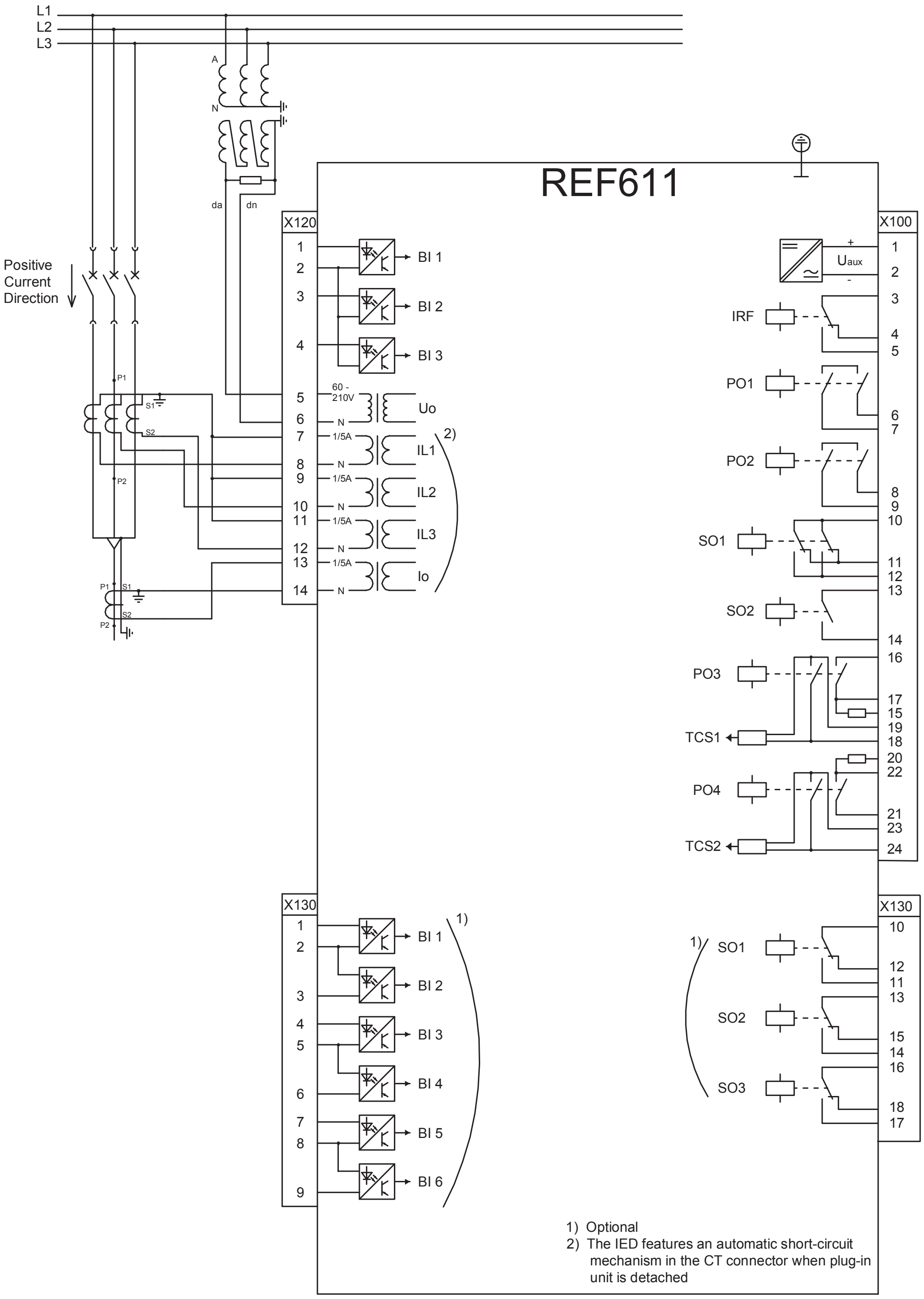


Figure 12: Connection diagram for configuration A

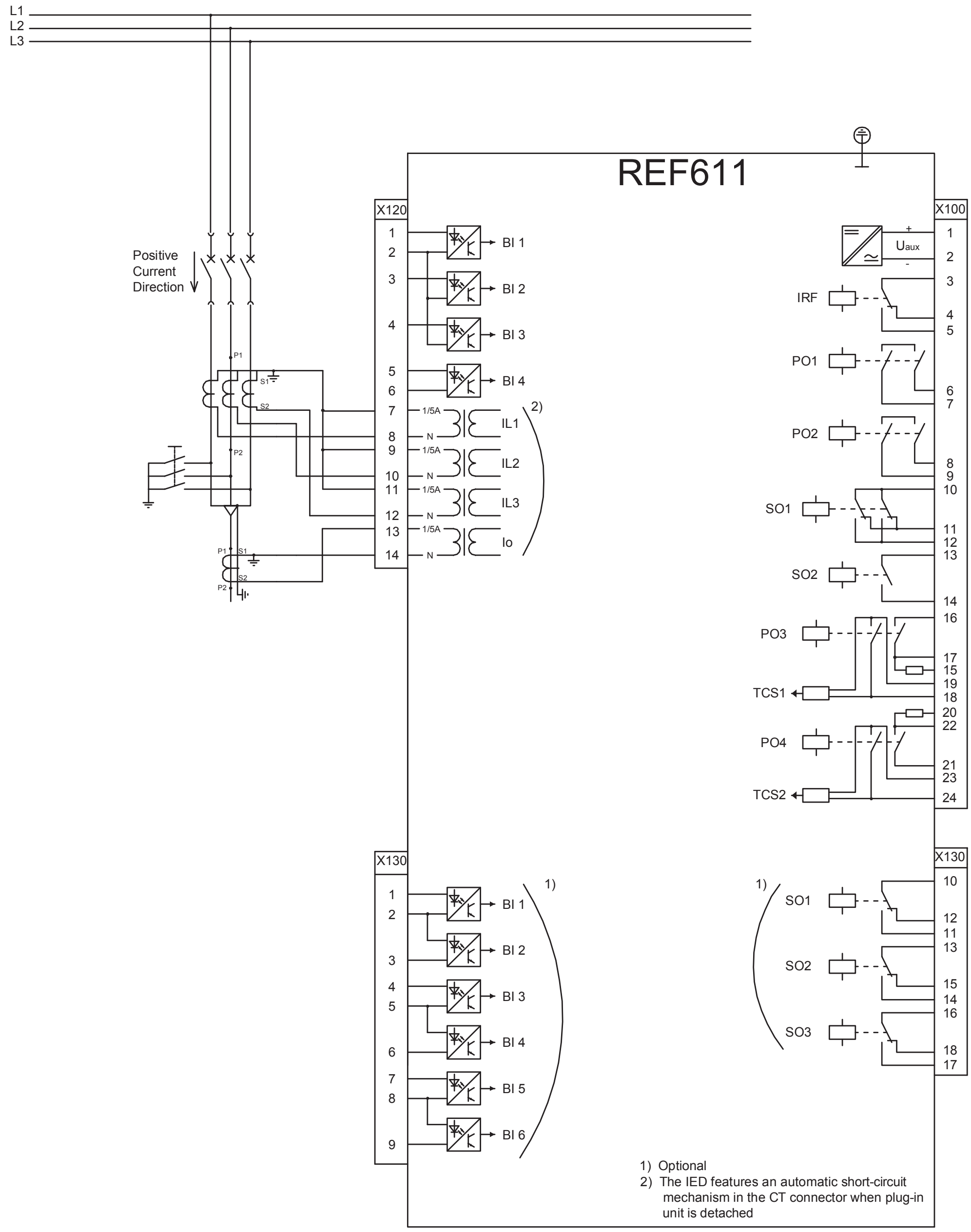


Figure 13: Connection diagram for configuration B

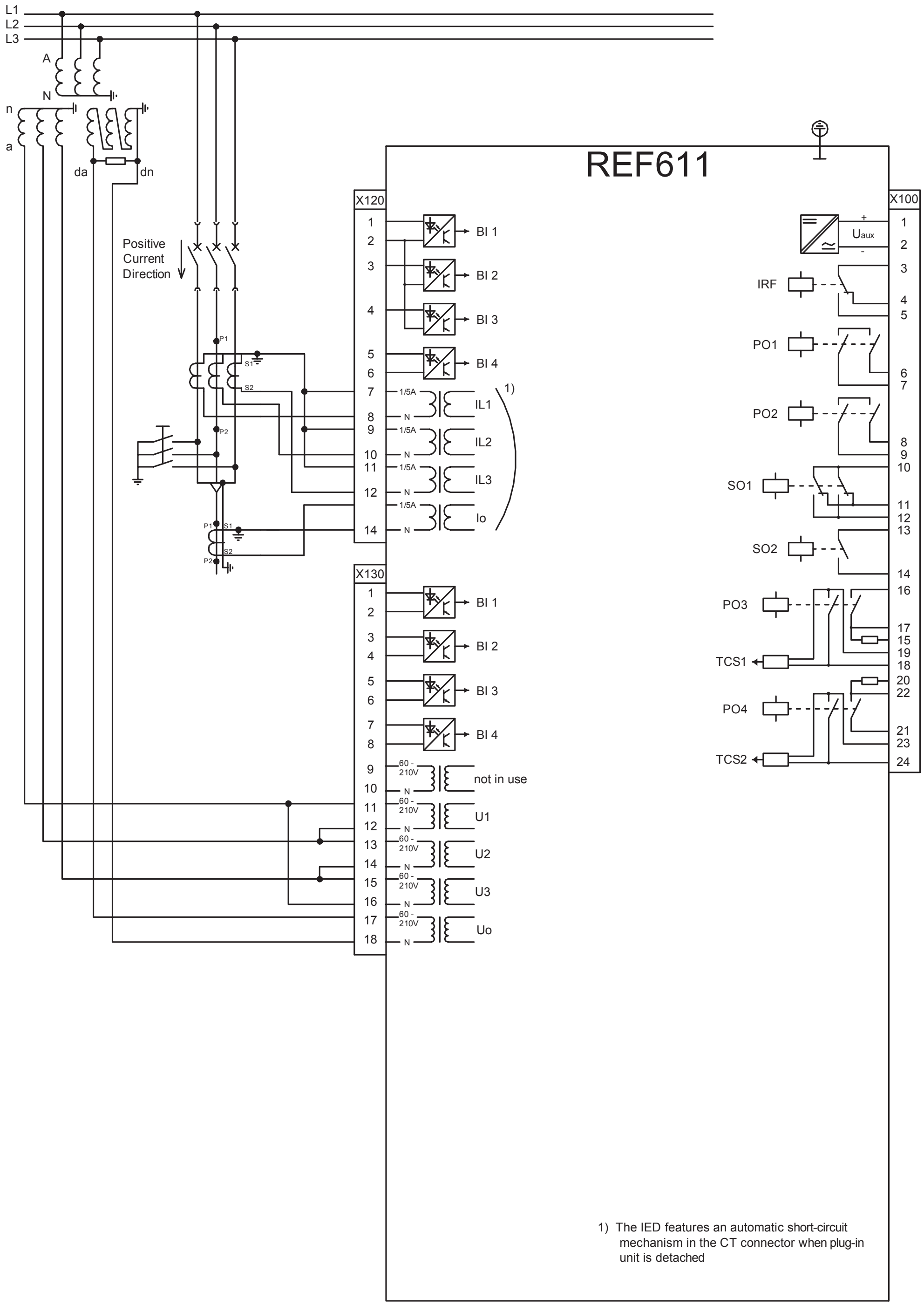


Figure 14: Connection diagram for configuration C

3.4 Configuration A

3.4.1 Applications

Configuration A for non-directional overcurrent and directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks.

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

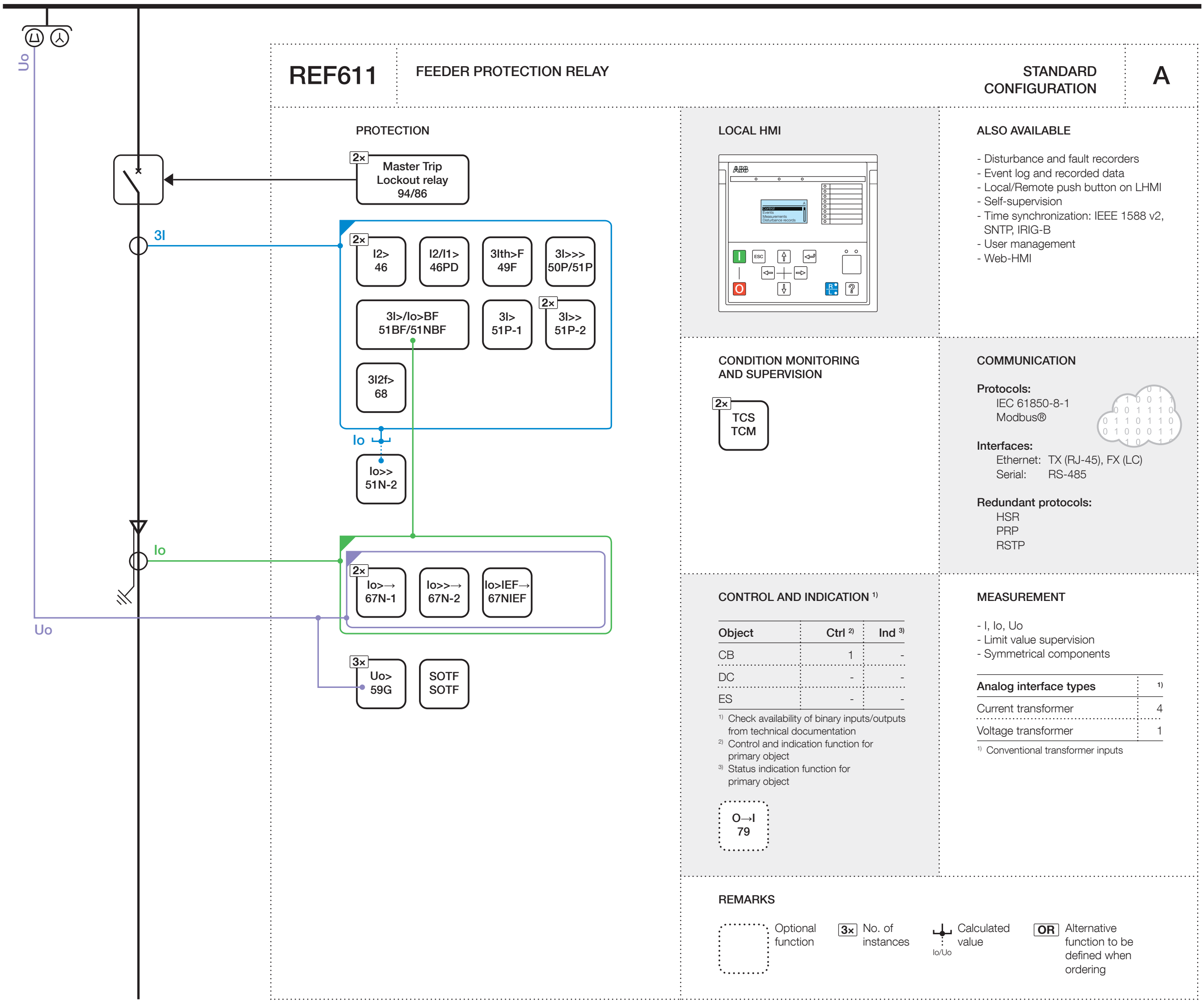


Figure 15: Functionality overview for configuration A

3.4.2.1 Default I/O connections

Table 11: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	Blocking of overcurrent instantaneous stage	X120:1-2
X120-BI2	Circuit breaker closed position indication	X120:3,2
X120-BI3	Circuit breaker open position indication	X120:4,2

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 circuit breaker/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	Non-directional overcurrent operate
2	Earth fault protection operate
3	Negative-sequence overcurrent/phase discontinuity operate
4	Thermal overload alarm
5	Autoreclose in progress
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
5	Uo

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 eight 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. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

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.

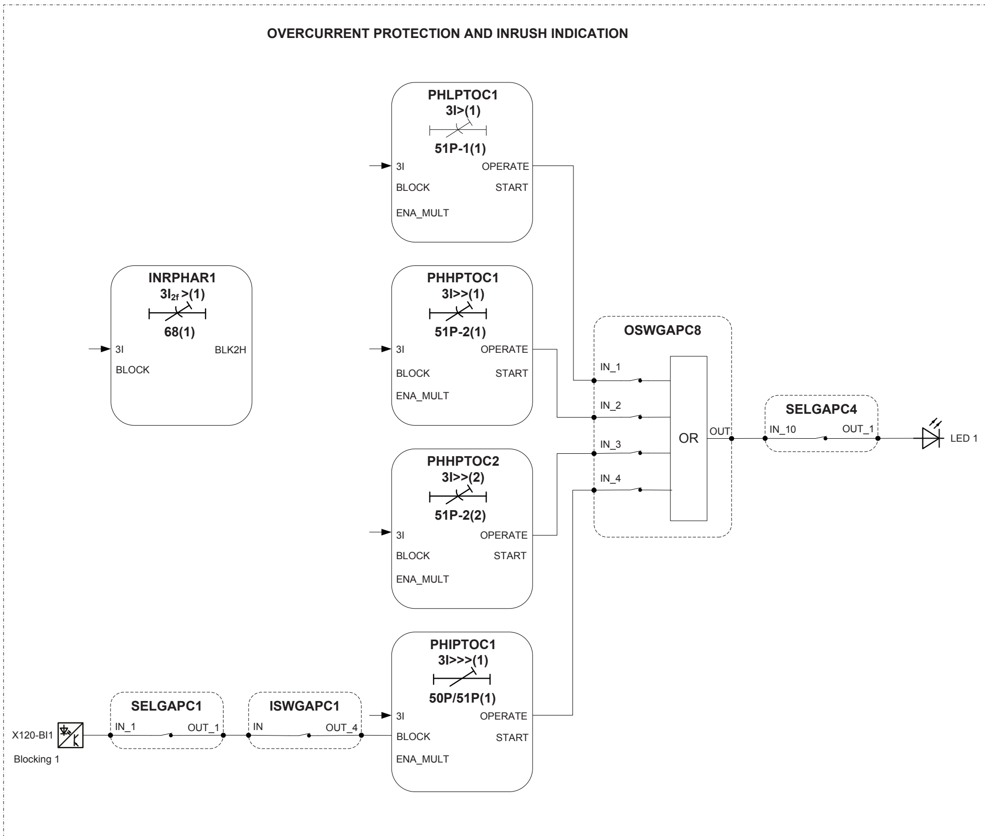


Figure 16: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage PHIPTOC1 can be blocked by energizing the binary input (X120:1-2). The inrush detection block's INRPHAR1 output `BLK2H` enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LED 1.

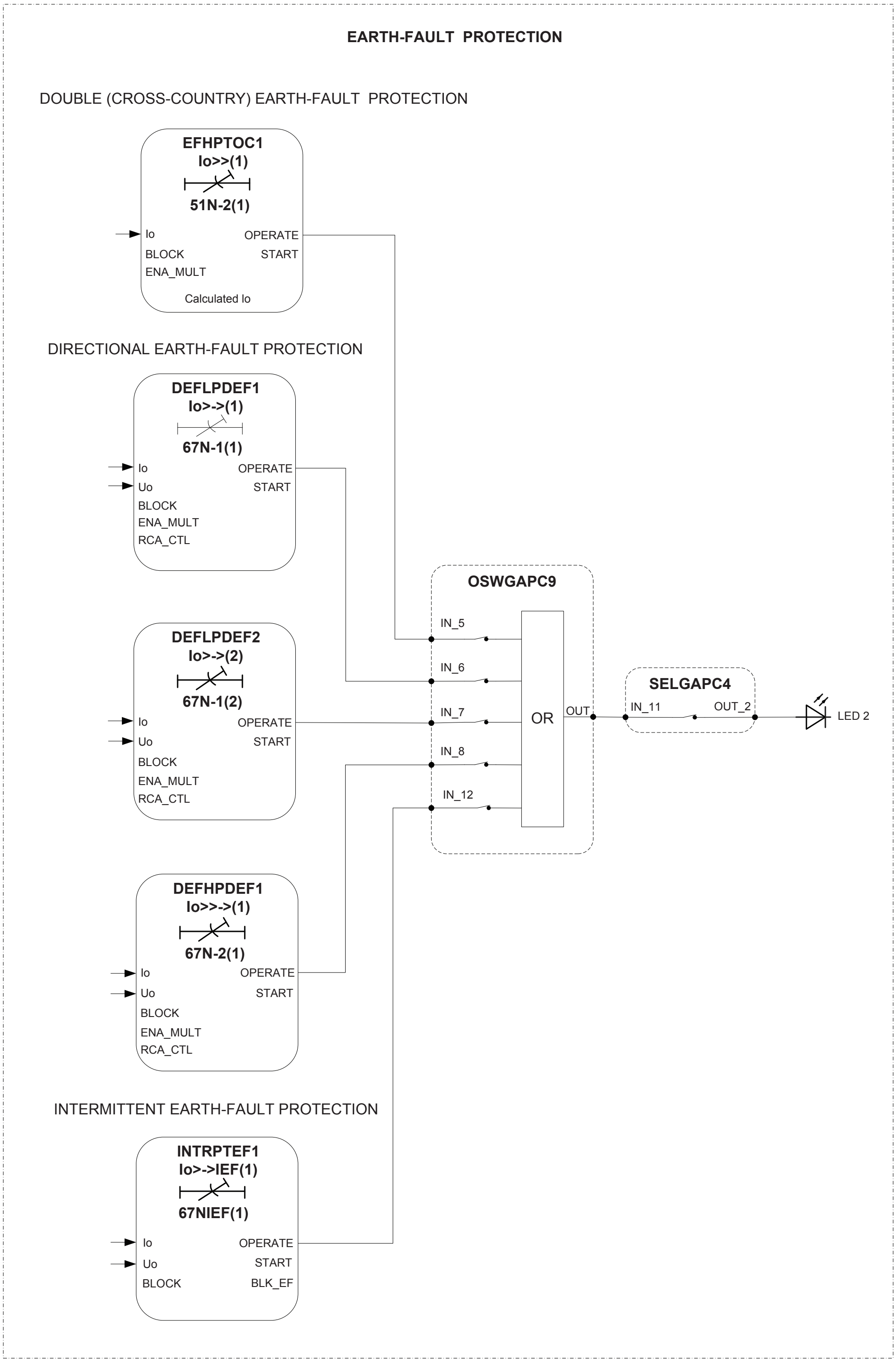


Figure 17: Earth-fault protection

Three stages are offered for directional earth-fault protection. In addition, there is a dedicated protection stage INTRPTEF either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block EFHPTOC is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

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

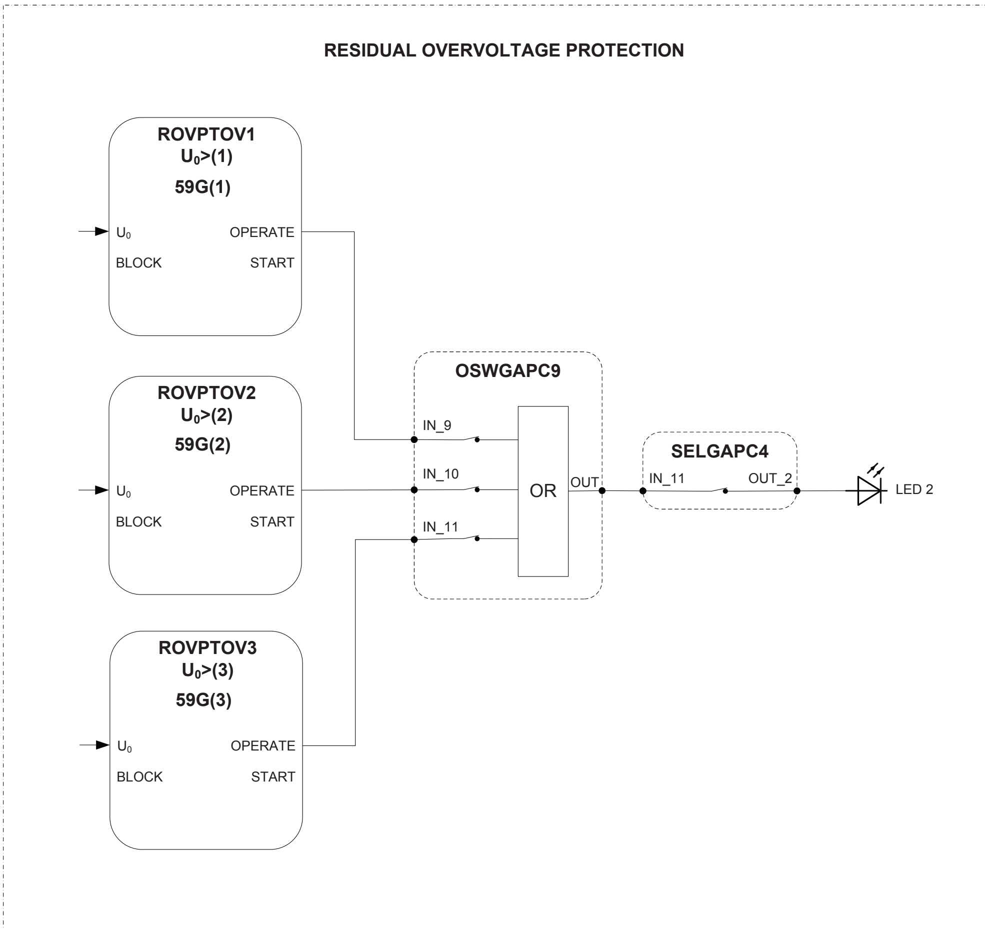


Figure 18: Residual overvoltage protection

The residual overvoltage protection ROVPTOV provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is also connected to alarm LED 2.

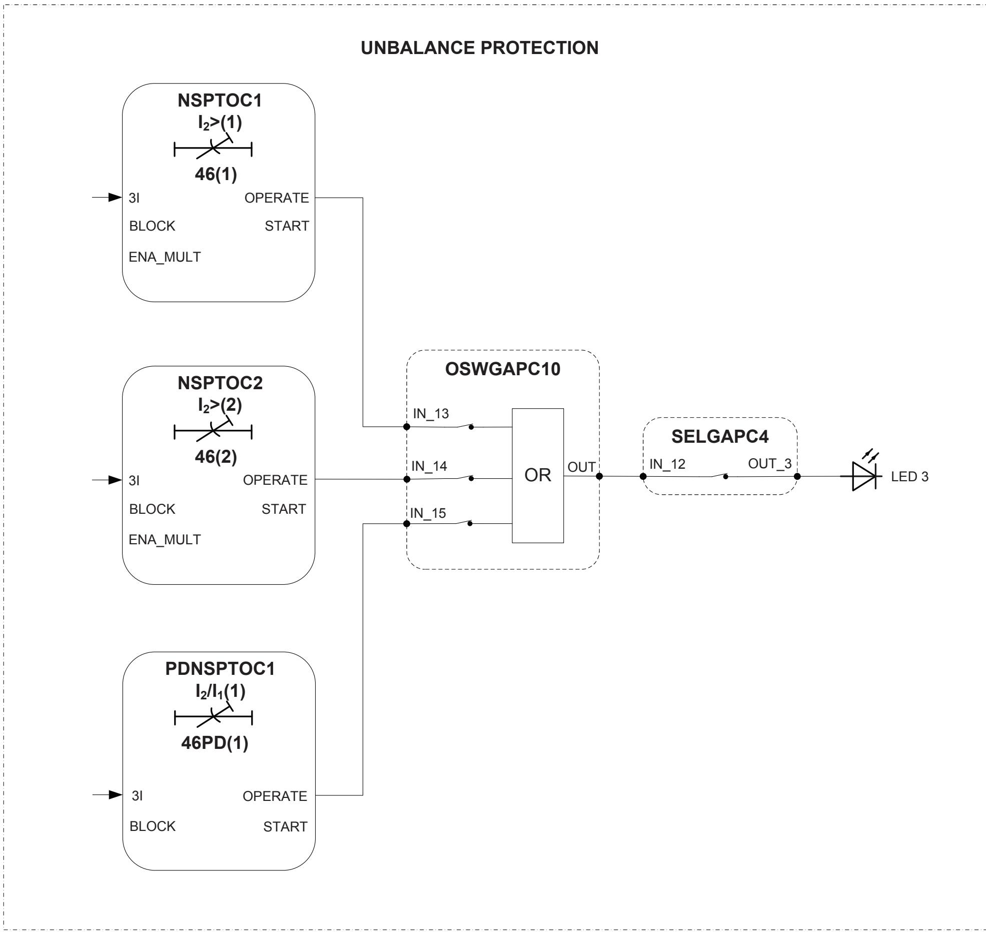


Figure 19: Unbalance protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 and one phase discontinuity stage PDNPSTOC1 are offered for unbalance protection. The phase discontinuity protection PDNPSTOC1 provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

The operate signals of these unbalance protections are connected to the Master Trip and to alarm LED 3.

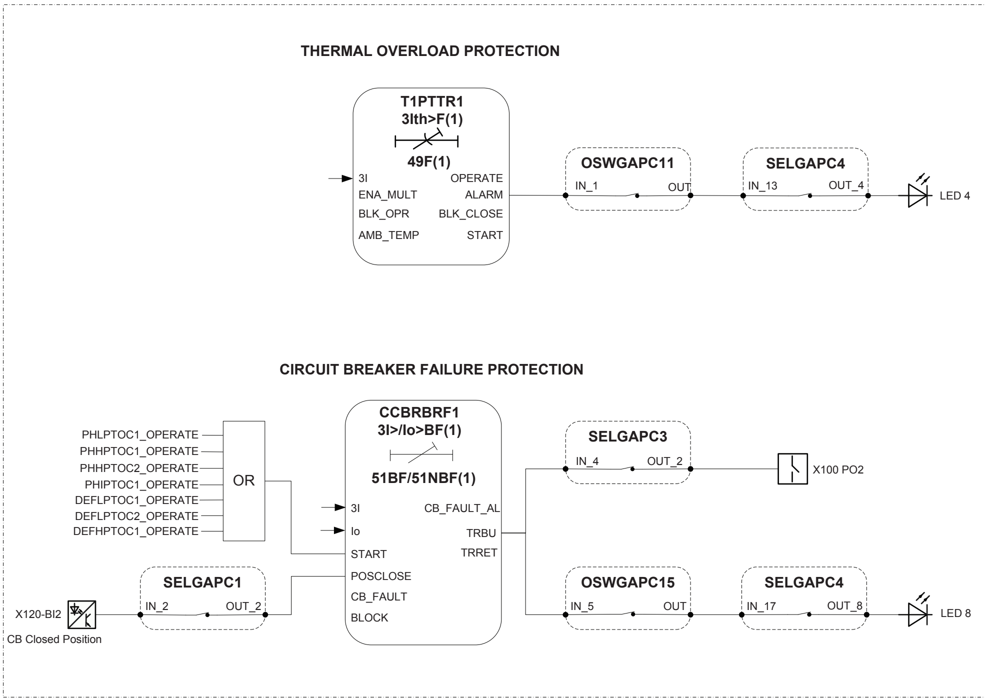


Figure 20: Thermal overload and circuit-breaker failure protection

The thermal overload protection T1PTTR1 provides indication on overload situations. LED 4 is used for the thermal overload protection alarm indication.

The circuit-breaker failure protection CCBRBRF1 is initiated via the start input by a number of different protection stages in the protection relay. The circuit-breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: `TRRET` and `TRBU`. The `TRRET` operate output is used for retripping its own breaker through the Master Trip 2. `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.

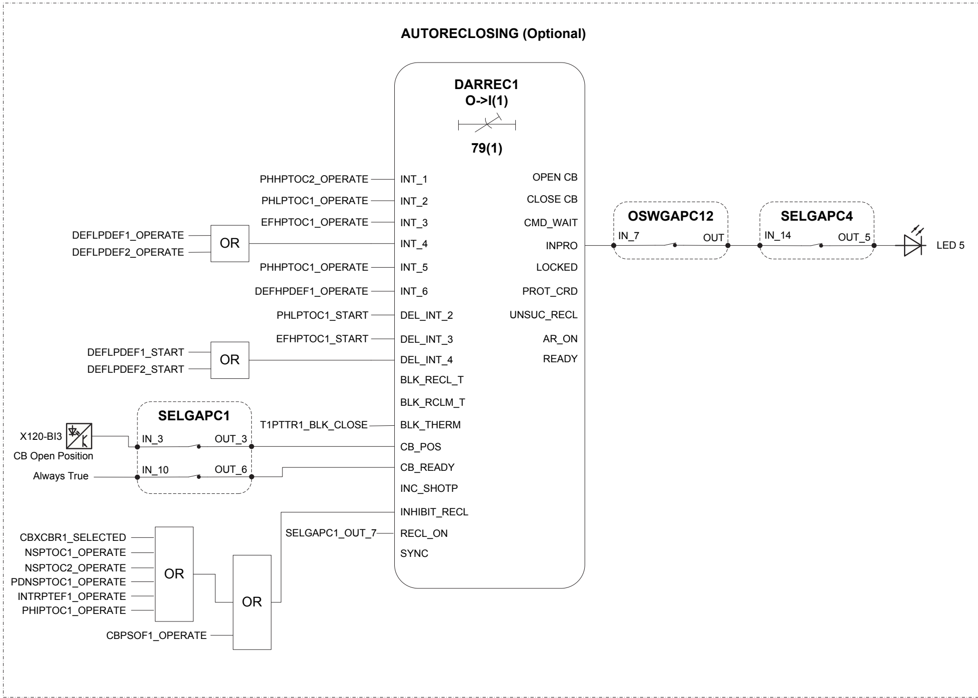


Figure 21: Autoreclosing

Autoreclosing DARREC1 is included as an optional function.

The autoreclose function is configured to be initiated by operate signals from a number of protection stages through the INT_1...INT_6 inputs and by start signals through the DEL_INT_2…4. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operations of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR_SELECTED signal.

The circuit breaker availability for the autoreclose sequence is expressed with the CB_READY input in DARREC1. In the configuration, this signal is connected with an always true signal through the SELGAPC1. As a result, the function assumes that the circuit breaker is available all the time.

The autoreclose sequence in progress indication INPRO is connected to the alarm LED 5.

3.4.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

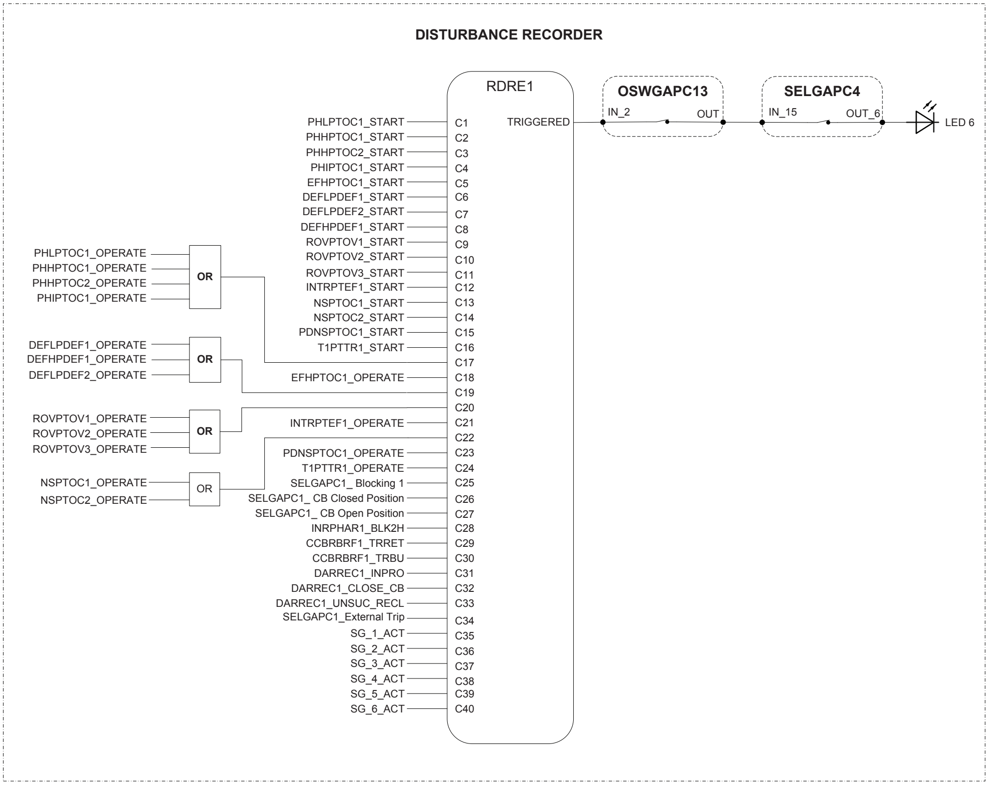


Figure 22: Disturbance recorder

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 autoreclose 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	PHLPTOC1_START	1=positive or rising
Binary channel 2	PHHPTOC1_START	1=positive or rising
Binary channel 3	PHHPTOC2_START	1=positive or rising
Binary channel 4	PHIPTOC1_START	1=positive or rising
Binary channel 5	EFHPTOC1_START	1=positive or rising
Binary channel 6	DEFLPDEF1_START	1=positive or rising
Binary channel 7	DEFLPDEF2_START	1=positive or rising
Binary channel 8	DEFHPDEF1_START	1=positive or rising
Binary channel 9	ROVPTOV1_START	1=positive or rising

Table continues on next page

Channel number	Channel ID text	Level trigger mode
Binary channel 10	ROVPTOV2_START	1=positive or rising
Binary channel 11	ROVPTOV3_START	1=positive or rising
Binary channel 12	INTRPTEF1_START	1=positive or rising
Binary channel 13	NSPTOC1_START	1=positive or rising
Binary channel 14	NSPTOC2_START	1=positive or rising
Binary channel 15	PDNSPTOC1_START	1=positive or rising
Binary channel 16	T1PTTR1_START	1=positive or rising
Binary channel 17	PHxPTOC_OPERATE	4=level trigger off
Binary channel 18	EFHPTOC1_OPERATE	4=level trigger off
Binary channel 19	DEFxPDEF_OPERATE	4=level trigger off
Binary channel 20	ROVPTOV_OPERATE	4=level trigger off
Binary channel 21	INTRPTEF1_OPERATE	4=level trigger off
Binary channel 22	NSPTOC1/2_OPERATE	4=level trigger off
Binary channel 23	PDNSPTOC1_OPERATE	4=level trigger off
Binary channel 24	T1PPTR1_OPERATE	4=level trigger off
Binary channel 25	SELGAPC1_Blocking 1	4=level trigger off
Binary channel 26	SELGAPC1_CB_Closed	4=level trigger off
Binary channel 27	SELGAPC1_CB_Open	4=level trigger off
Binary channel 28	INRPHAR1_BLK2H	4=level trigger off
Binary channel 29	CCBRBRF1_TRRET	4=level trigger off
Binary channel 30	CCBRBRF1_TRBU	4=level trigger off
Binary channel 31	DARREC1_INPRO	4=level trigger off
Binary channel 32	DARREC1_CLOSE_CB	4=level trigger off
Binary channel 33	DARREC1_UNSUC_RECL	4=level trigger off
Binary channel 34	SELGAPC1_External Trip	4=level trigger off
Binary channel 35	SG_1_ACT	4=level trigger off
Binary channel 36	SG_2_ACT	4=level trigger off
Binary channel 37	SG_3_ACT	4=level trigger off
Binary channel 38	SG_4_ACT	4=level trigger off
Binary channel 39	SG_5_ACT	4=level trigger off
Binary channel 40	SG_6_ACT	4=level trigger off

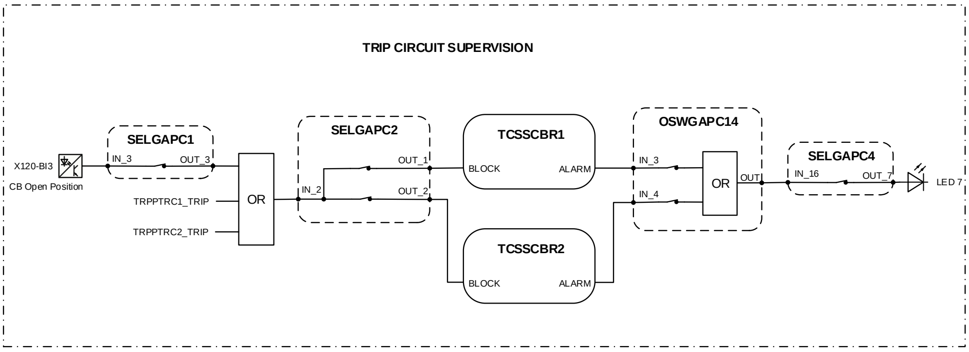


Figure 23: Trip circuit supervision

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

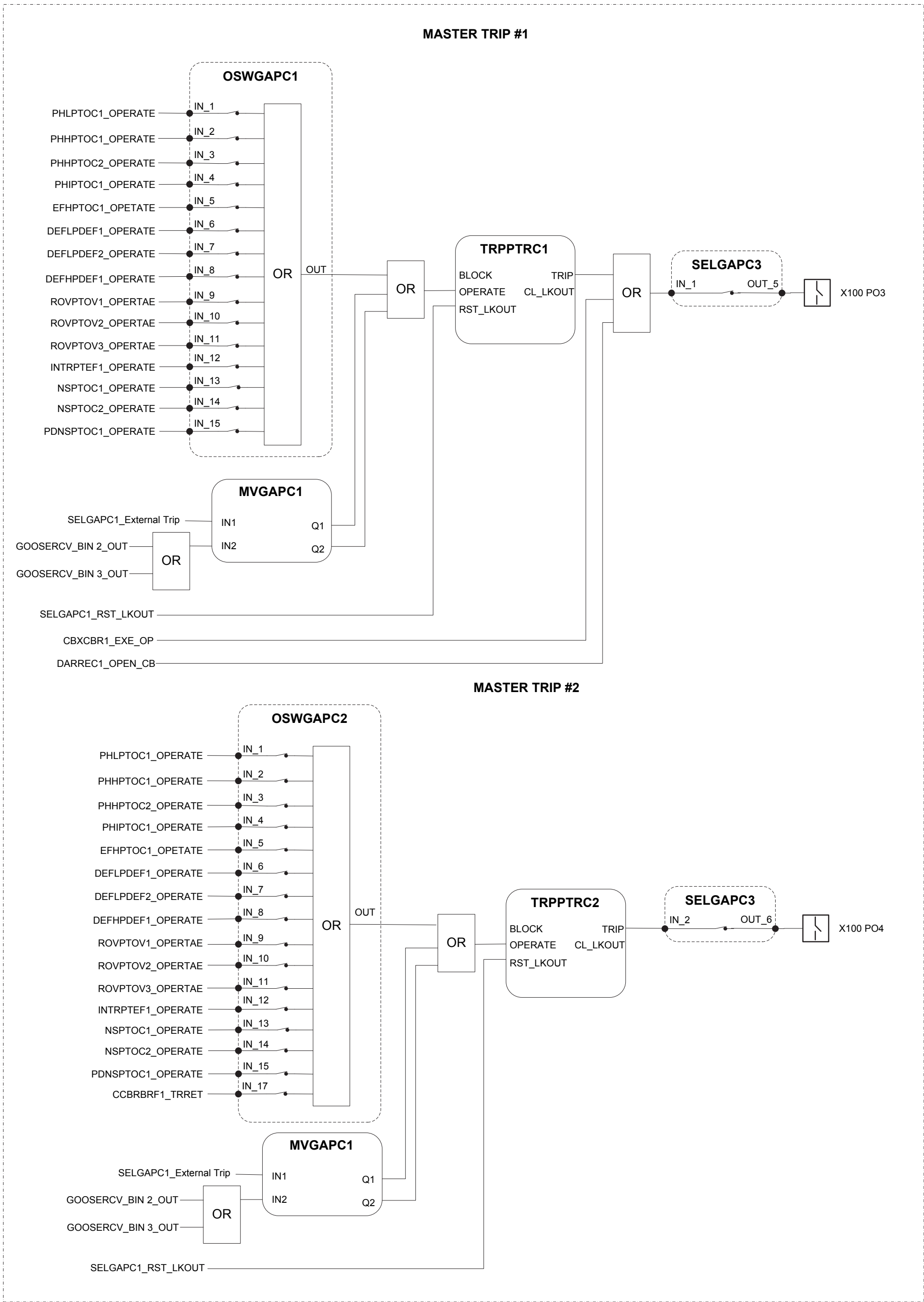


Figure 24: Master trip

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 2 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 the Master Trip. If the lockout operation mode is selected, it is used to enable external reset.

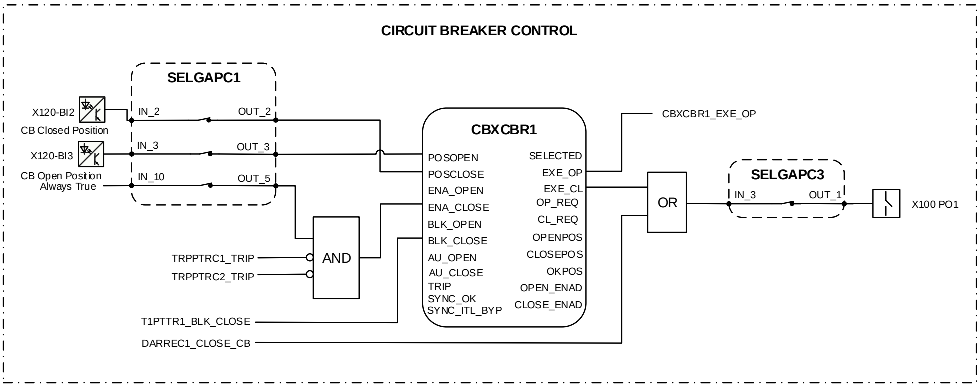


Figure 25: Circuit breaker control

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.

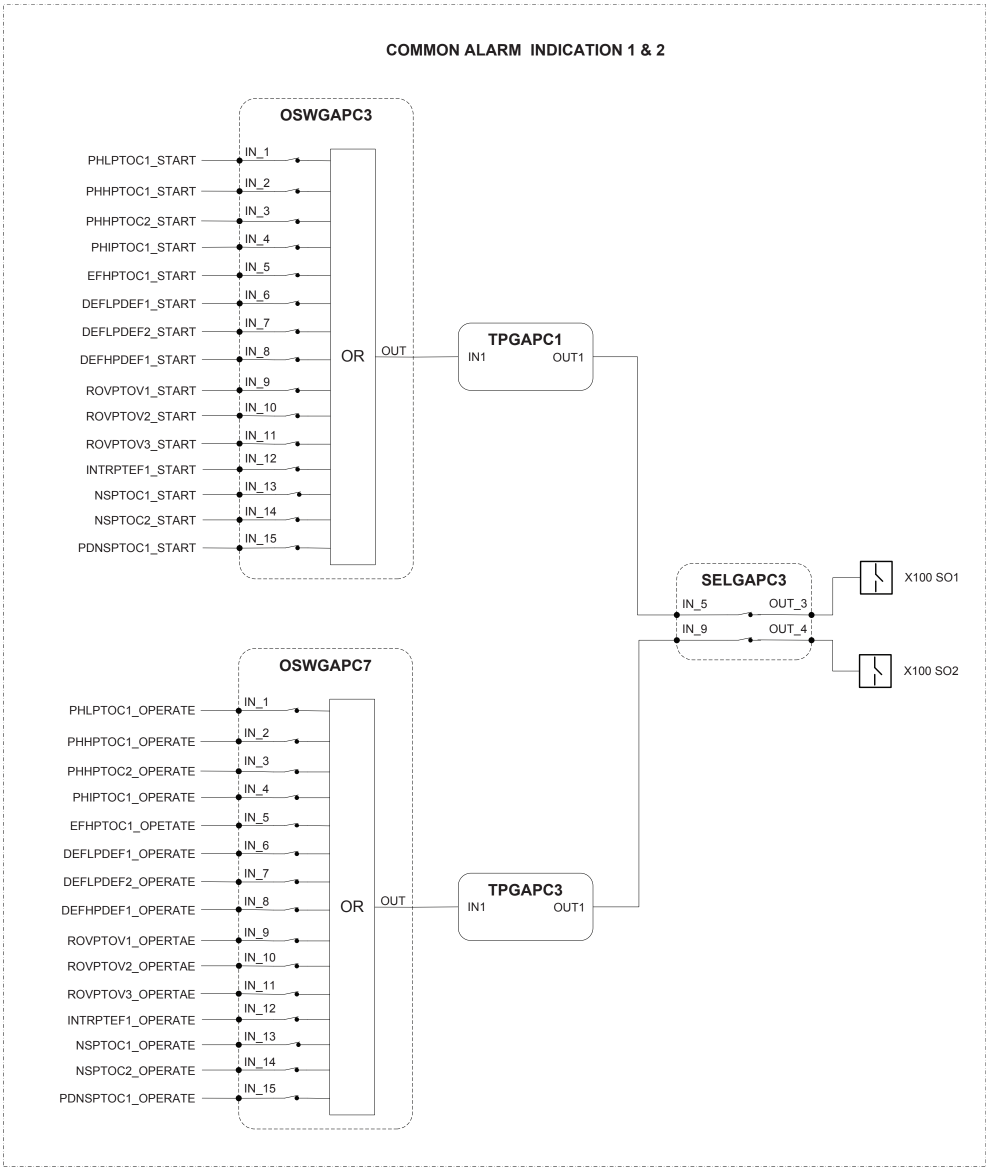


Figure 26: Common alarm indication

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 they are 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.

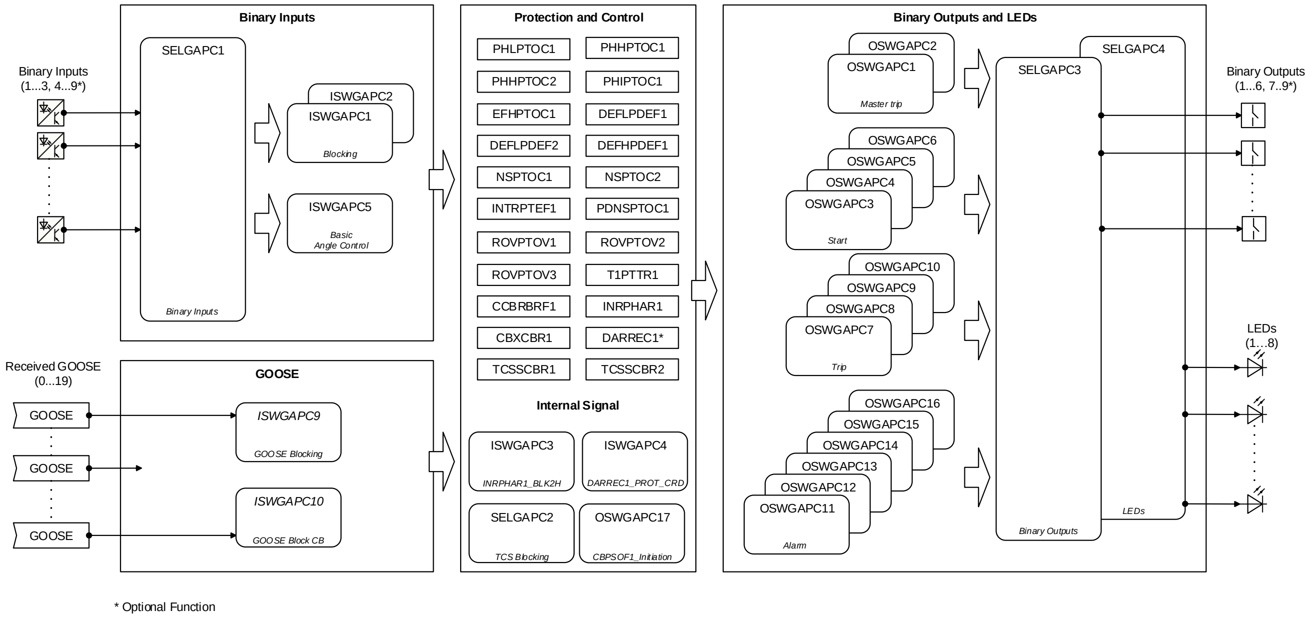


Figure 27: Configuration A switch group overview

3.4.4.1 Binary inputs

The binary inputs group includes one SELGAPC and three 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. ISWGAPC5 is used to control the characteristic angle of DEFxPDEF.

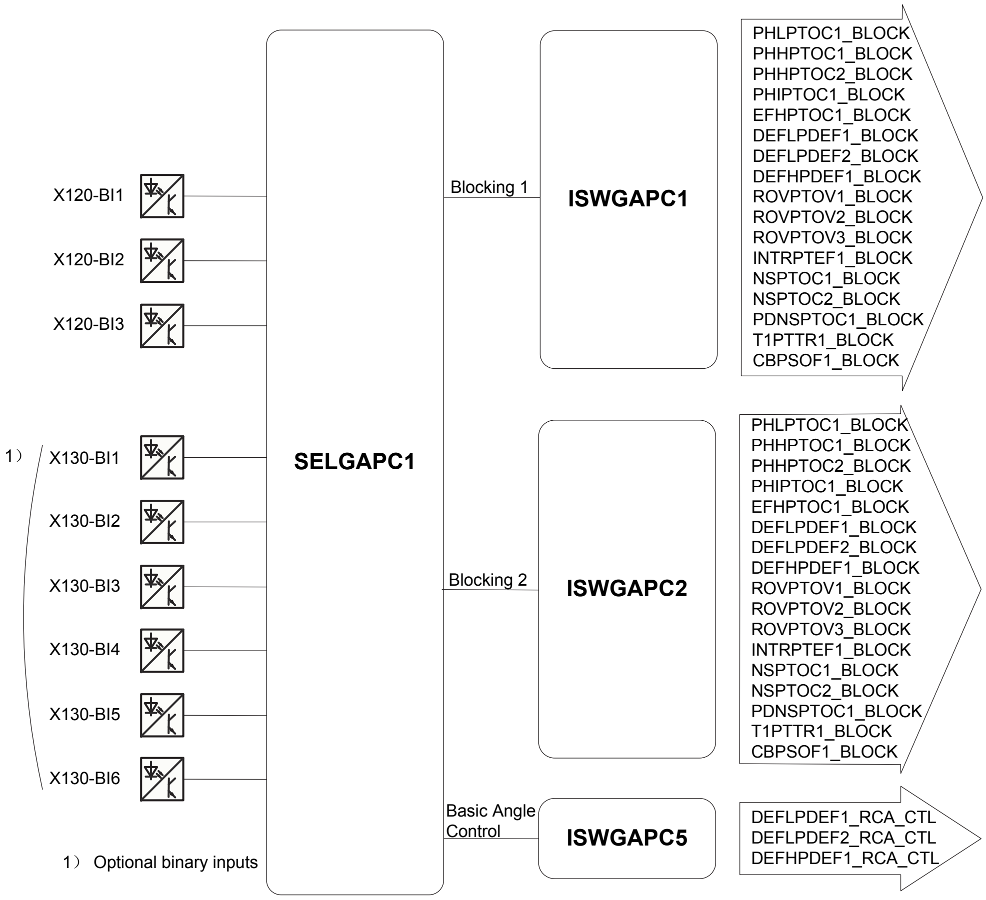


Figure 28: Binary inputs

SELGAPC1

SELGAPC1 has inputs from protection relay binary inputs. `IN_1`...`IN_3` are binary inputs from X120. `IN_4`...`IN_9` can be used while X130 optional card is taken into use. An always true signal is connected to `IN_10`. SELGAPC1 outputs are used to route inputs to different functions. By setting SELGAPC1, binary inputs can be configured for different purposes.

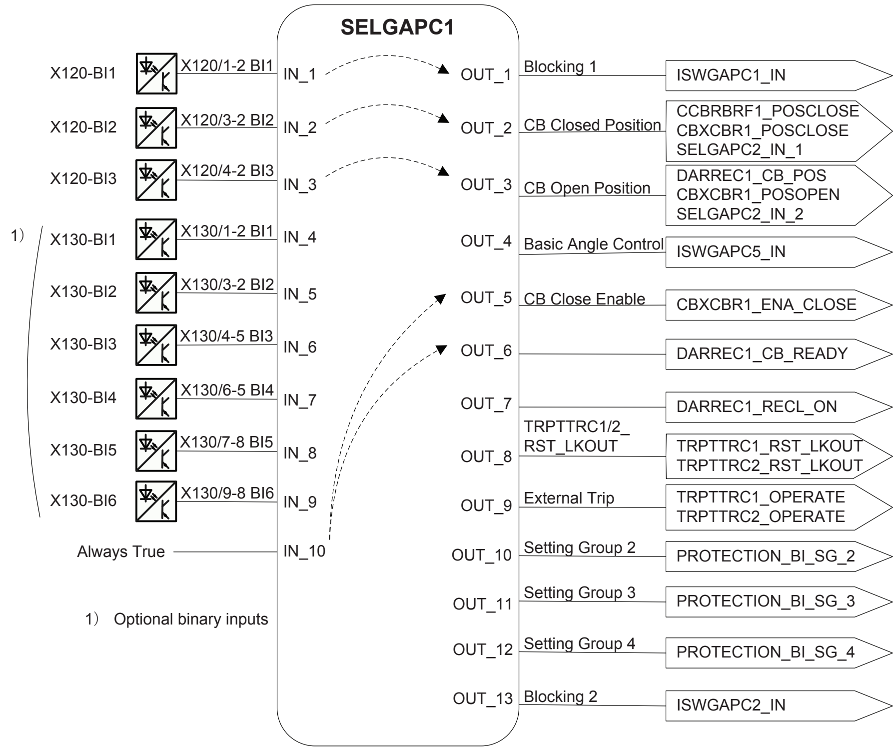


Figure 29: SELGAPC1

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.

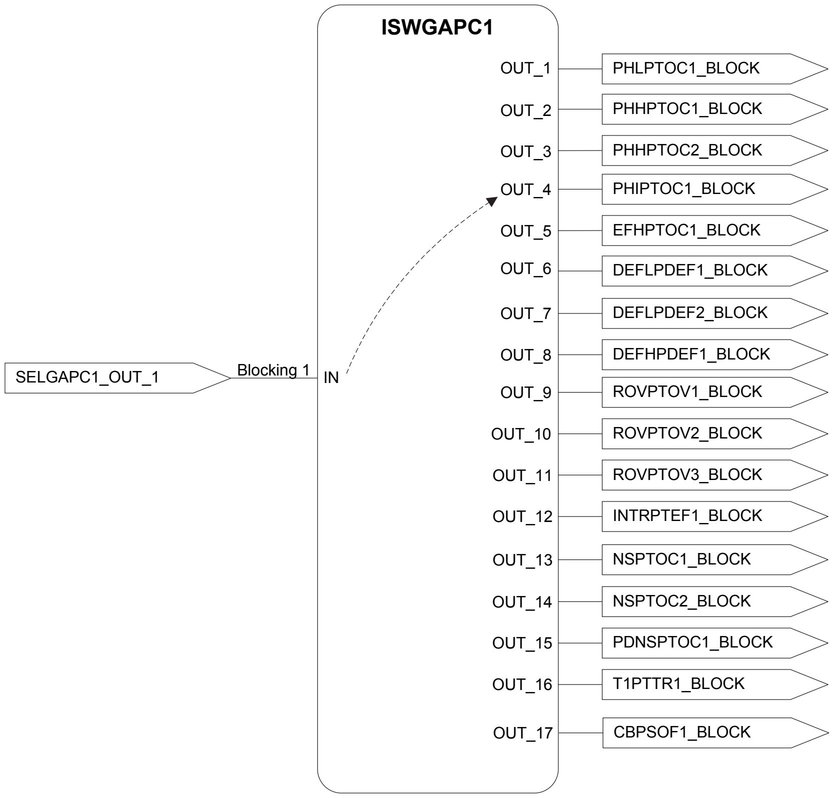


Figure 30: ISWGAPC1

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.

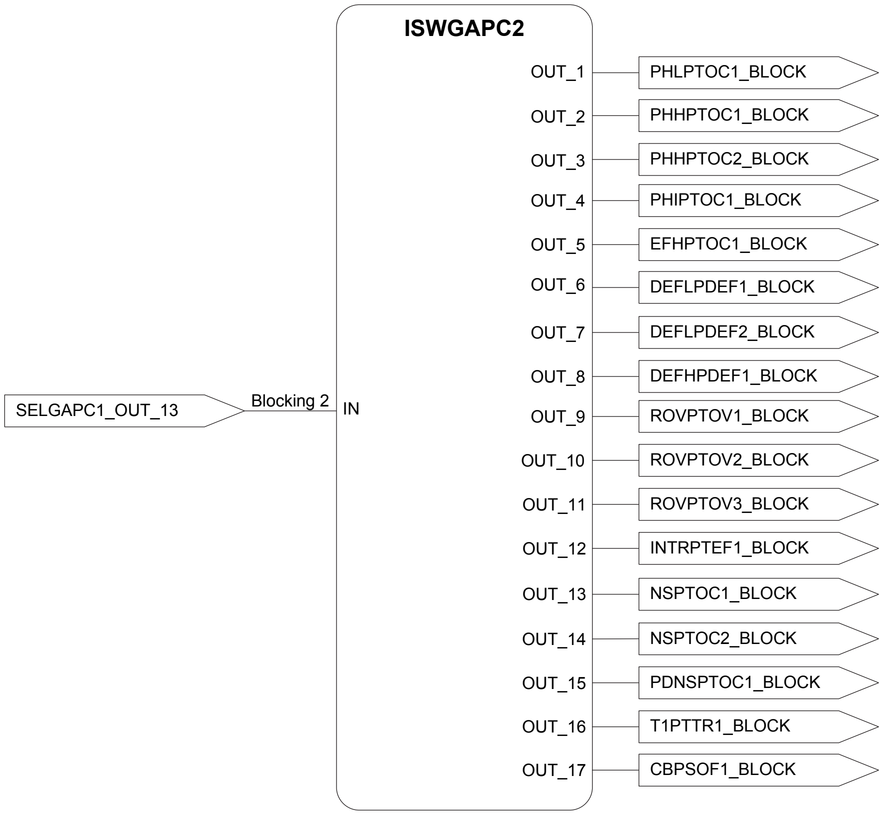


Figure 31: ISWGAPC2

ISWGAPC5

ISWGAPC5 input is used to select which directional earth-fault protection is controlled by ISWGAPC5 input by changing the ISWGAPC5 parameters. ISWGAPC5 input is routed from SELGAPC1 output `OUT_4 Basic Angle Control`. ISWGAPC5 outputs are connected to `RCA_CTL` inputs of directional earth-fault protection functions.

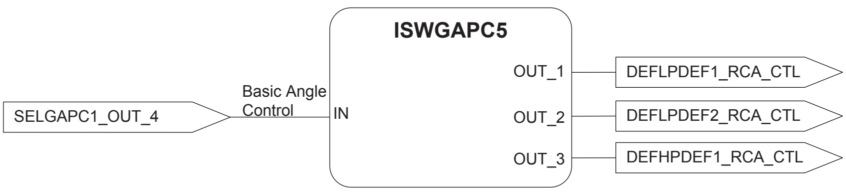


Figure 32: ISWGAPC5

3.4.4.2 Internal signals

The internal signal group is used to configure logic connections between function blocks. There are two ISWGAPC instances, one SELGAPC and one OSWGAPC instance in the group.

ISWGAPC3 is used to configure which protection function enables the current multiplier if the INRPHAR1 function detects inrush. ISWGAPC4 is used to configure the cooperation between the autoreclose function and the protection functions. The autoreclose function DARREC1 can block protection functions according to the application. SELGAPC2 is used to configure TCS blocking from the circuit breaker open or close position. OSWGAPC17 is used for connecting switch onto fault function CBPSOF. The inputs are start signals routed from the protection functions.

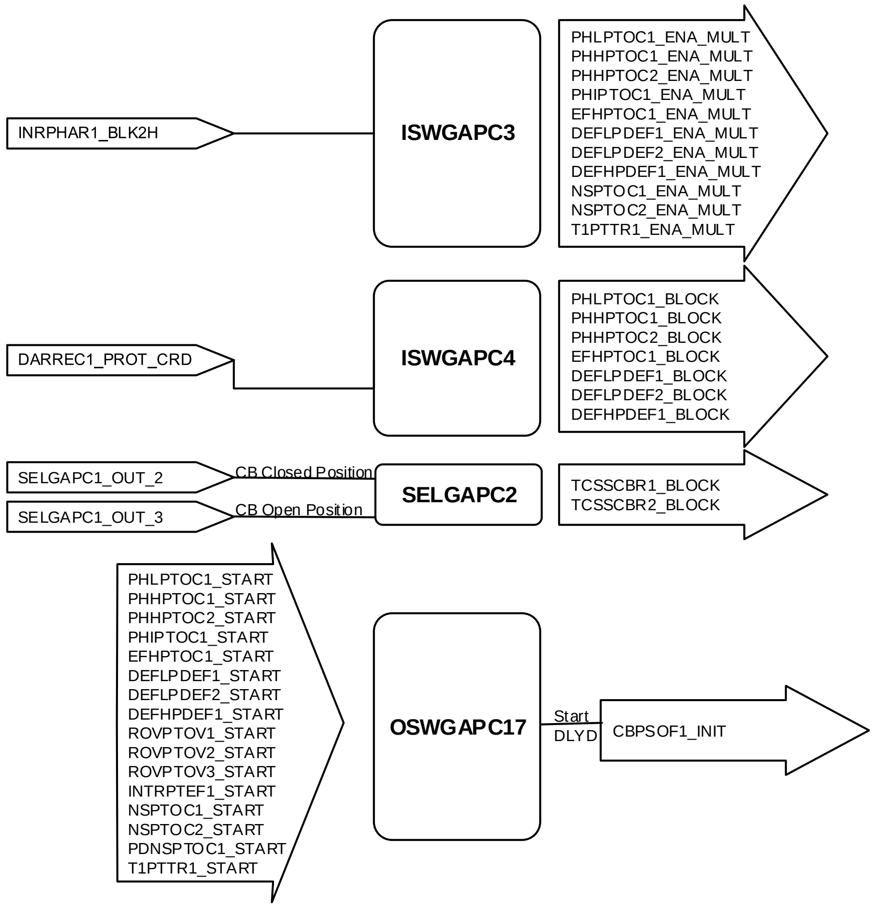


Figure 33: Internal signal

ISWGAPC3

ISWGAPC3 input is used to configure which protection function enables current multiplier while inrush is detected by INRPHAR1, by changing the ISWGAPC3 parameters. ISWGAPC3 input is routed from INRPHAR1 output `BLK2H`. ISWGAPC3 outputs are connected to the `ENA_MULT` inputs of the protection functions.

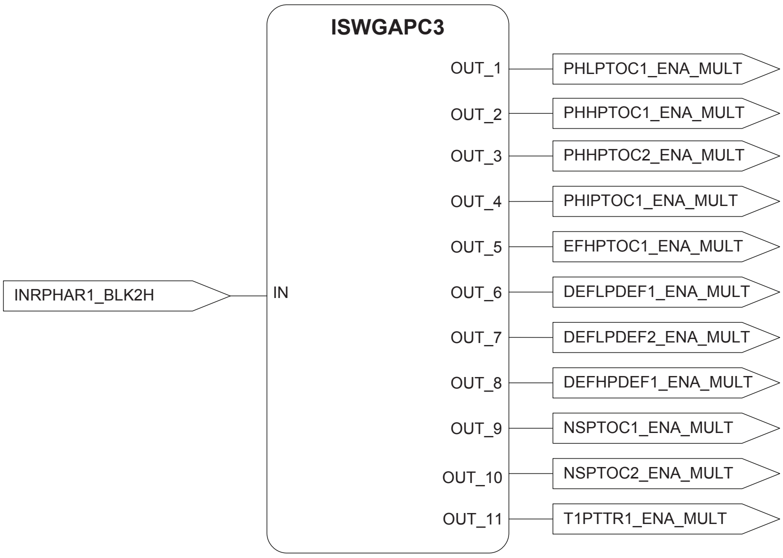


Figure 34: ISWGAPC3

ISWGAPC4

ISWGAPC4 input is used to configure which protection function is blocked by the autoreclosing function by changing the ISWGAPC4 parameters. ISWGAPC4 input is routed from DARREC1 output `PROT_CRD`. ISWGAPC4 outputs are connected to the `BLOCK` inputs of some of the protection functions.

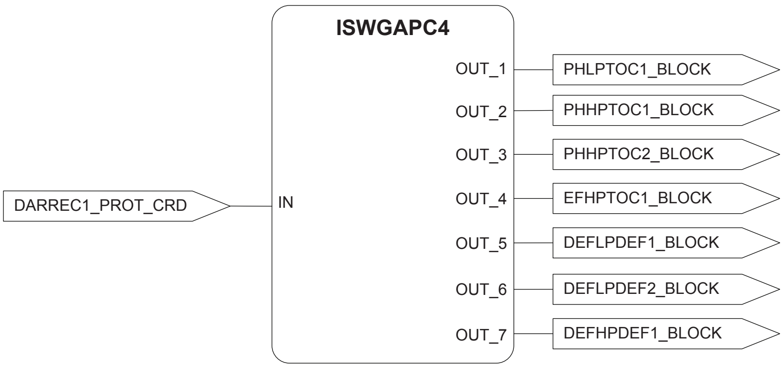


Figure 35: ISWGAPC4

SELGAPC2

SELGAPC2 inputs represent the circuit breaker closed and open position 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 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).

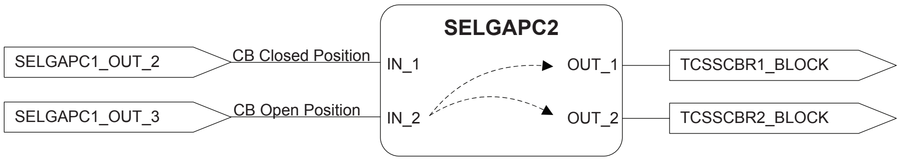


Figure 36: SELGAPC2

OSWGAPC17

OSWGAPC17 is used to route the protection function start signals to the `StartDLYD` input of the switch onto fault function CBPSOF. CBPSOF provides an instantaneous trip or a time delayed trip when closing the breaker while a fault exists. OSWGAPC17 output is connected to CBPSOF function indicating the detected fault.

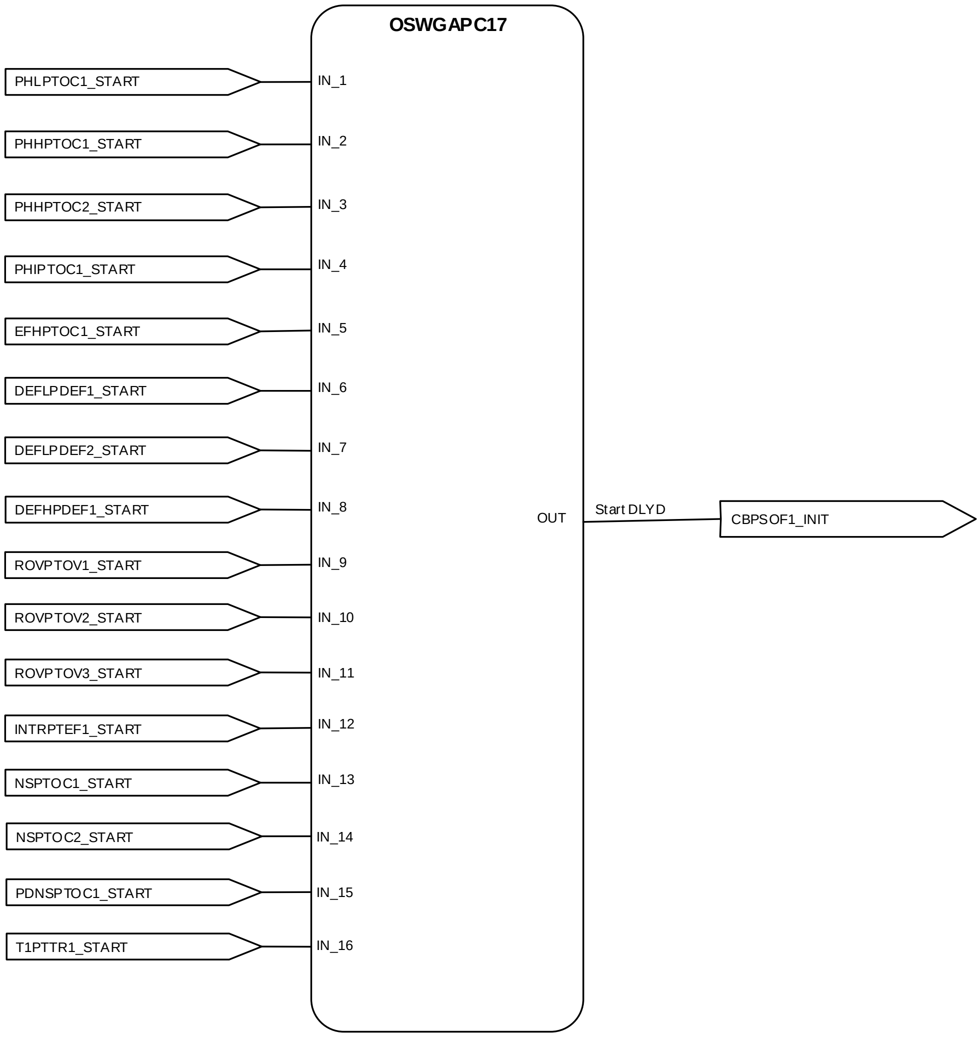


Figure 37: OSWGAPC17

3.4.4.3 Binary outputs and LEDs

In configuration A, signals are routed to binary outputs and LEDs are configured by OSWGAPC. The 16 OSWGAPC instances are categorized in four groups, including two master trip, four start, four trip and six alarm signals. The OSWGAPC output is connected with binary outputs and LEDs via SELGAPC3 and SELGAPC4.

- SELGAPC3 is used to configure OSWGAPC signals to the protection relay's binary outputs. SELGAPC4 is used to configure OSWGAPC signals to LEDs.
- OSWGAPC1 and OSWGAPC2 are used for the Master trip. The inputs are routed from the protection function's operate and the circuit breaker failure's re-trip.
- OSWGAPC3 to OSWGAPC6 are used for the start signal. The inputs are start signals routed from the protection functions.
- OSWGAPC7 to OSWGAPC10 are used for the trip signal. The inputs are operation signals routed from the protection functions.
- OSWGAPC11 to OSWGAPC16 are used for the alarm signal. The inputs are alarm signals routed from the protection and monitoring functions.

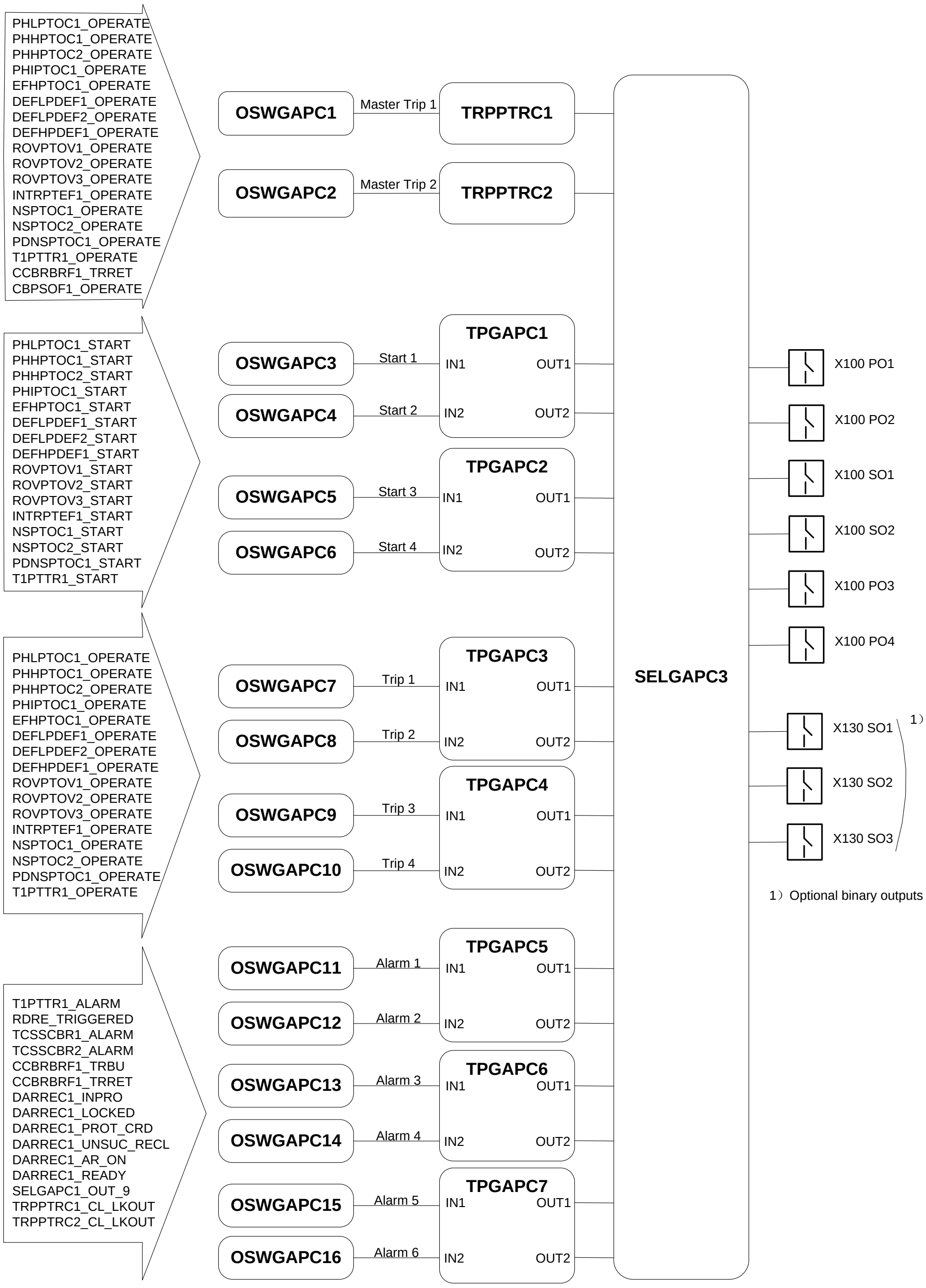


Figure 38: Binary outputs

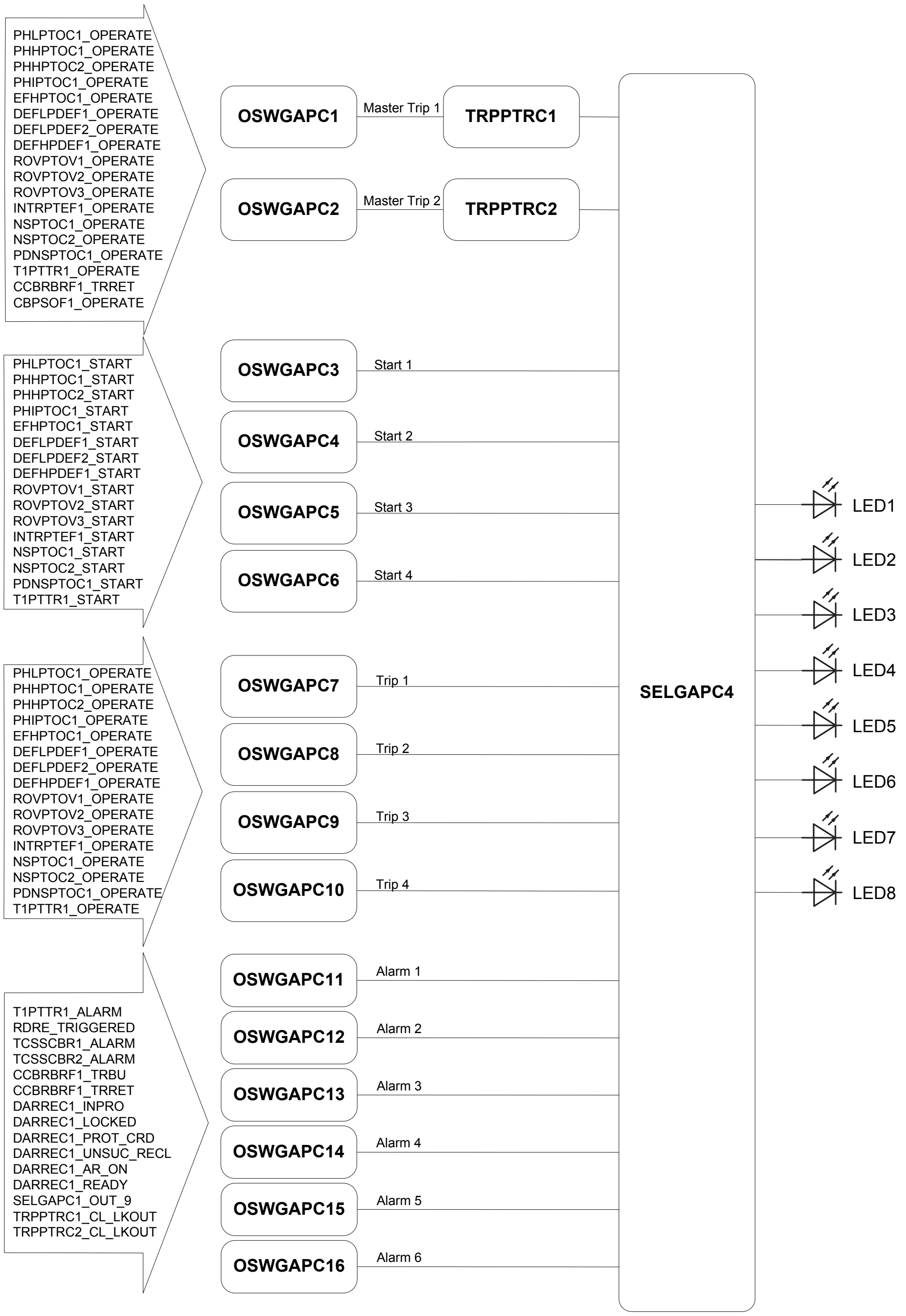


Figure 39: LEDs

SELGAPC3

SELGAPC3 is used to configure the OSWGAPC outputs to the protection relay binary outputs. 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 to X100 binary outputs. If X130 optional card is taken into use, SELGAPC3 outputs also connected to the X130 binary outputs.

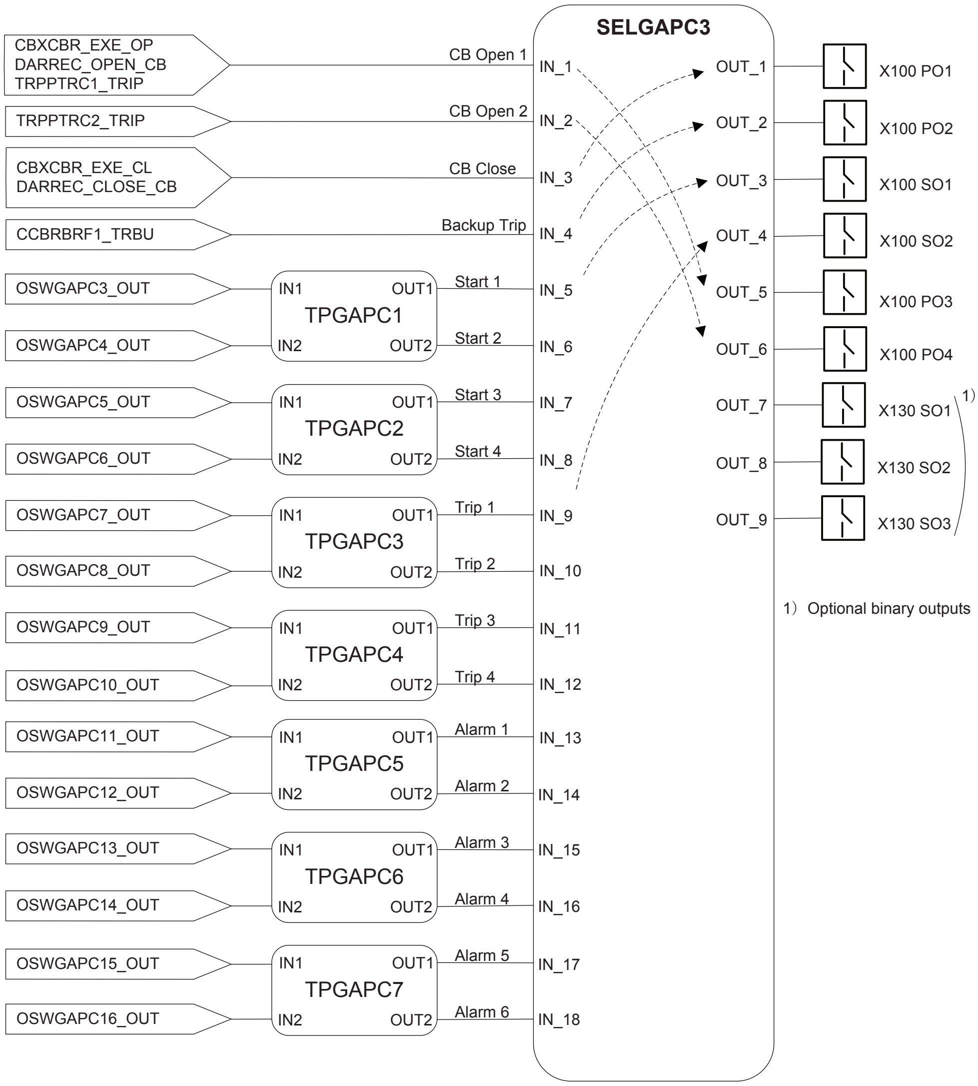


Figure 40: SELGAPC3

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.

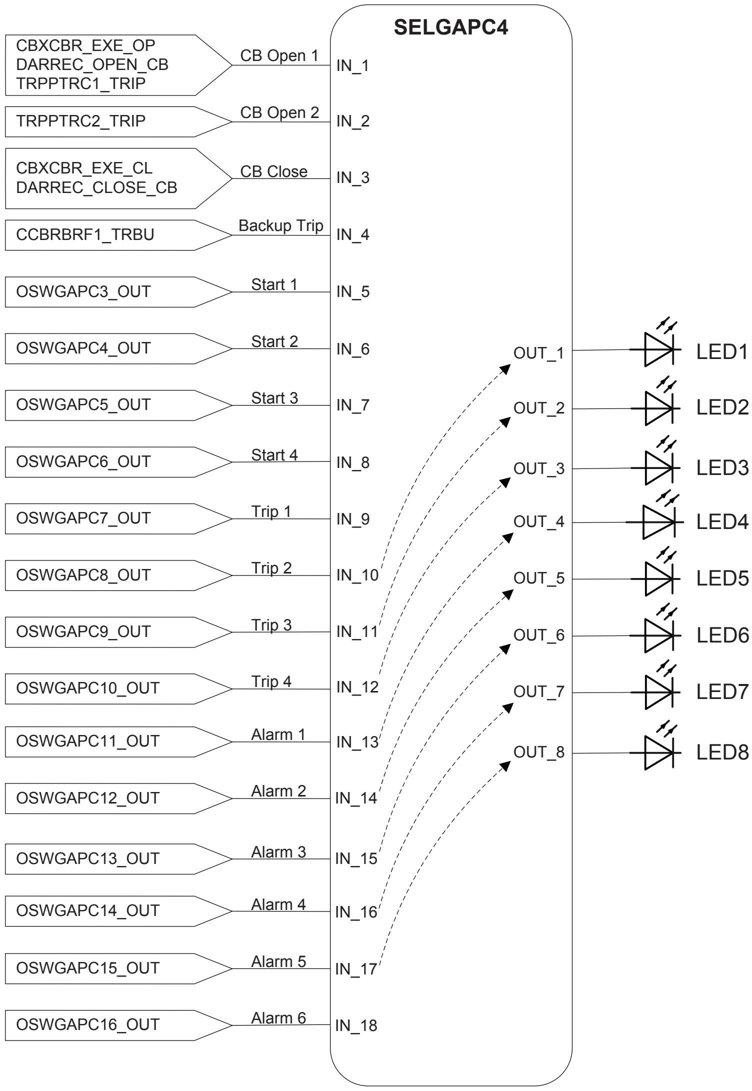


Figure 41: SELGAPC4

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's operate signals. The output is connected to TRPPTRC function. The default connections for OSWGAPC1 and OSWGAPC2 are different.

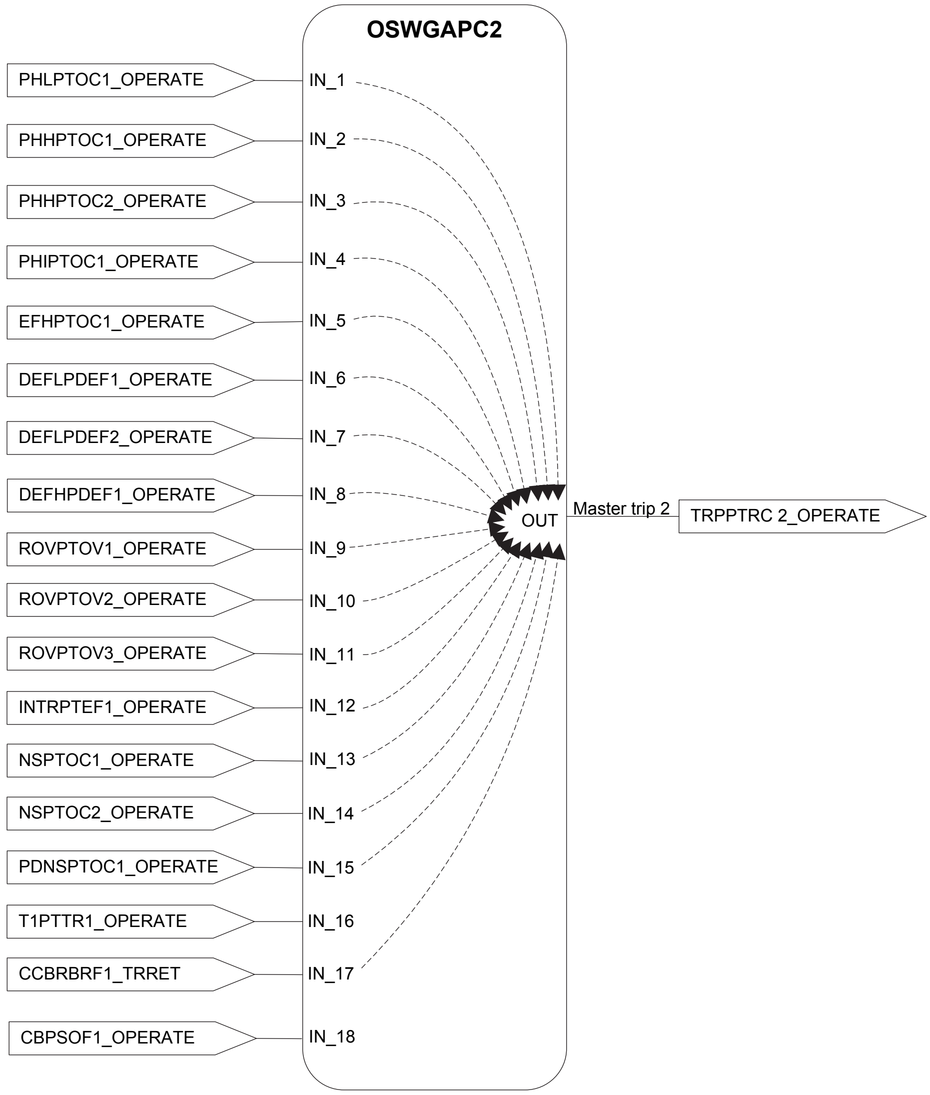


Figure 42: OSWGAPC1

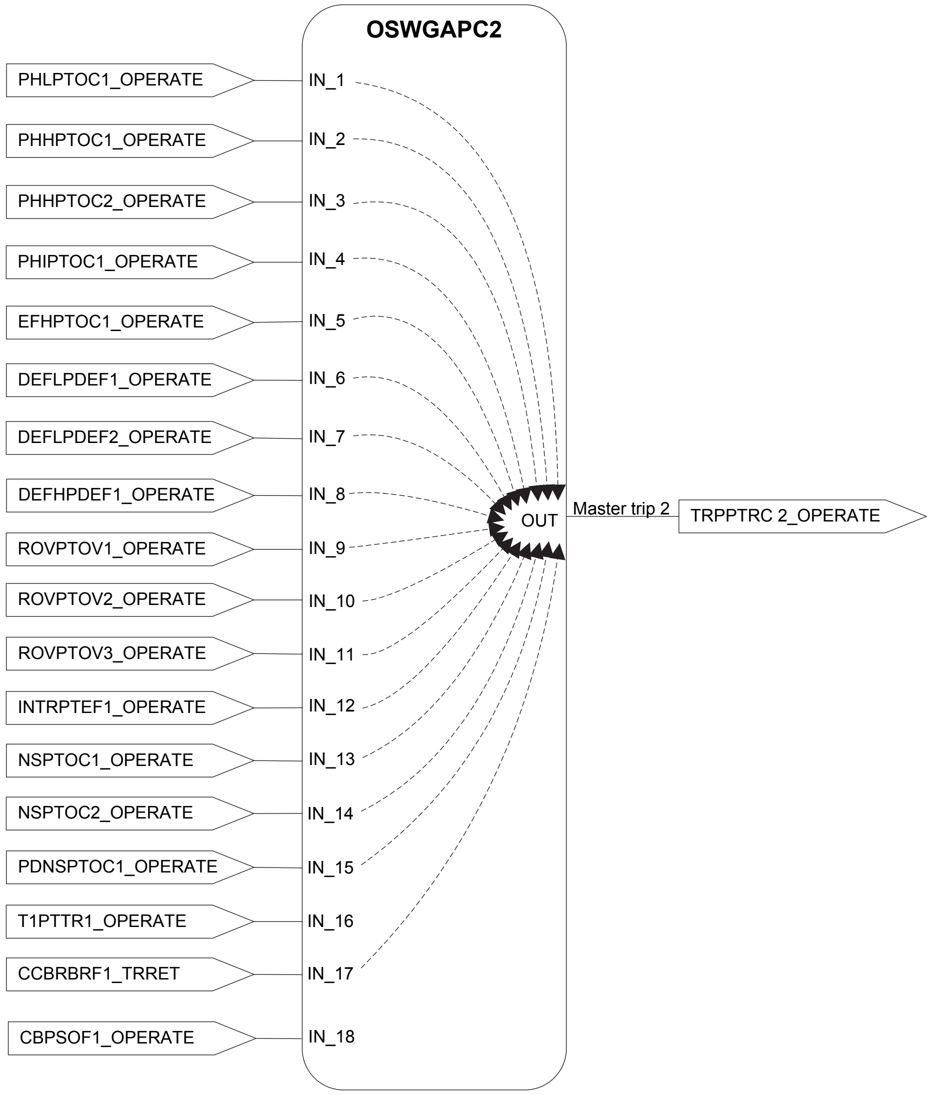


Figure 43: OSWGAPC2

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 routed to SELGAPC4 directly.

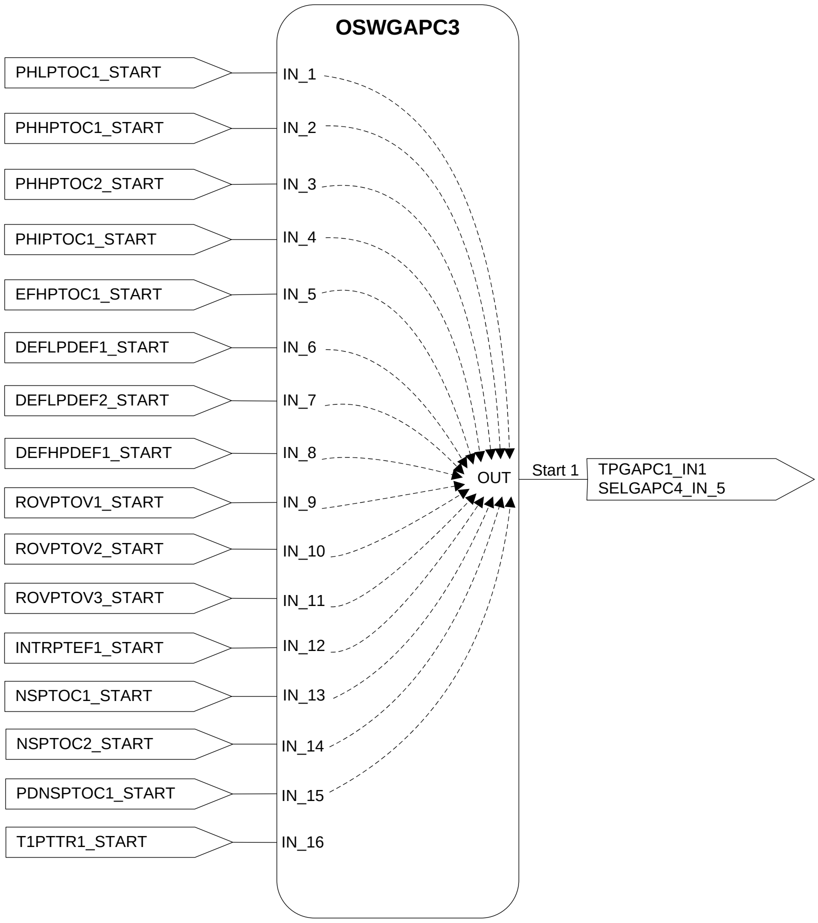


Figure 44: OSWGAPC3

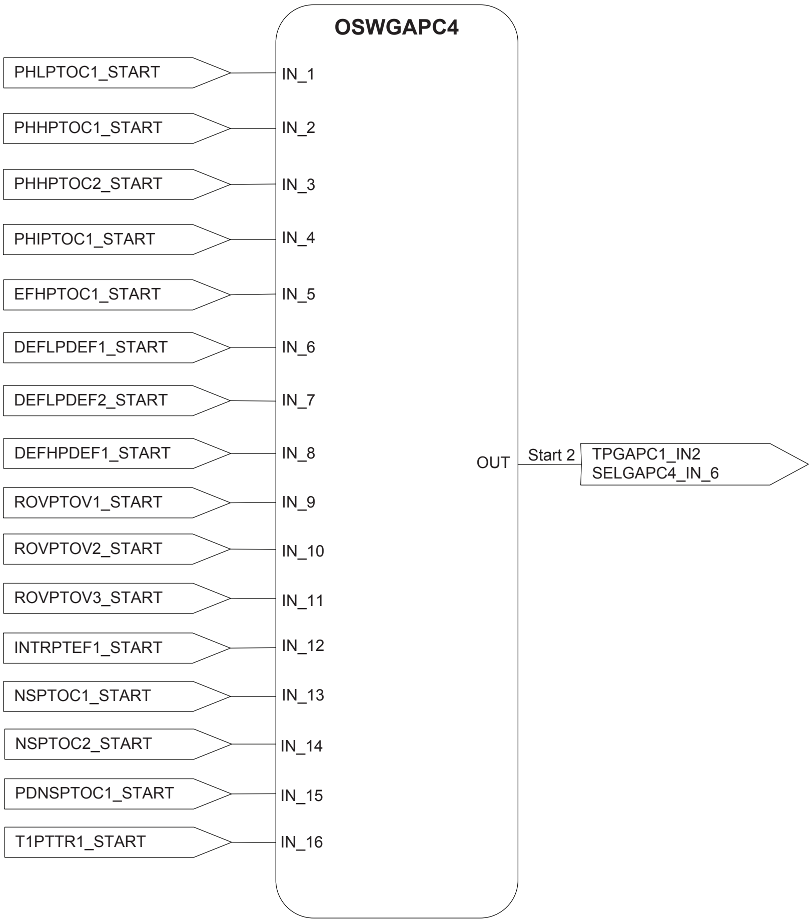


Figure 45: OSWGAPC4

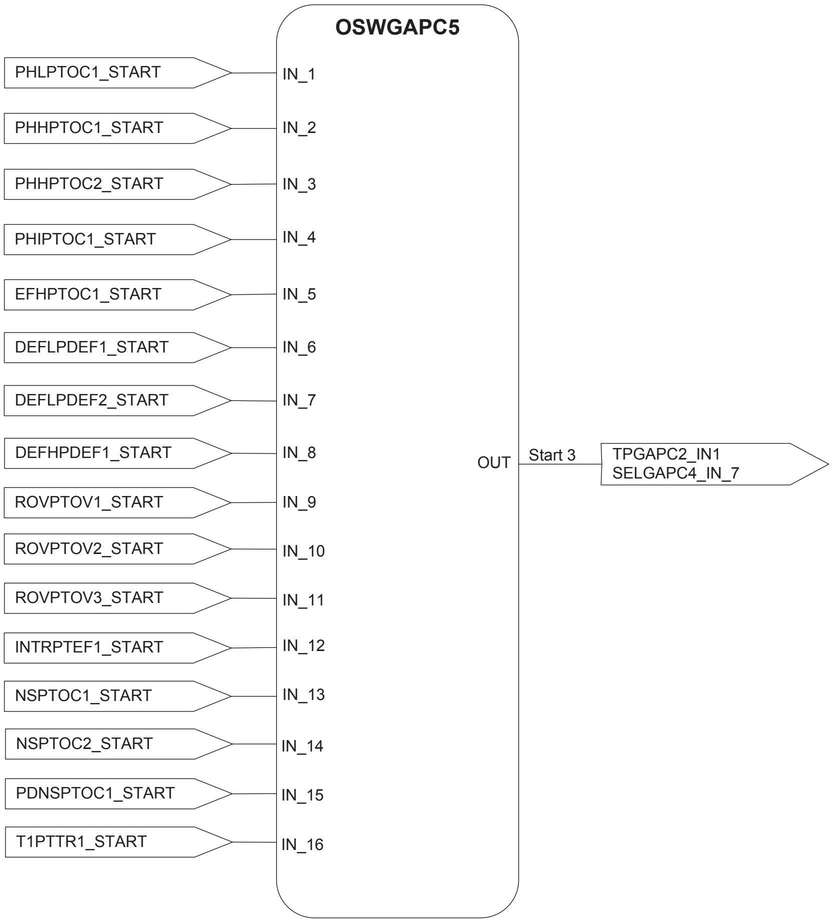


Figure 46: OSWGAPC5

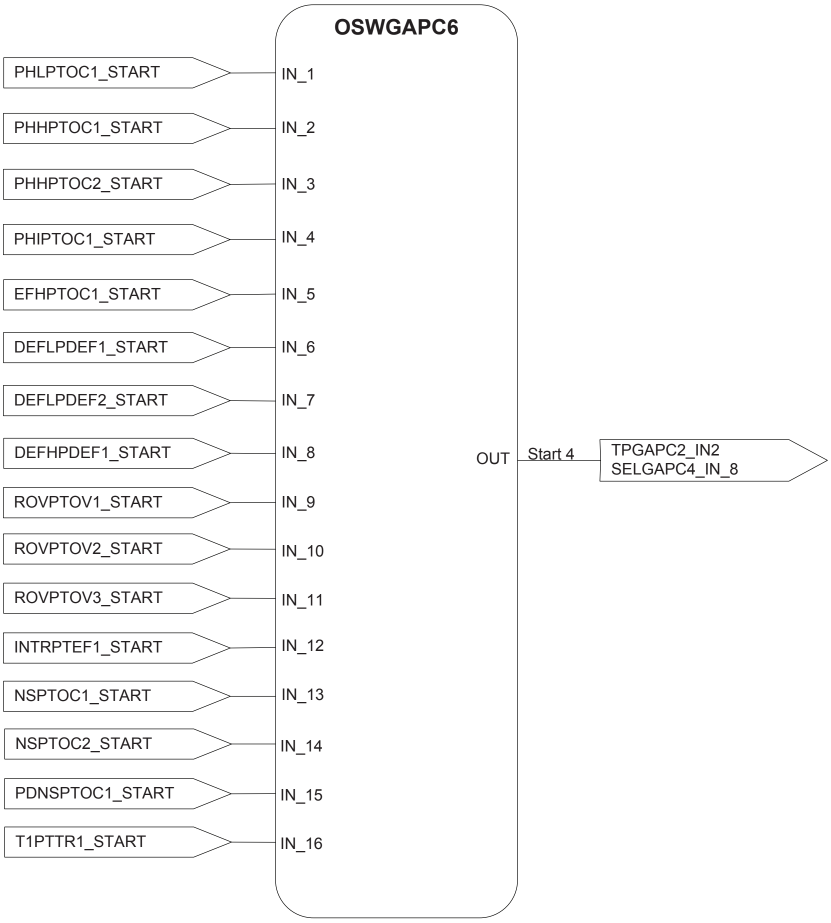


Figure 47: OSWGAPC6

Trip OSWGAPCs

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

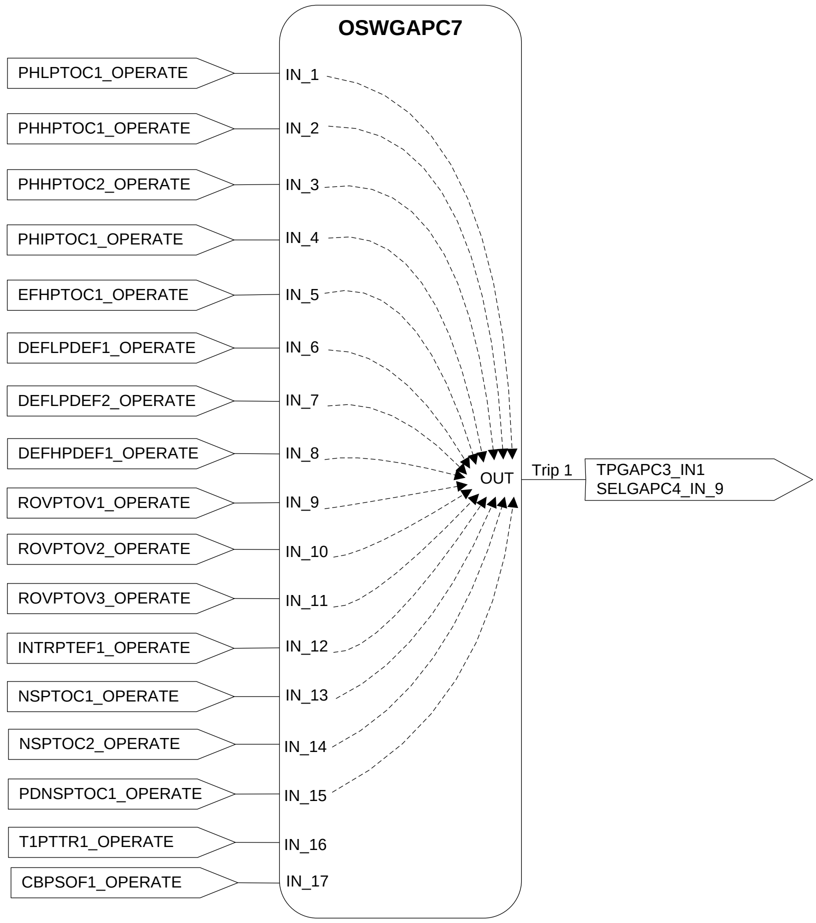


Figure 48: OSWGAPC7

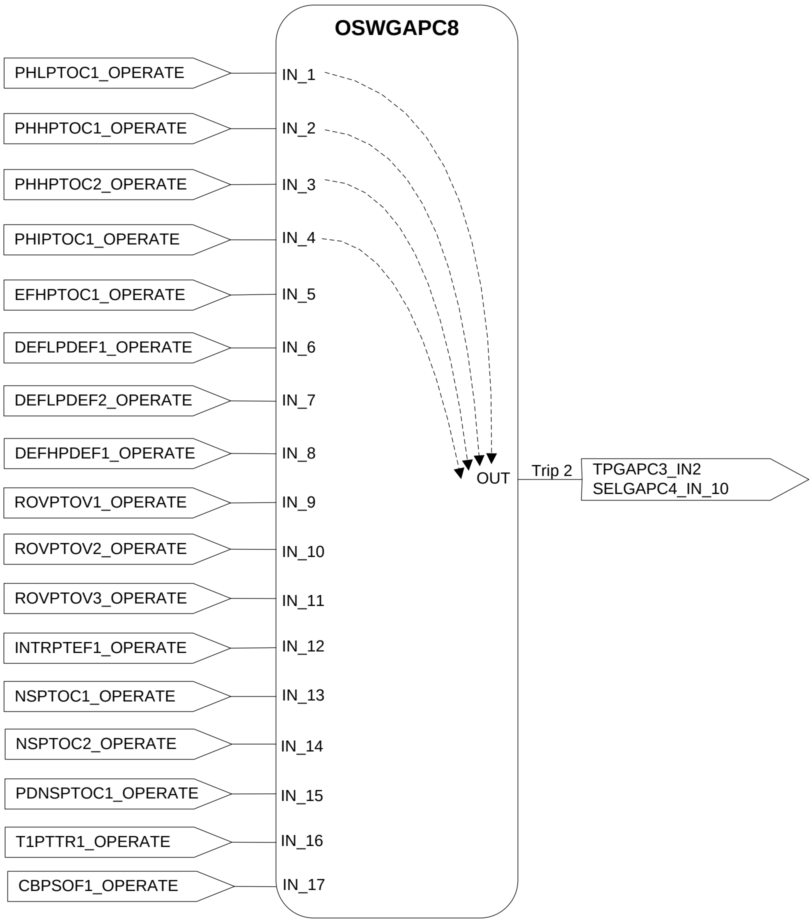


Figure 49: OSWGAPC8

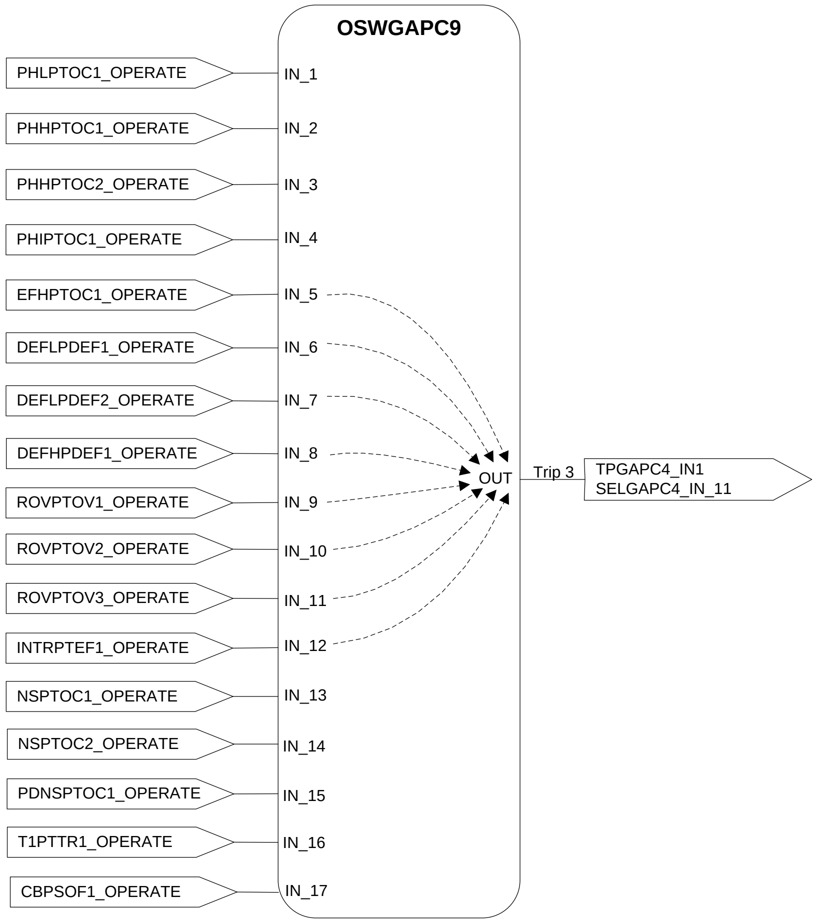


Figure 50: OSWGAPC9

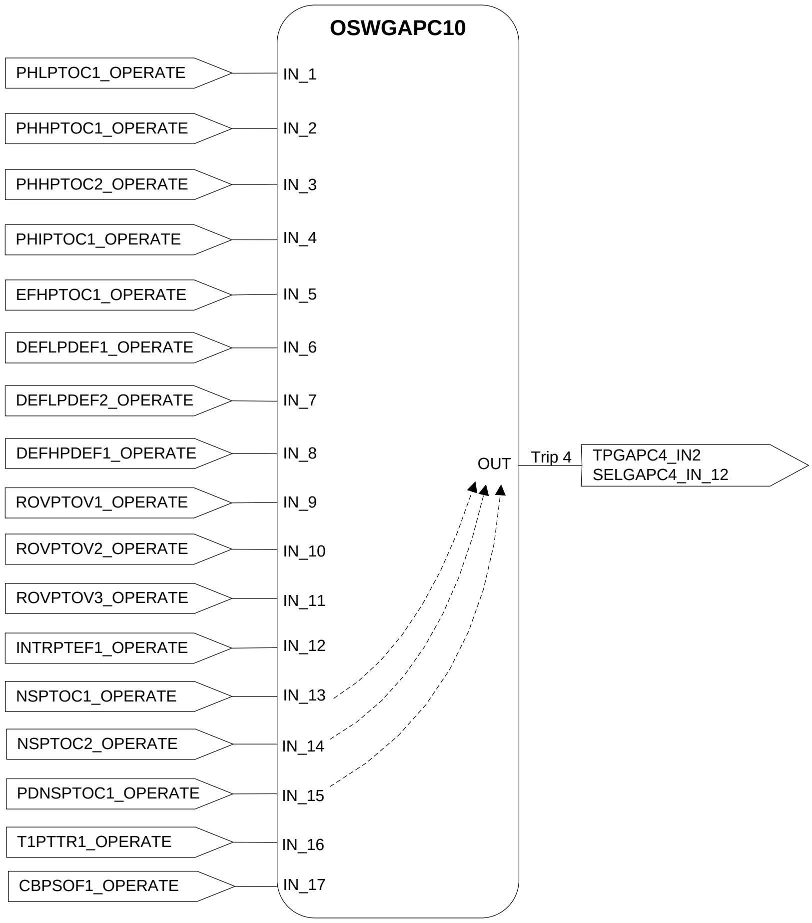


Figure 51: OSWGAPC10

Alarm OSWGAPCs

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

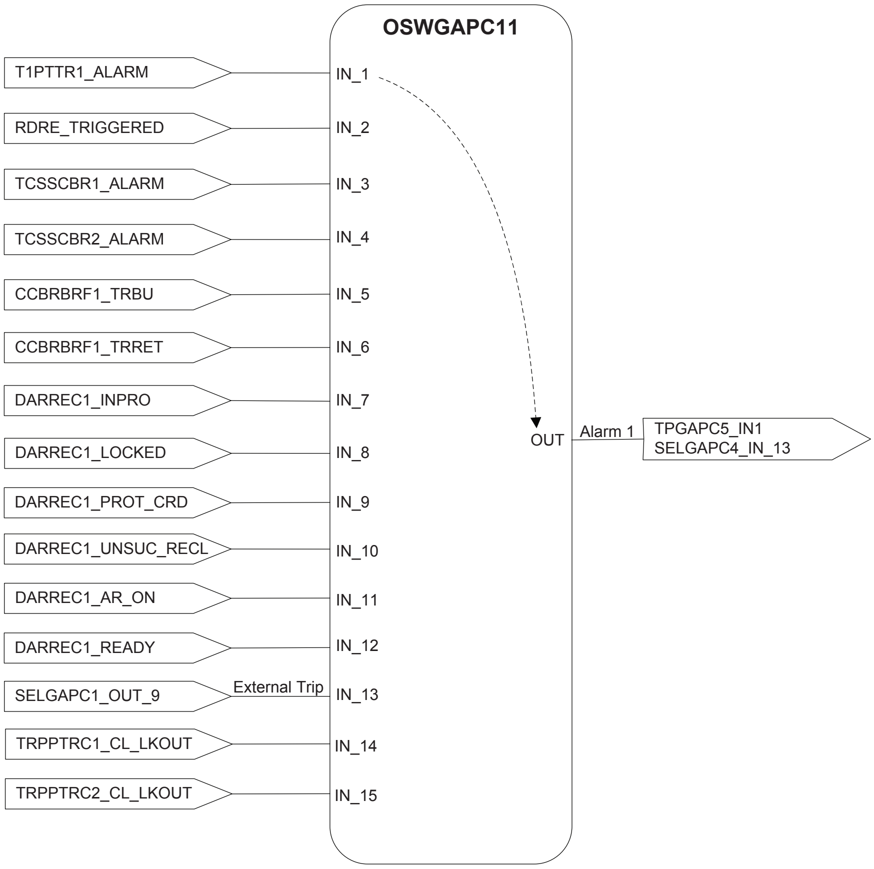


Figure 52: OSWGAPC11

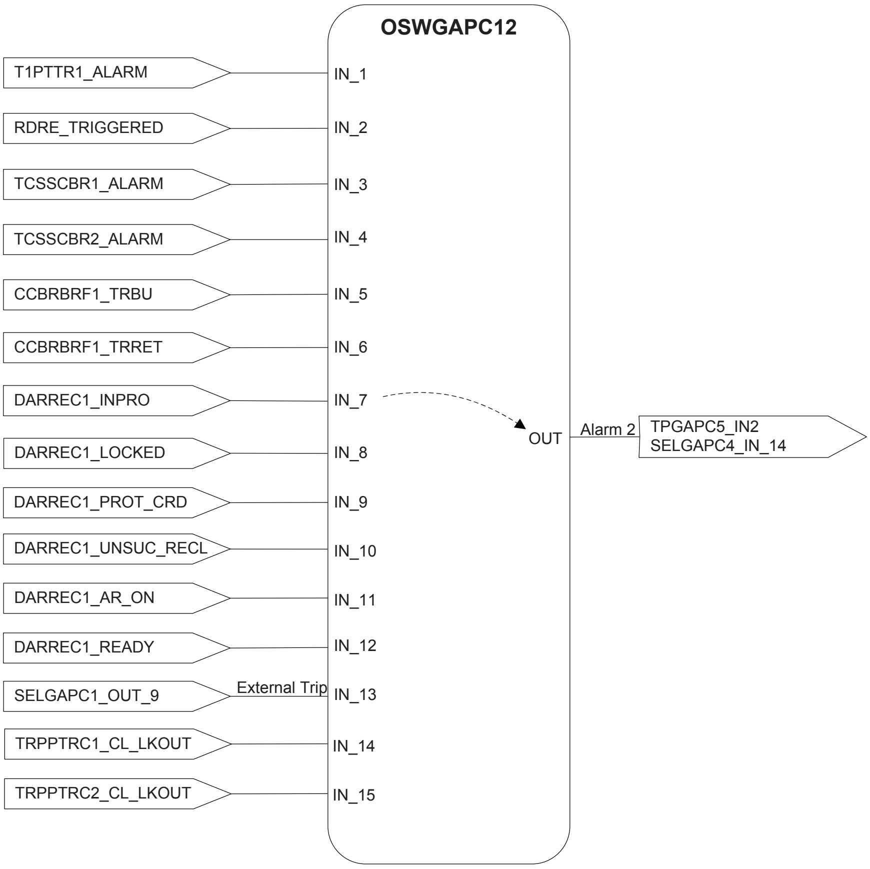


Figure 53: OSWGAPC12

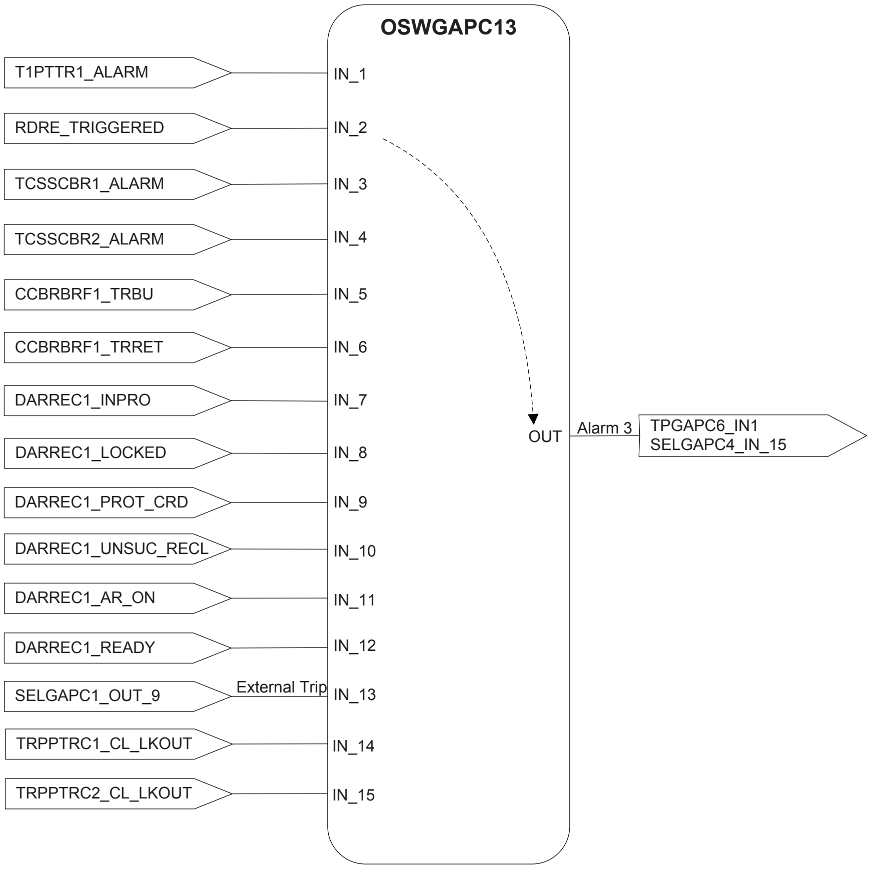


Figure 54: OSWGAPC13

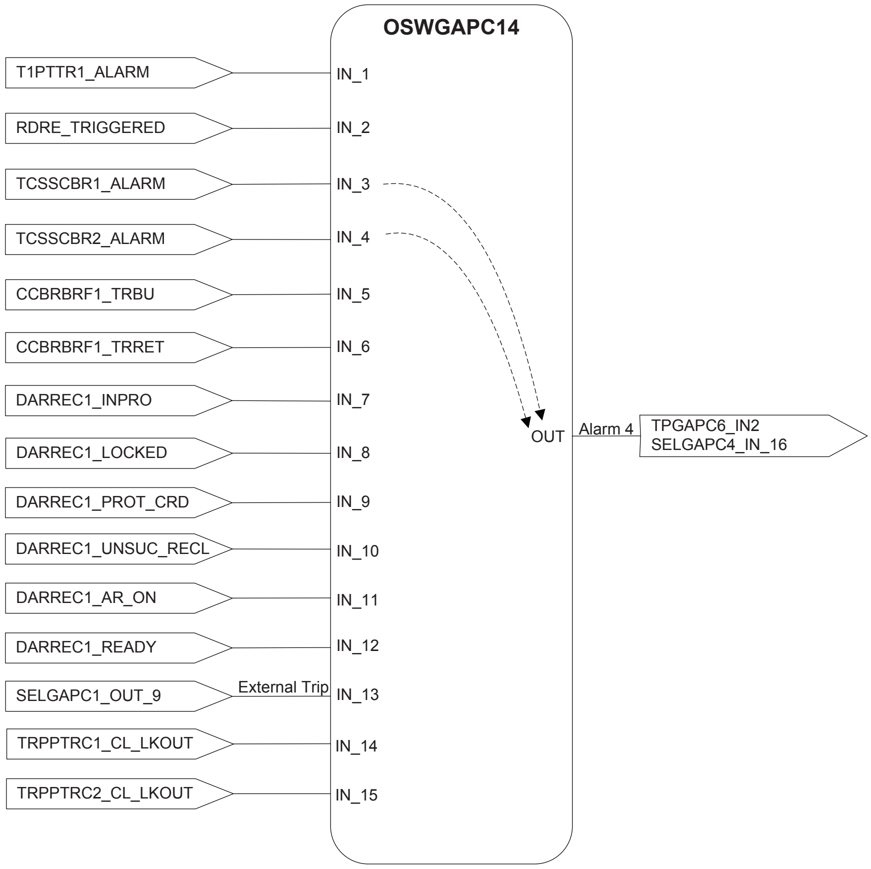


Figure 55: OSWGAPC14

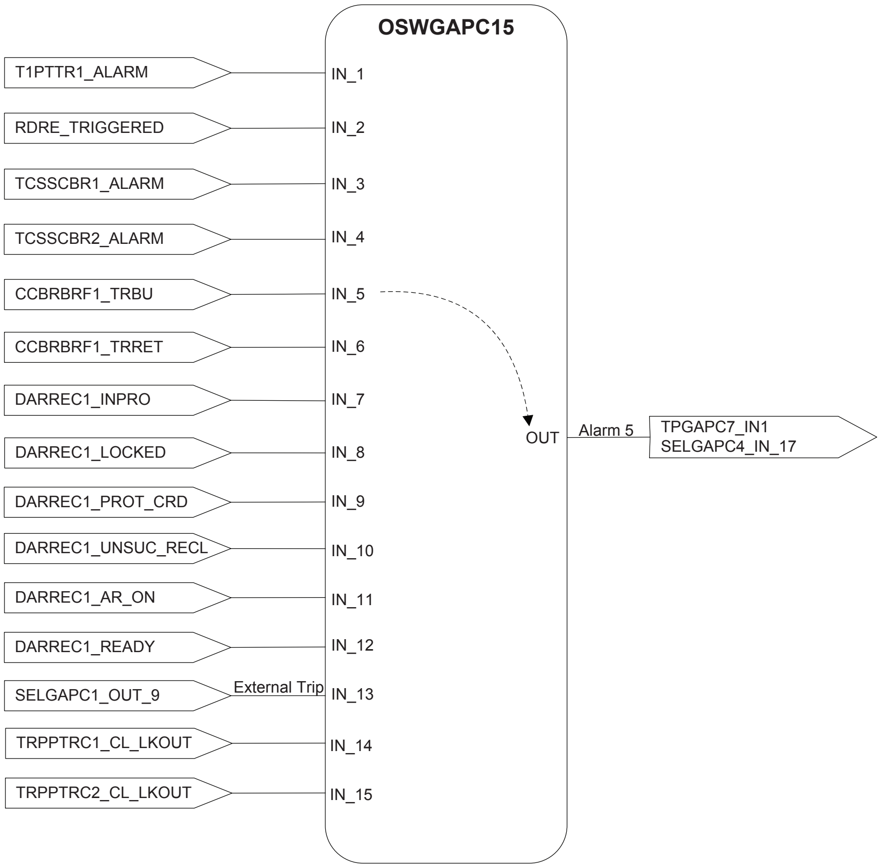


Figure 56: OSWGAPC15

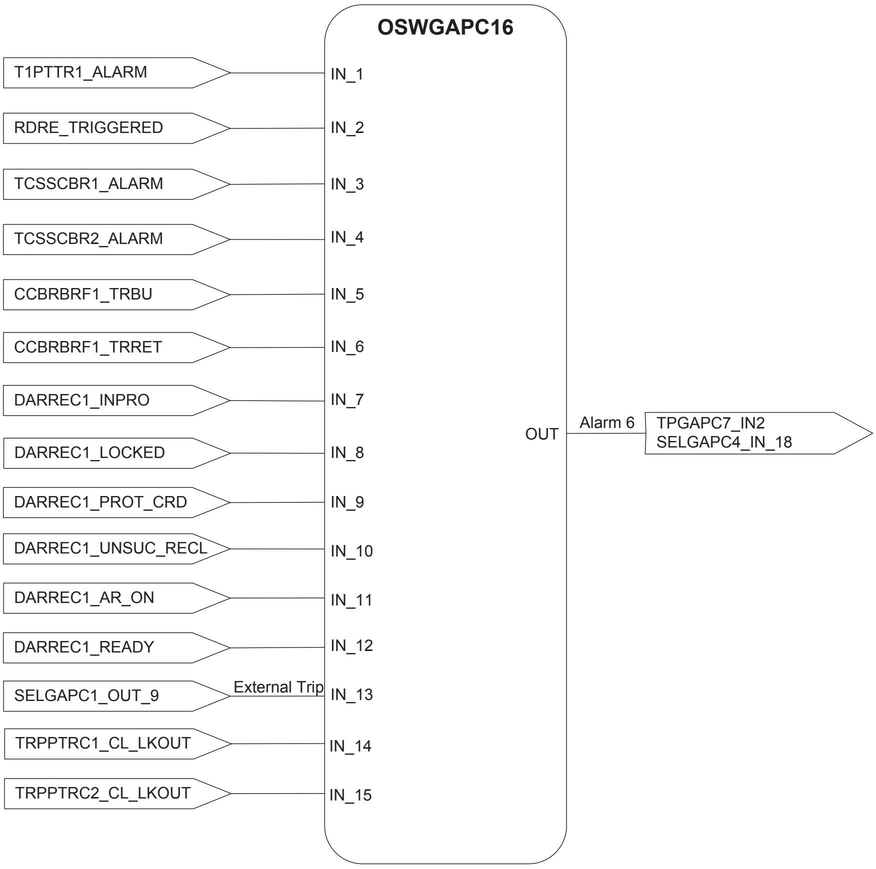


Figure 57: OSWGAPC16

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 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.

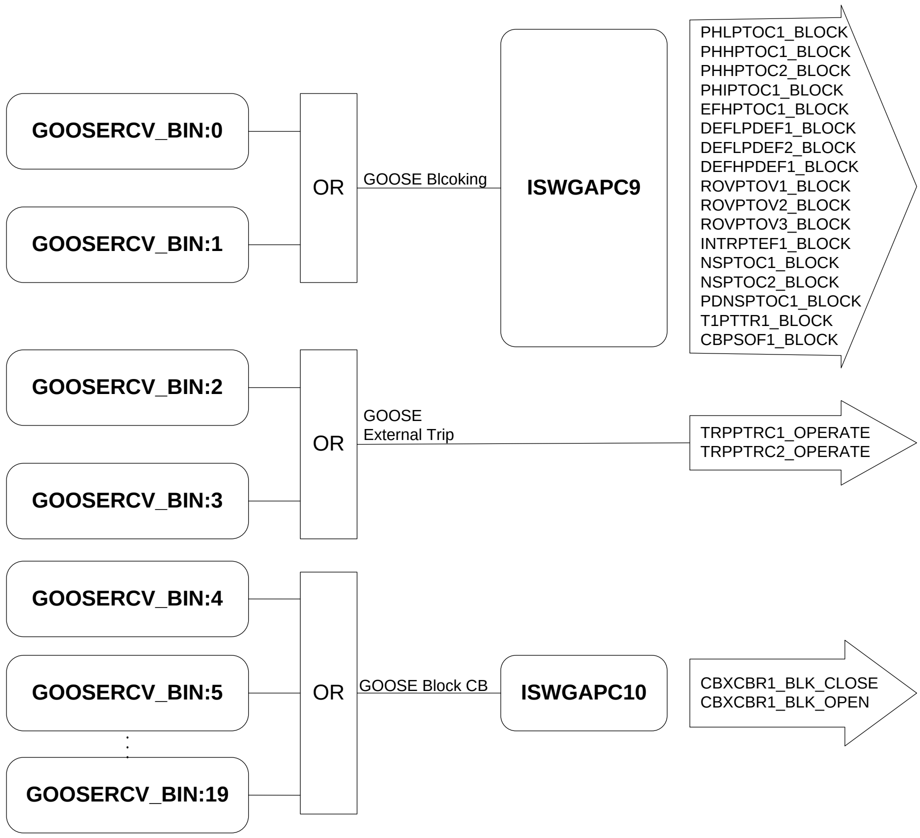


Figure 58: GOOSE overview

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 block inputs of the protection functions.

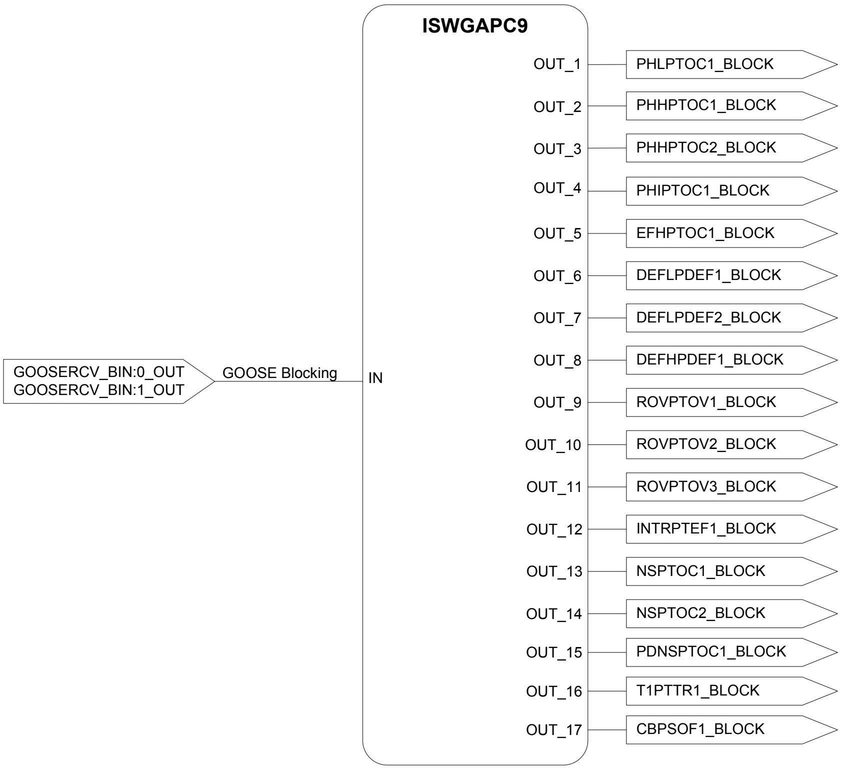


Figure 59: ISWGAPC9

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's close and open operation.

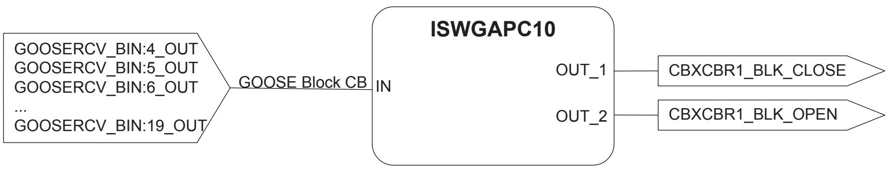


Figure 60: ISWGAPC10

3.5 Configuration B

3.5.1 Applications

Configuration B for non-directional overcurrent and non-directional earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks.

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.

3.5.2 Functions

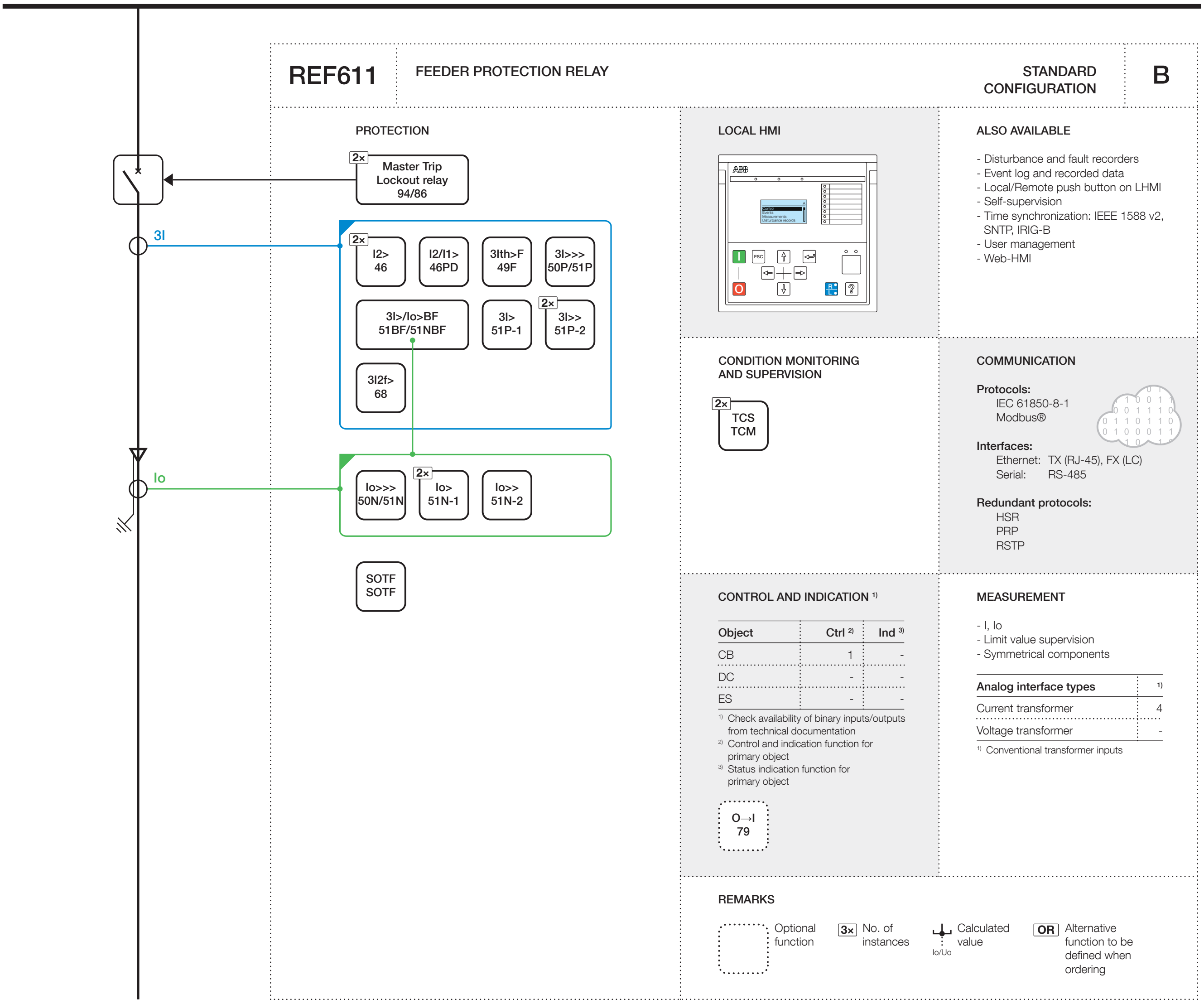


Figure 61: Functionality overview for configuration B

3.5.2.1 Default I/O connections

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	Blocking of overcurrent instantaneous stage	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	Reset of master trip lockout	X120:5-6

Table 17: 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 circuit breaker/trip coil 2	X100:20-24
X100-SO1	General start indication	X100:10-12
X100-SO2	General operate indication	X100:13-15

Table 18: Default connections for LEDs

LED	Description
1	Non-directional overcurrent operate
2	Earth fault operate
3	Negative-sequence overcurrent/phase discontinuity operate
4	Thermal overload alarm
5	Autoreclose in progress
6	Disturbance recorder triggered
7	Trip circuit supervision alarm
8	Circuit-breaker failure operate

3.5.2.2 Predefined disturbance recorder connections

Table 19: 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.

3.5.3 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.

3.5.3.1 Functional diagrams for protection

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

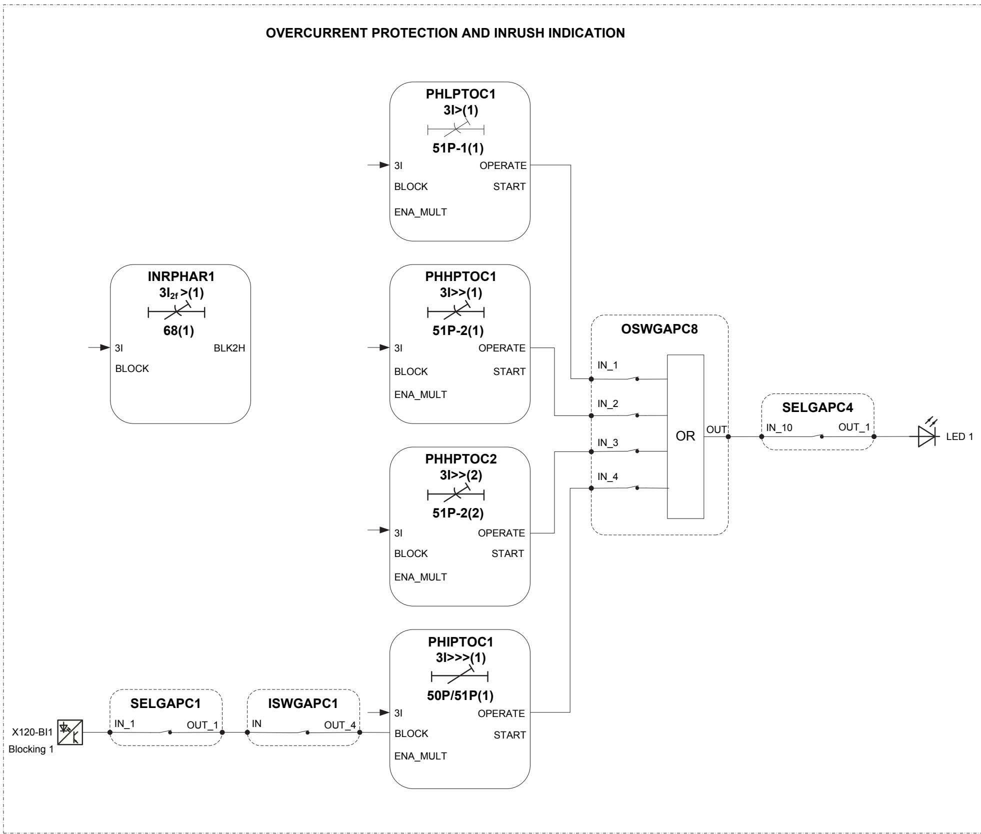


Figure 62: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage PHIPTOC1 can be blocked by energizing the binary input (X120:1-2). The inrush detection block's INRPHAR1 output `BLK2H` enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LED 1.

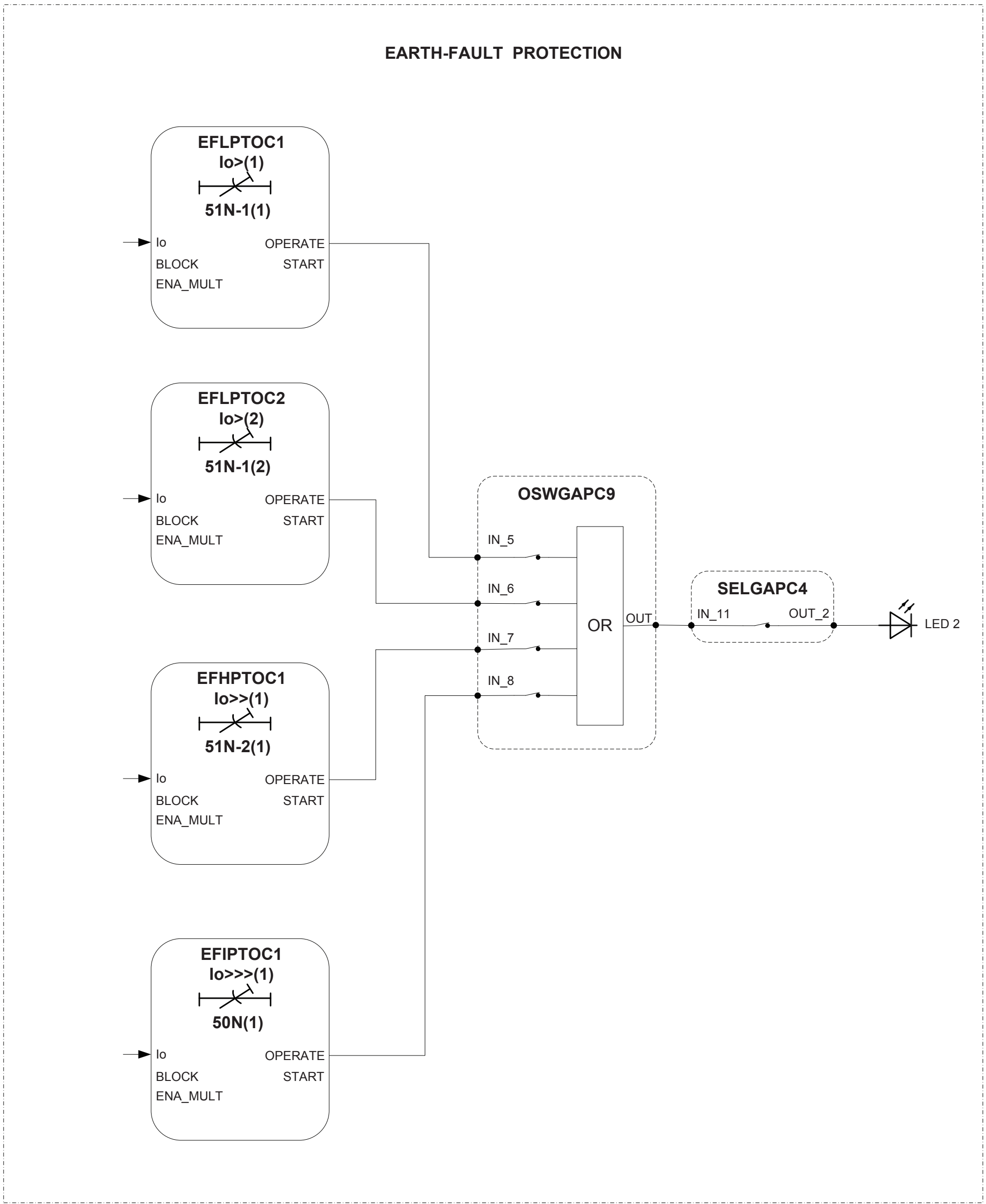


Figure 63: Earth-fault protection

Four stages are offered for non-directional earth-fault protection.

All operate signals are connected to the Master Trip as well as to the alarm LED 2.

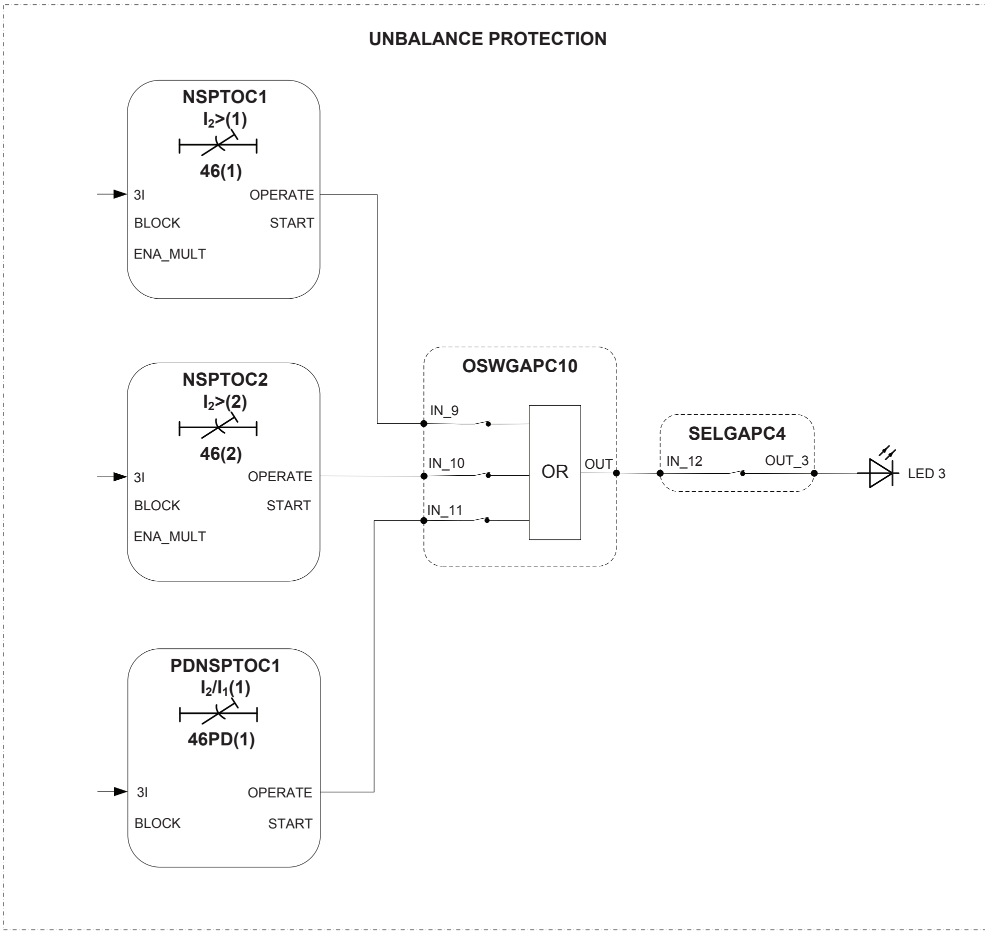


Figure 64: Unbalance protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 and one phase discontinuity stage PDNPSTOC1 are offered for the unbalance protection. The phase discontinuity protection PDNPSTOC1 provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

The operate signals of these unbalance protections are connected to the Master Trip and also to alarm LED 3.

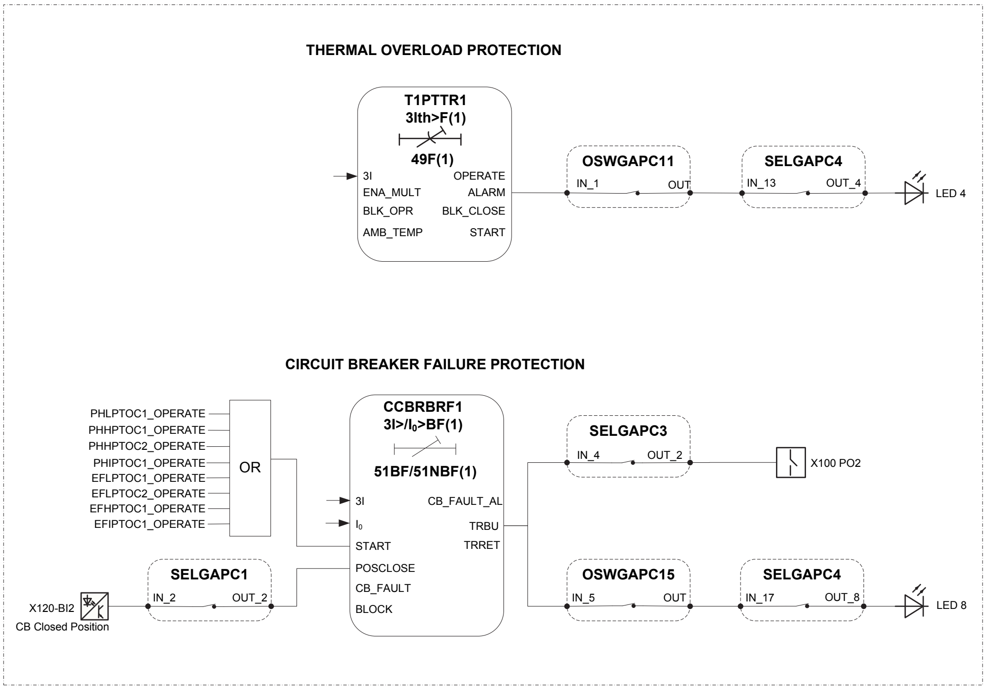


Figure 65: Thermal overload and circuit-breaker failure protection

The thermal overload protection T1PTTR1 provides indication on overload situations. LED 4 is used for the thermal overload protection alarm indication.

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 the backup (`TRBU`) operate indication.

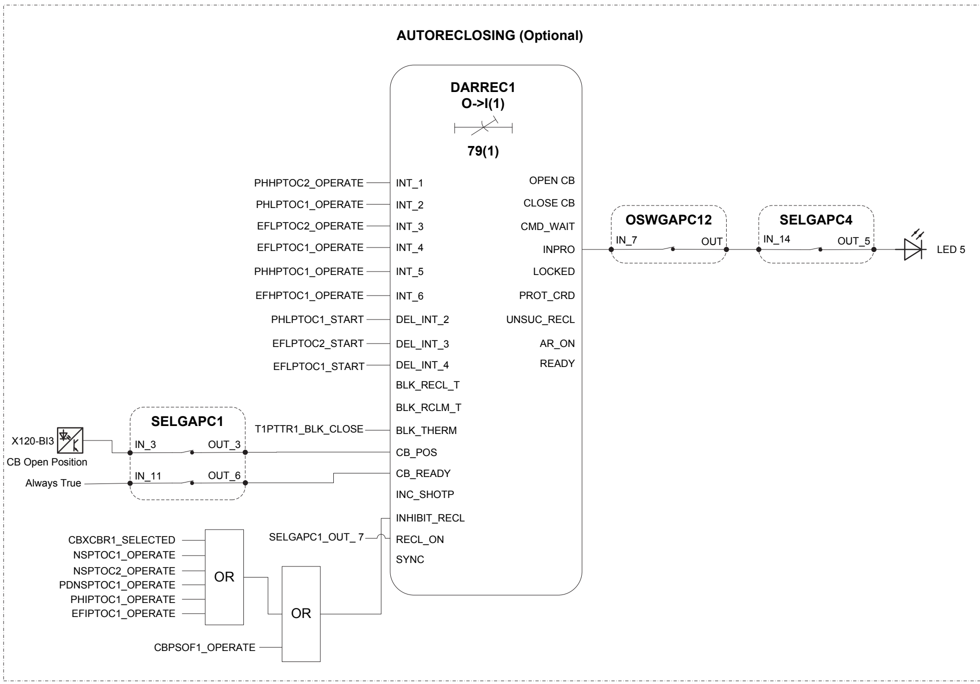


Figure 66: Autoreclosing

Autoreclosing DARREC1 is included as an optional function.

The autoreclose function is configured to be initiated by operate signals from a number of protection stages through the `INT_1...6` inputs and by start signals through the DEL_INT_2…4. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the `INHIBIT_RECL` input. By default, the operations of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR_SELECTED signal.

The circuit breaker availability for the autoreclose sequence is expressed with the `CB_READY` input in DARREC1. In the configuration, this signal is connected with an always true signal through SELGAPC1. As a result, the function assumes that the circuit breaker is available all the time.

The autoreclose sequence in progress indication INPRO is connected to the alarm LED 5.

3.5.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

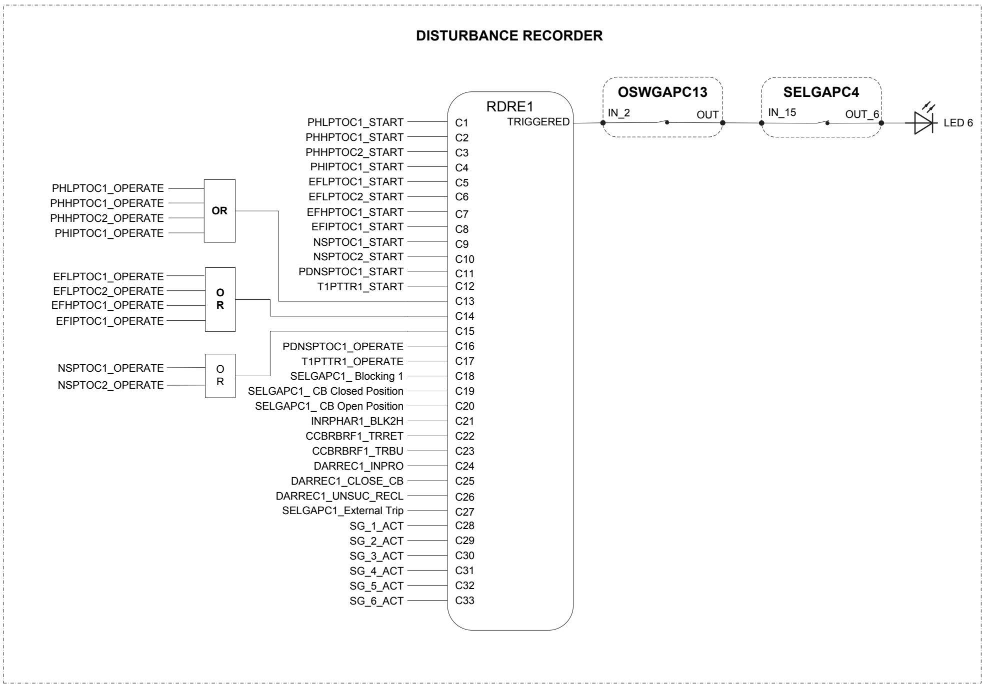


Figure 67: Disturbance recorder

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 autoreclose 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 20: 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	PHHPTOC1_START	1=positive or rising
Binary channel 3	PHHPTOC2_START	1=positive or rising
Binary channel 4	PHIPTOC1_START	1=positive or rising
Binary channel 5	EFLPTOC1_START	1=positive or rising
Binary channel 6	EFLPTOC2_START	1=positive or rising
Binary channel 7	EFHPTOC1_START	1=positive or rising
Binary channel 8	EFIPTOC1_START	1=positive or rising
Binary channel 9	NSPTOC1_START	1=positive or rising
Binary channel 10	NSPTOC2_START	1=positive or rising
Binary channel 11	PDNSPTOC1_START	1=positive or rising
Table continues on next page		

Channel number	Channel id text	Level trigger mode
Binary channel 12	T1PTTR1_START	1=positive or rising
Binary channel 13	PHxPTOC_OPERATE	4=level trigger off
Binary channel 14	EFxPTOC_OPERATE	4=level trigger off
Binary channel 15	NSPTOC1/2_OPERATE	4=level trigger off
Binary channel 16	PDNSPTOC1_OPERATE	4=level trigger off
Binary channel 17	T1PPTR1_OPERATE	4=level trigger off
Binary channel 18	SELGAPC1_Blocking 1	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	INRPHAR1_BLK2H	4=level trigger off
Binary channel 22	CCBRBRF1_TRRET	4=level trigger off
Binary channel 23	CCBRBRF1_TRBU	4=level trigger off
Binary channel 24	DARREC1_INPRO	4=level trigger off
Binary channel 25	DARREC1_CLOSE_CB	4=level trigger off
Binary channel 26	DARREC1_UNSUC_RECL	4=level trigger off
Binary channel 27	SELGAPC1_External Trip	4=level trigger off
Binary channel 28	SG_1_ACT	4=level trigger off
Binary channel 29	SG_2_ACT	4=level trigger off
Binary channel 30	SG_3_ACT	4=level trigger off
Binary channel 31	SG_4_ACT	4=level trigger off
Binary channel 32	SG_5_ACT	4=level trigger off
Binary channel 33	SG_6_ACT	4=level trigger off

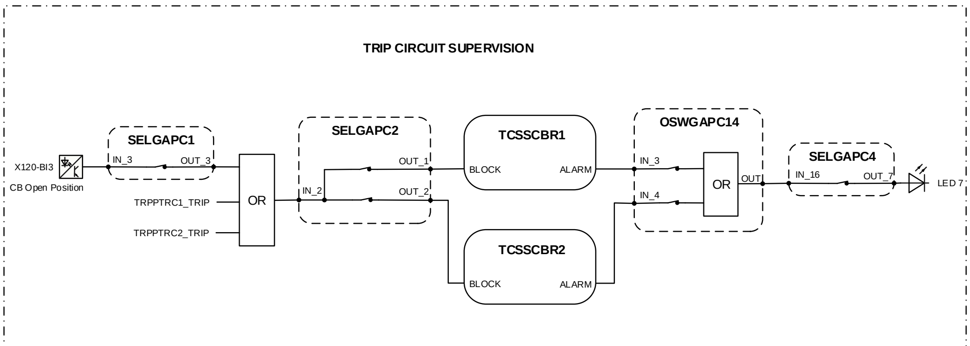


Figure 68: Trip circuit supervision

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 Master Trip (TRPPTRC1 and TRPPTRC2) and the circuit breaker open position. The TCS alarm indication is connected to LED 7.

3.5.3.3 Functional diagrams for control

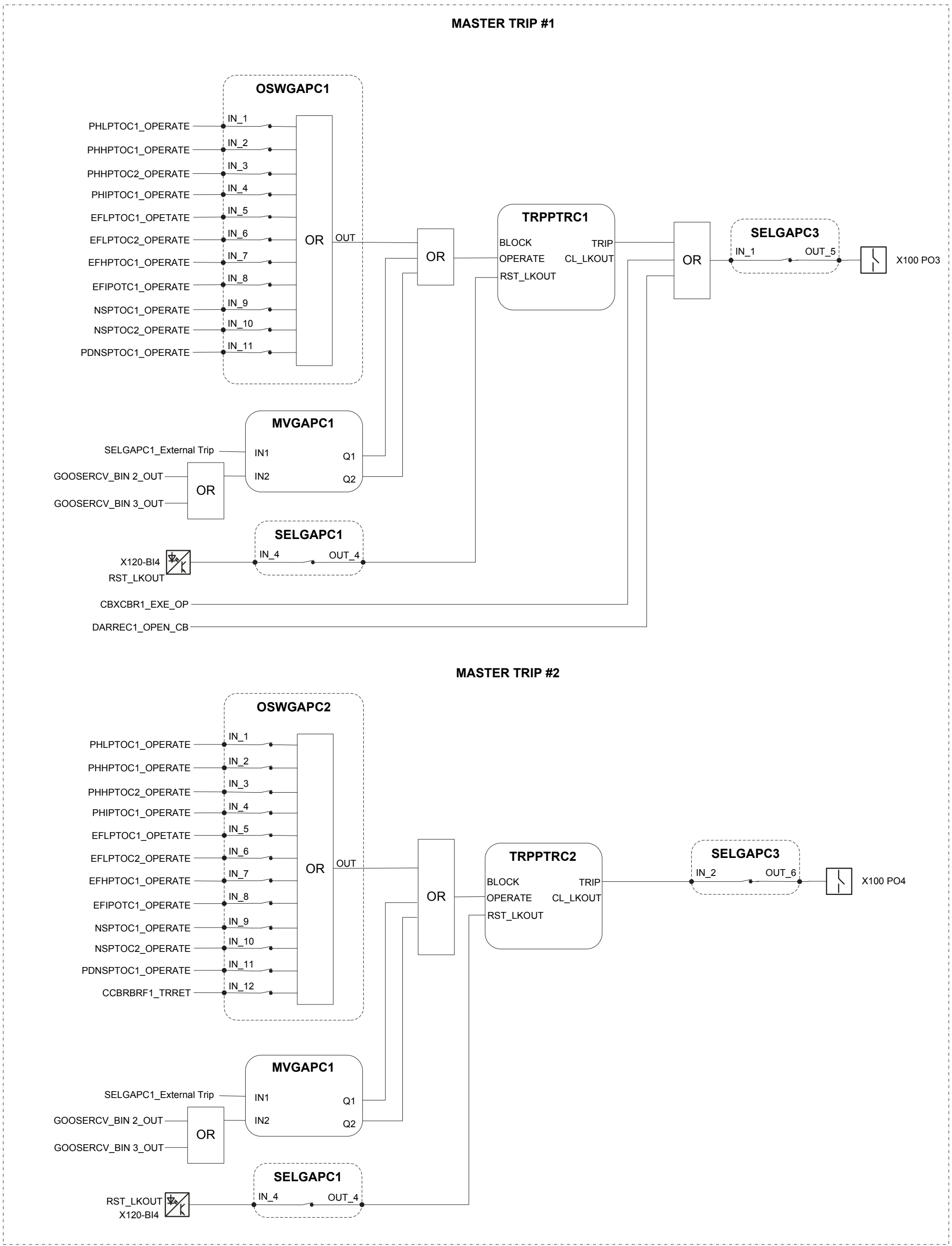


Figure 69: Master trip

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 the external reset.

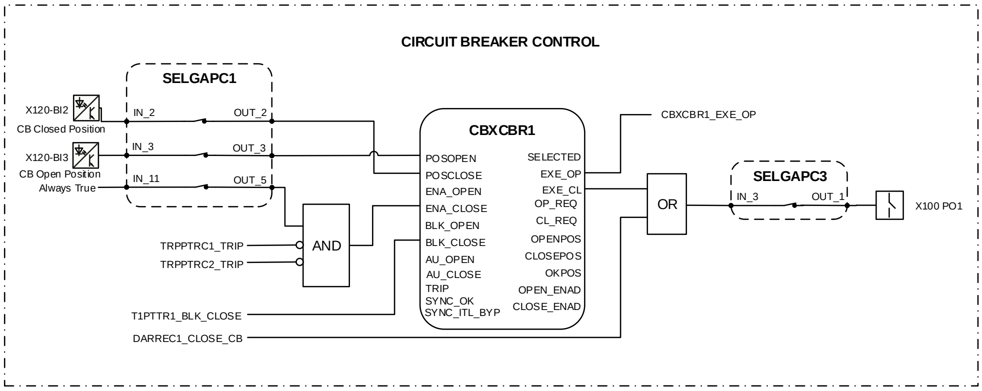


Figure 70: Circuit breaker control

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.

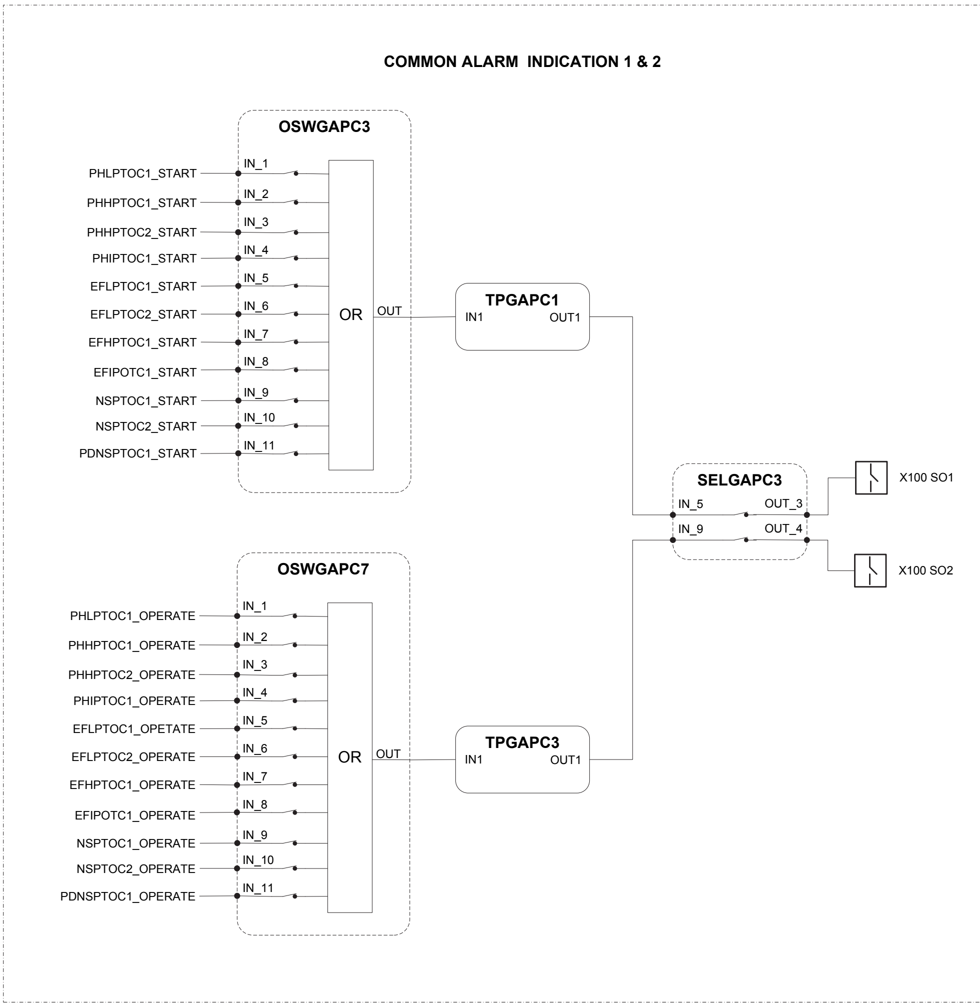


Figure 71: Common alarm indication

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.

3.5.4 Switch groups

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

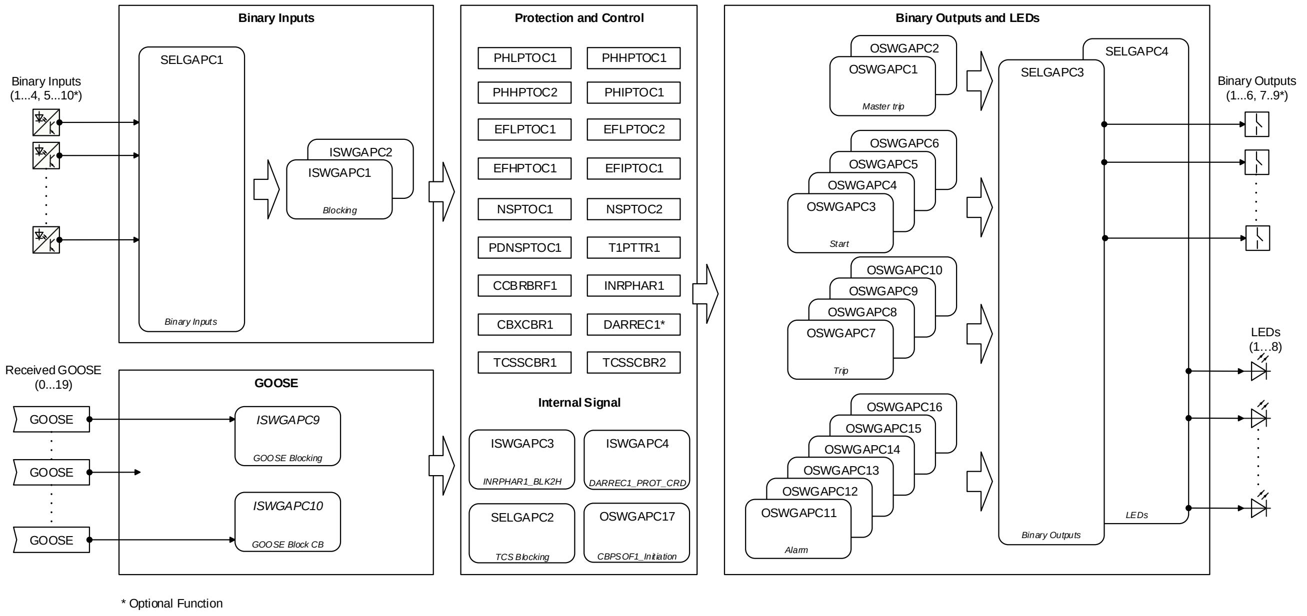


Figure 72: Configuration B switch group overview

3.5.4.1 Binary inputs

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.

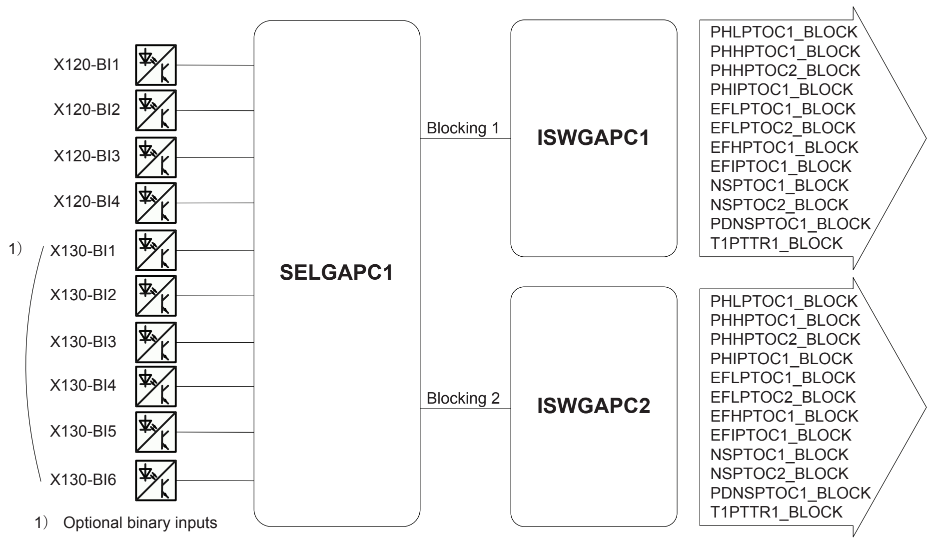


Figure 73: Binary inputs

SELGAPC1

SELGAPC1 has inputs from protection relay binary inputs. IN_1...IN_4 are binary inputs from X100. IN_5...IN_10 can be used while X130 optional card is taken into use. An always true signal is connected to IN_11. SELGAPC1 outputs are used to route inputs to different functions. By setting SELGAPC1, binary inputs can be configured for different purposes.

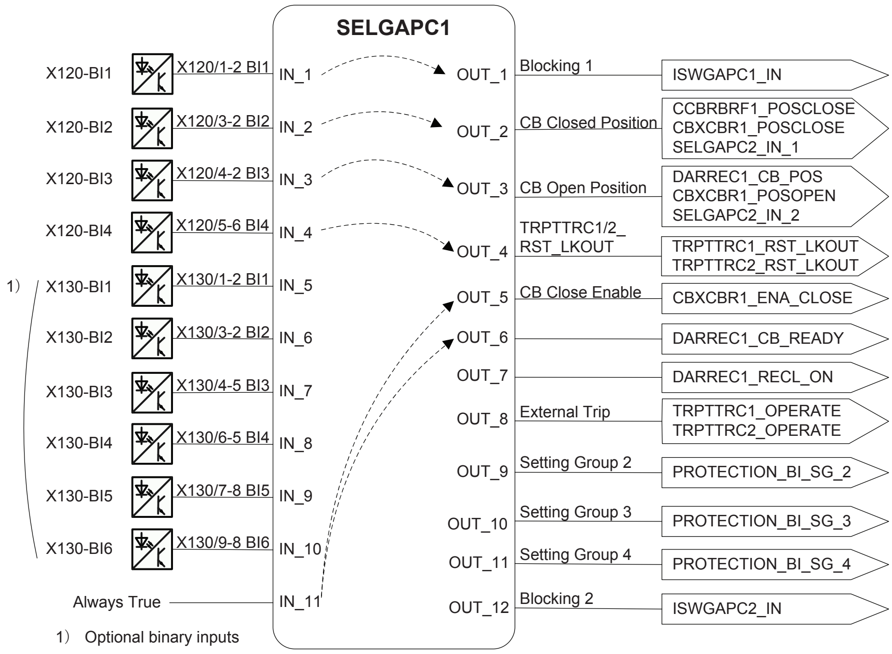


Figure 74: SELGAPC1

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.

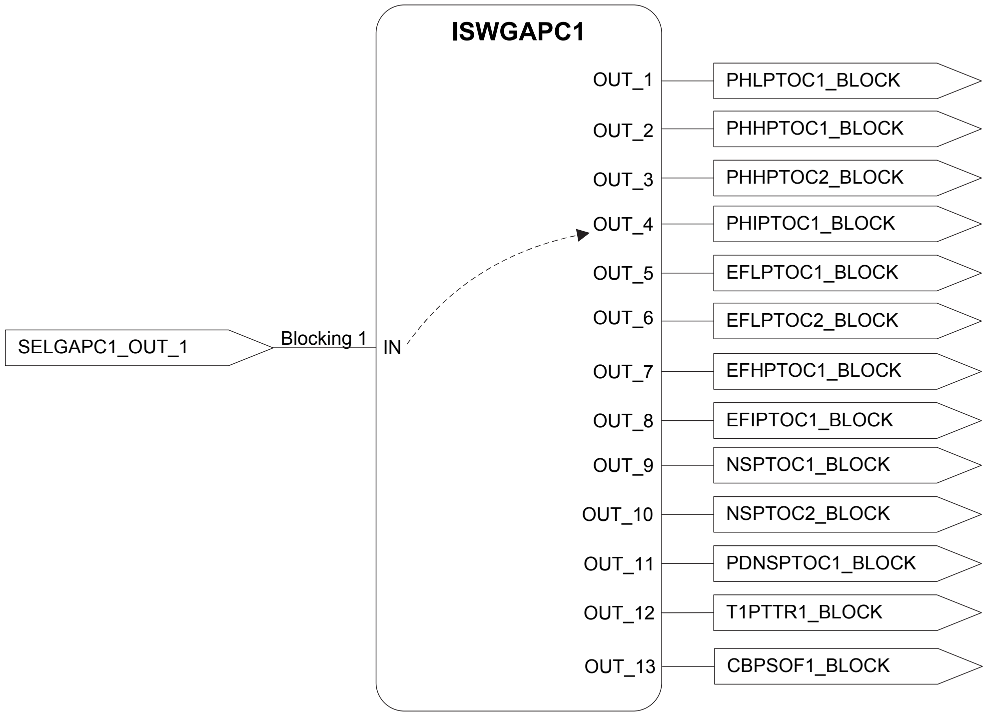


Figure 75: ISWGAPC1

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_12 Blocking 2`. ISWGAPC2 outputs are connected to the `BLOCK` inputs of the protection functions.

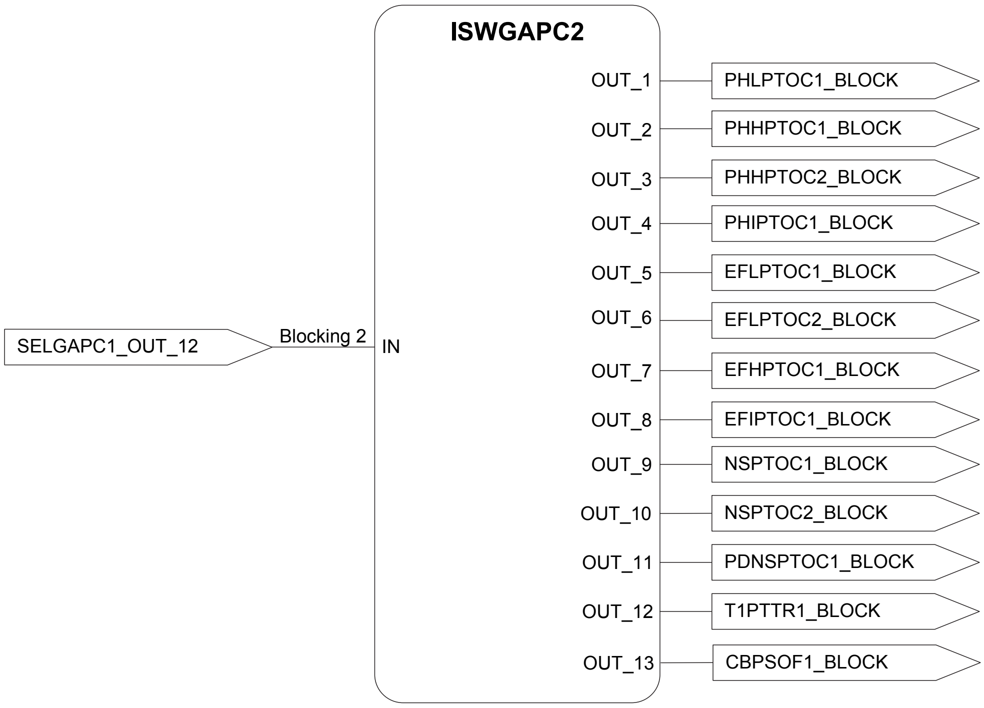


Figure 76: ISWGAPC2

3.5.4.2 Internal signals

The internal signal group is used to configure logic connections between function blocks. There are two ISWGAPC instances, one SELGAPC and one OSWGAPC instance in this group.

ISWGAPC3 is used to configure which protection function enables current multiplier if inrush is detected by the INRPHAR1 function. ISWGAPC4 is used to configure the cooperation between the autoreclose function and protection functions. Autoreclose function DARREC1 can block protection functions according to the application. SELGAPC2 is used to configure TCS blocking from the circuit breaker open or close position. OSWGAPC17 is used for connecting switch onto fault function CBPSOF. The inputs are start signals routed from the protection functions.

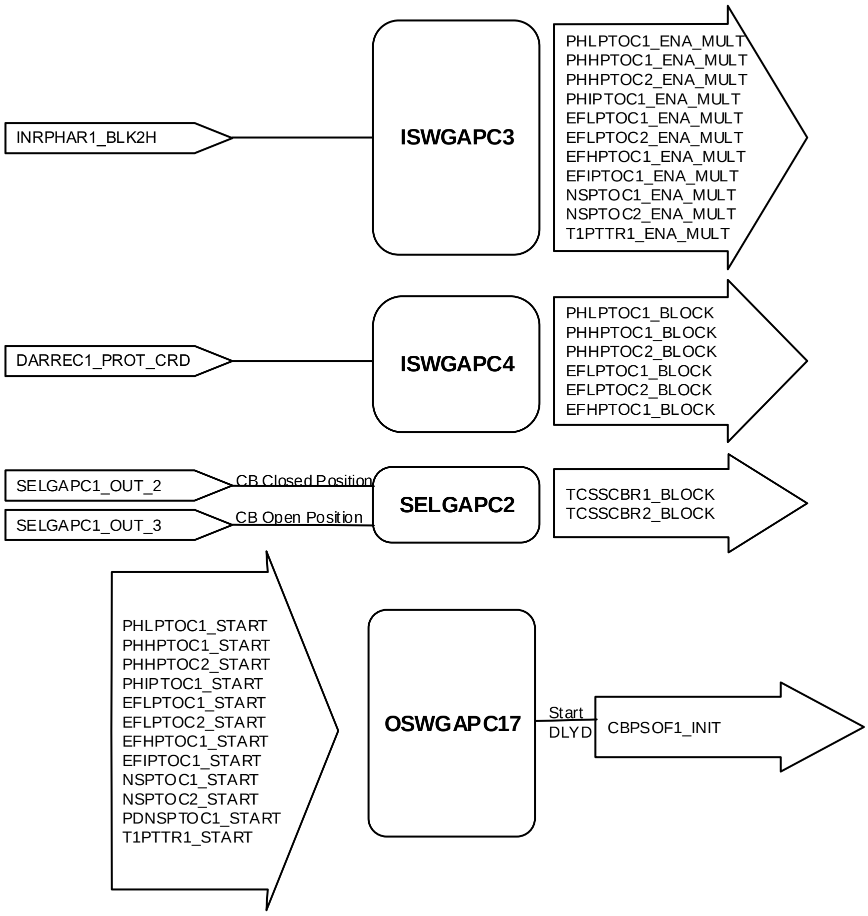


Figure 77: Internal signal

ISWGAPC3

ISWGAPC3 input is used to configure which protection function enables current multiplier while inrush is detected by INRPHAR1 by changing the ISWGAPC3 parameters. ISWGAPC3 input is routed from INRPHAR1 output `BLK2H`. ISWGAPC3 outputs are connected to the `ENA_MULT` inputs of the protection functions.

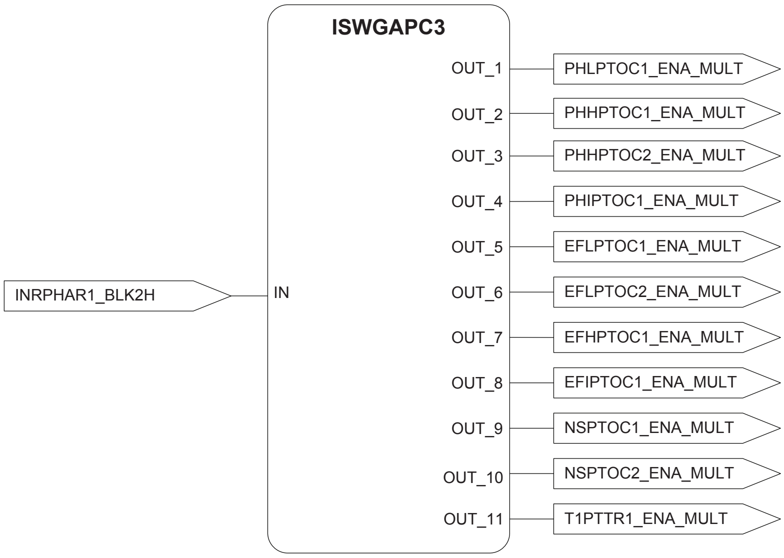


Figure 78: ISWGAPC3

ISWGAPC4

ISWGAPC4 input is used to configure which protection function is blocked by the autoreclosing function by changing the ISWGAPC4 parameters. ISWGAPC4 input is routed from DARREC1 output `PROT_CRD`. ISWGAPC4 outputs are connected to the `BLOCK` inputs of some of the protection functions.

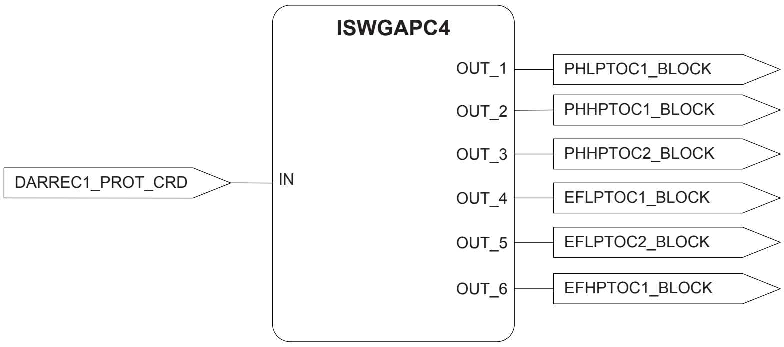


Figure 79: ISWGAPC4

SELGAPC2

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

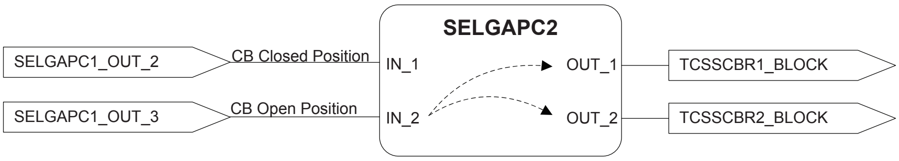


Figure 80: SELGAPC2

OSWGAPC17

OSWGAPC17 is used to route the protection function start signals to the `StartDLYD` input of the switch onto fault function CBPSOF. CBPSOF provides an instantaneous trip or a time delayed trip when closing the breaker while a fault exists. OSWGAPC17 output is connected to CBPSOF function indicating the detected fault.

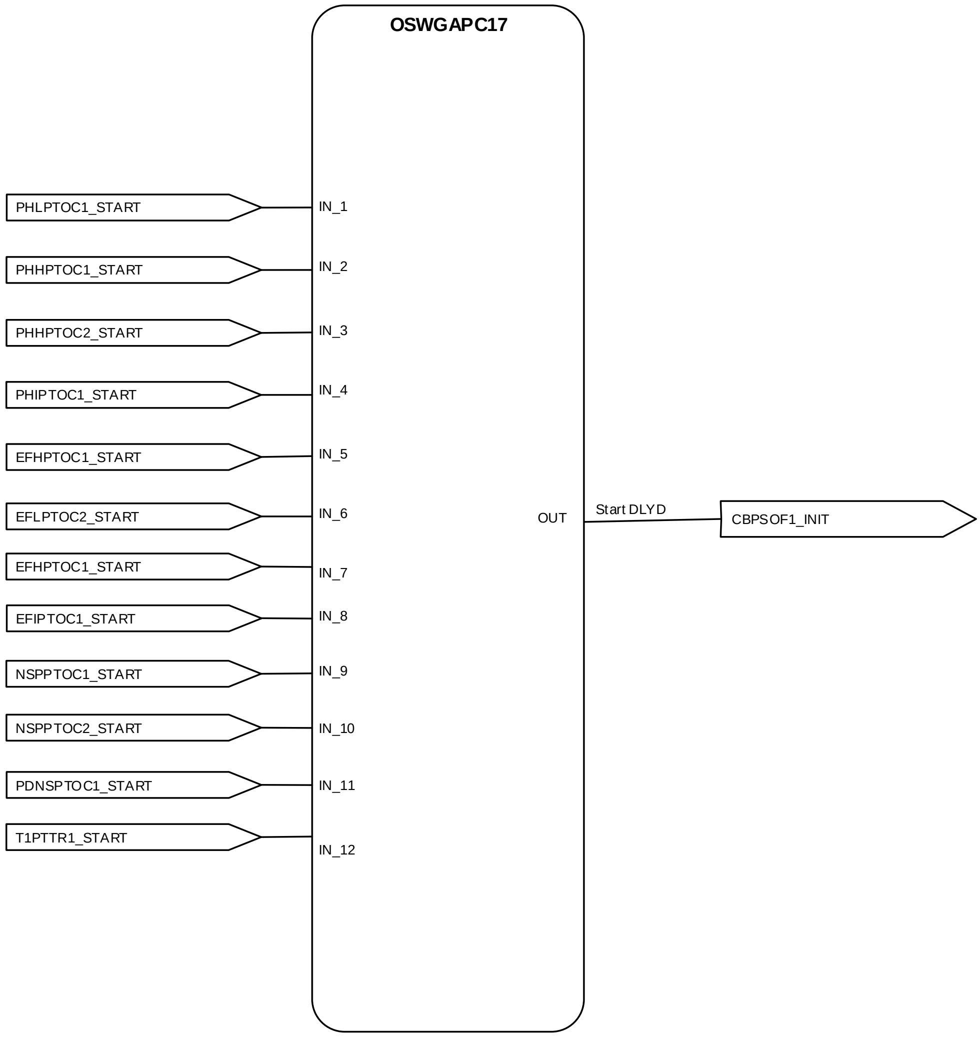


Figure 81: OSWGAPC17

3.5.4.3 Binary outputs and LEDs

In configuration B, signals are routed to binary outputs and LEDs are configured by OSWGAPC. The 16 OSWGAPC instances are categorized in four groups, including two 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 the OSWGAPC signals to protection relay binary outputs. SELGAPC4 is used to configure the OSWGAPC signals to LEDs.
- OSWGAPC1 and OSWGAPC2 are used for Master trip. The inputs are from the protection functions operate and breaker failures retrip.
- 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.

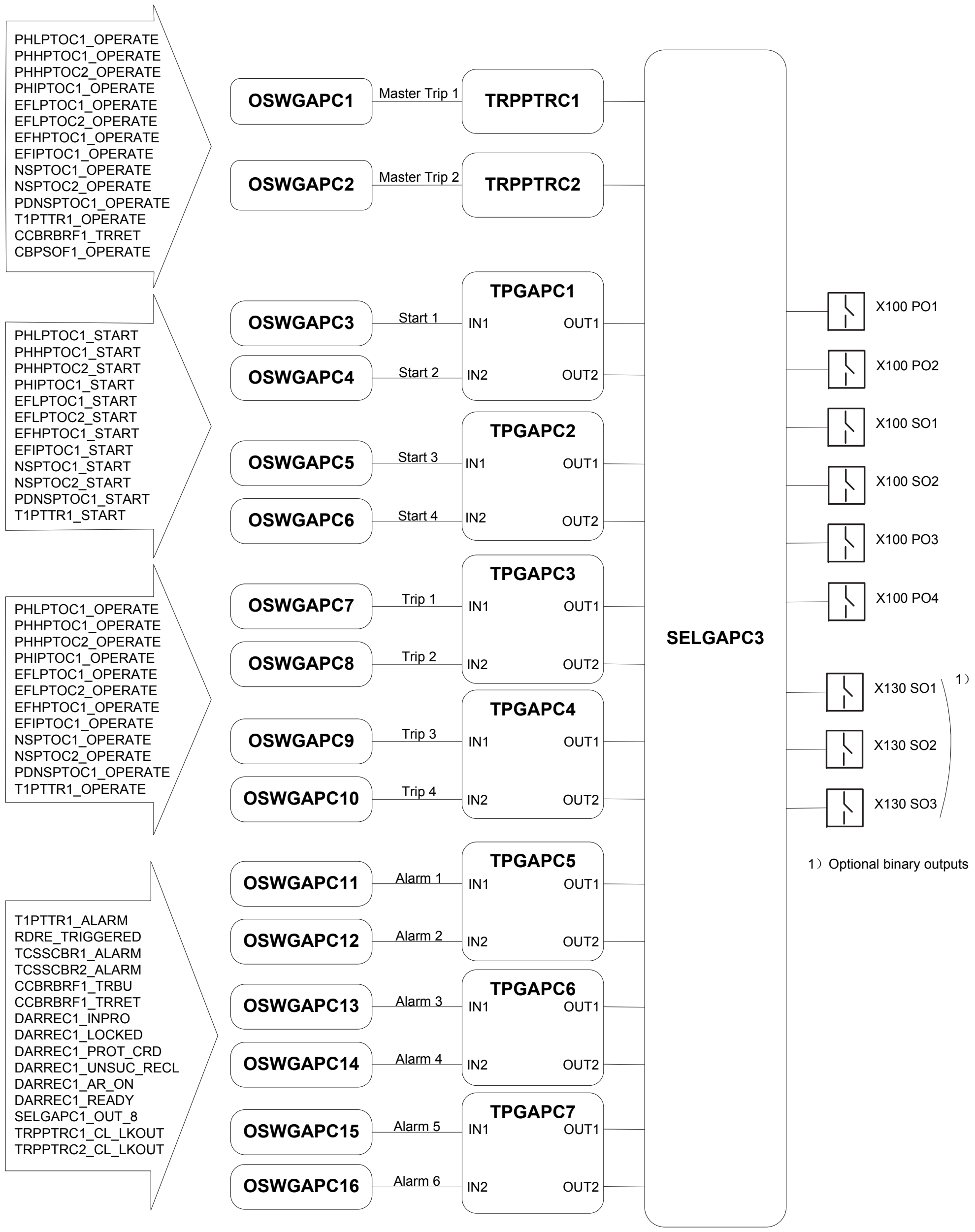


Figure 82: Binary outputs

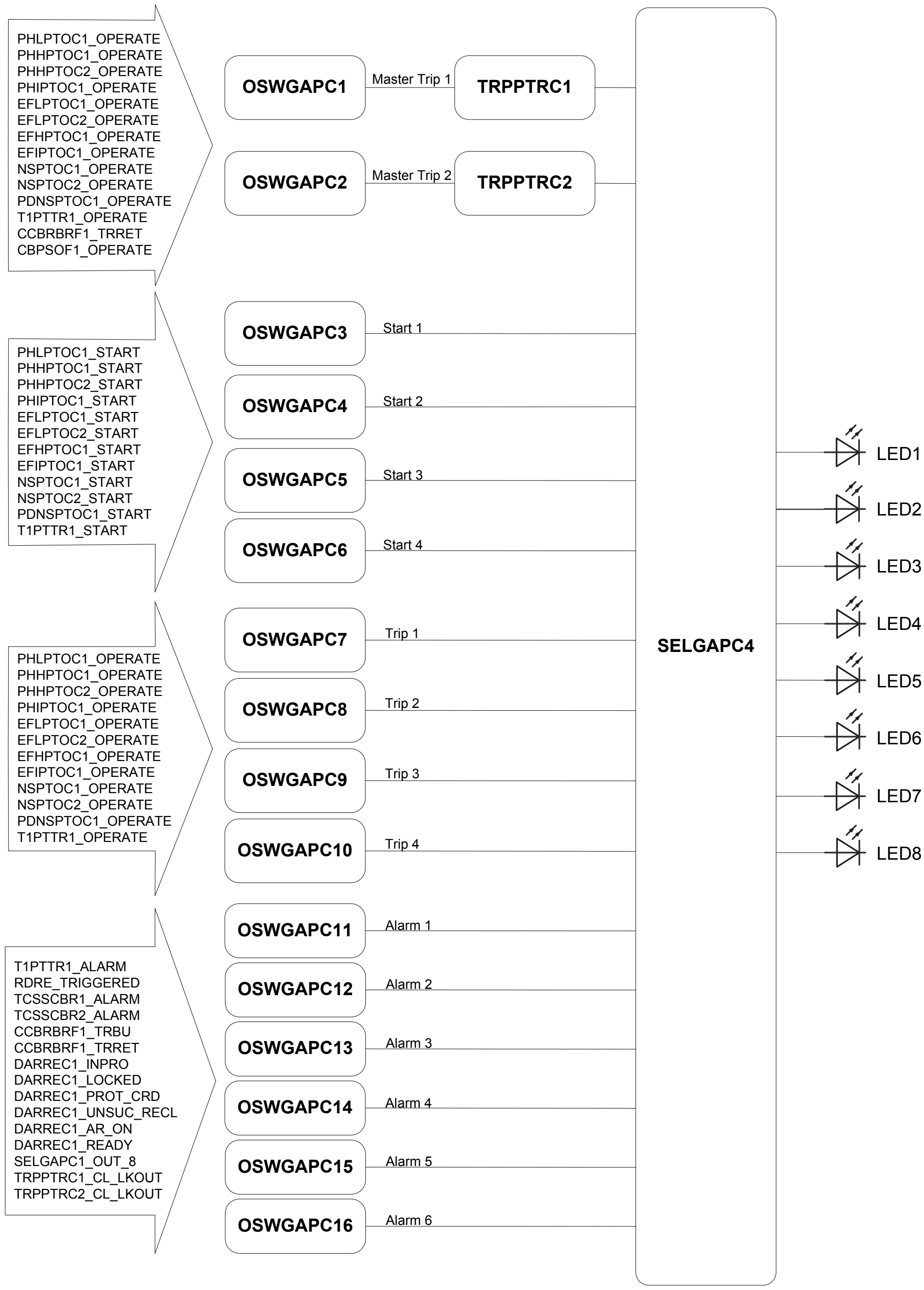


Figure 83: LEDs

SELGAPC3

SELGAPC3 is used to configure the OSWGAPC outputs to the protection relay binary outputs. 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 the X100 binary outputs. If the X130 optional card is taken into use, SELGAPC3 outputs are also connected to the X130 binary outputs.

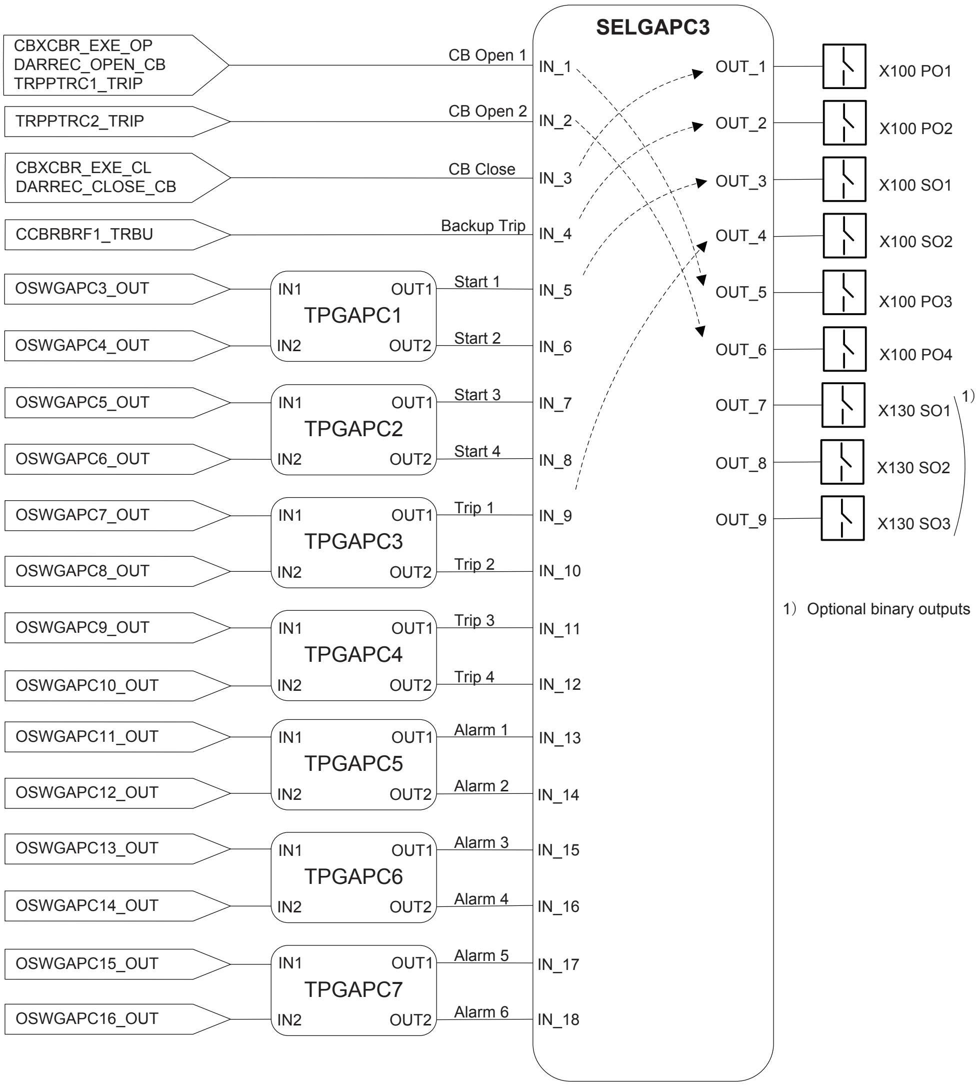


Figure 84: SELGAPC3

SELGAPC4

SELGAPC4 is used to configure 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 with programmable LED1 to LED8.

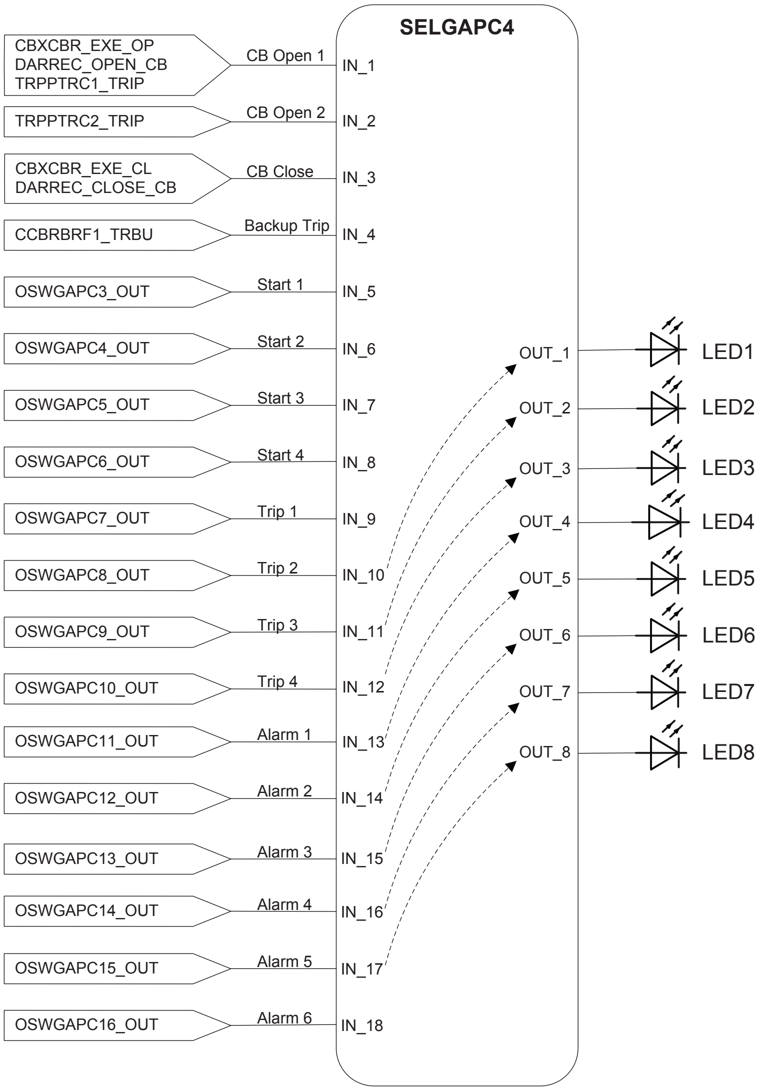


Figure 85: SELGAPC4

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.

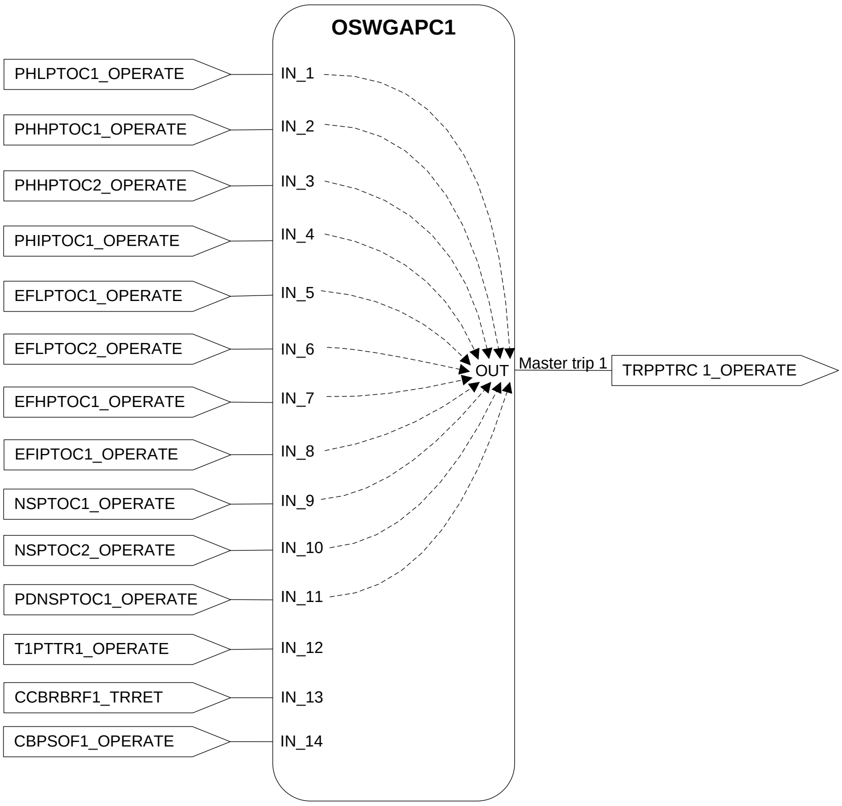


Figure 86: OSWGAPC1

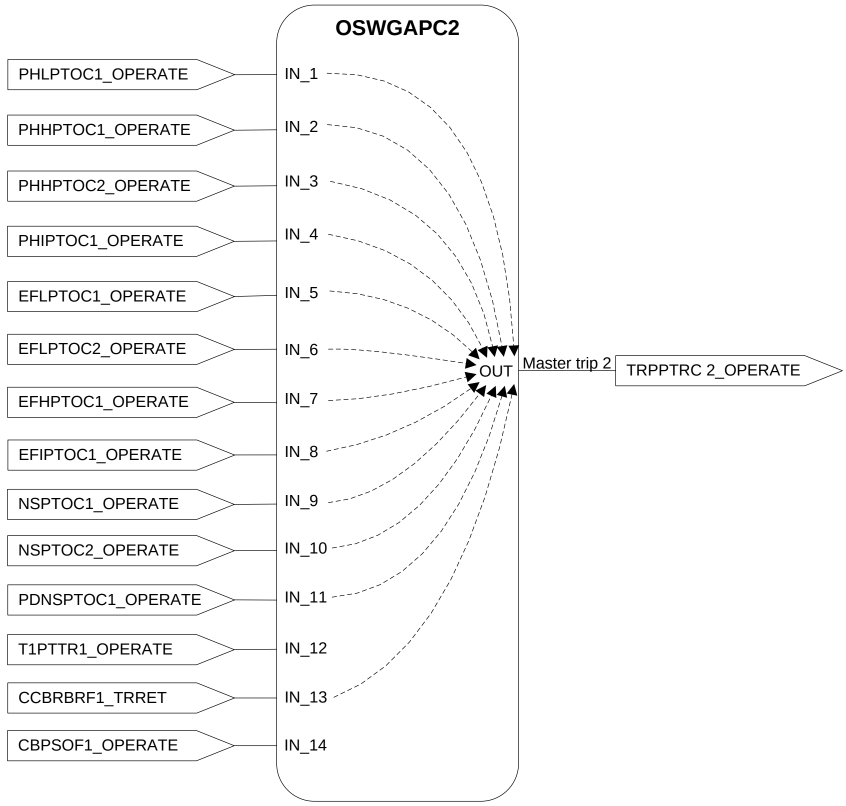


Figure 87: OSWGAPC2

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 the TPGAPC timer and to SELGAPC4 directly.

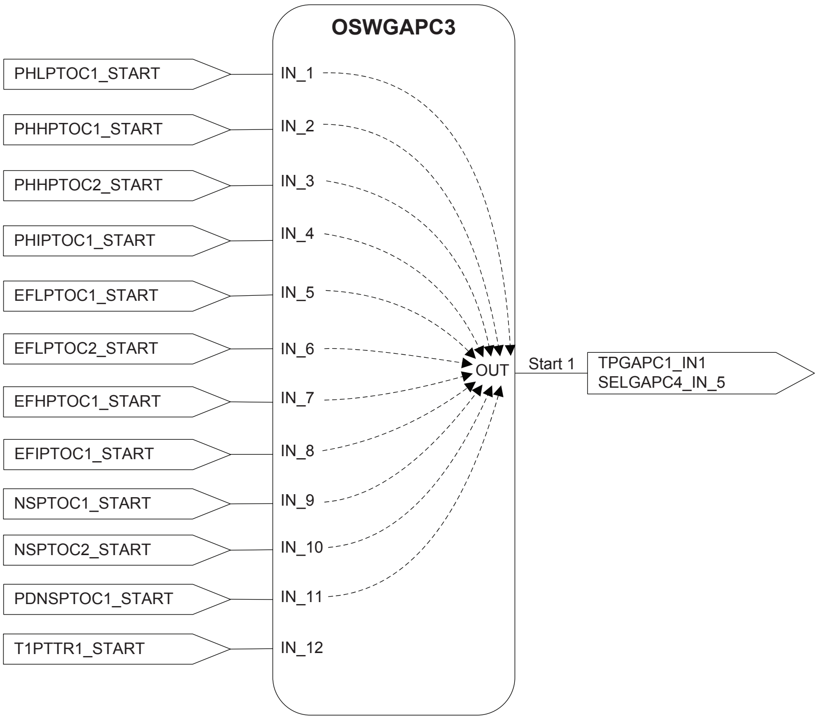


Figure 88: OSWGAPC3

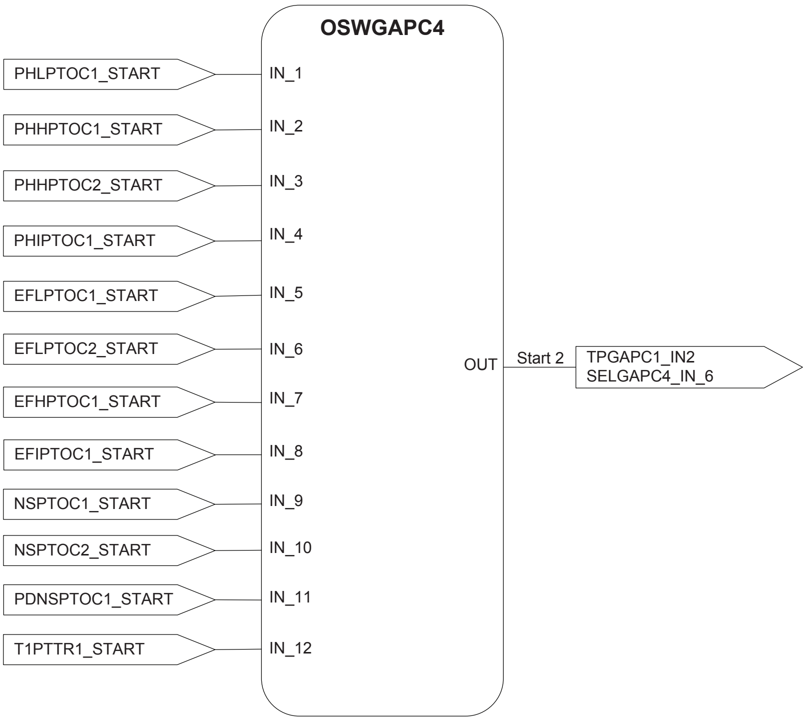


Figure 89: OSWGAPC4

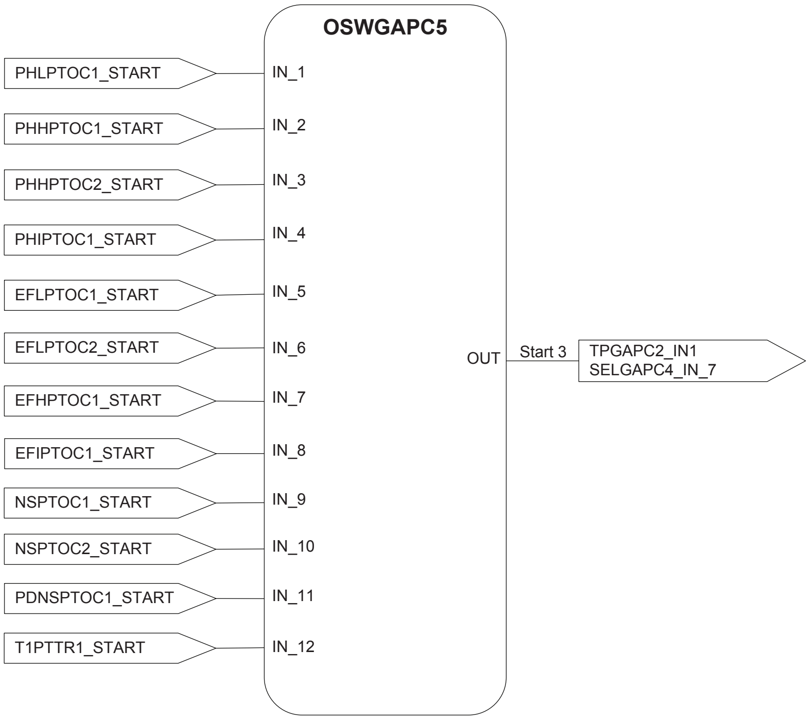


Figure 90: OSWGAPC5

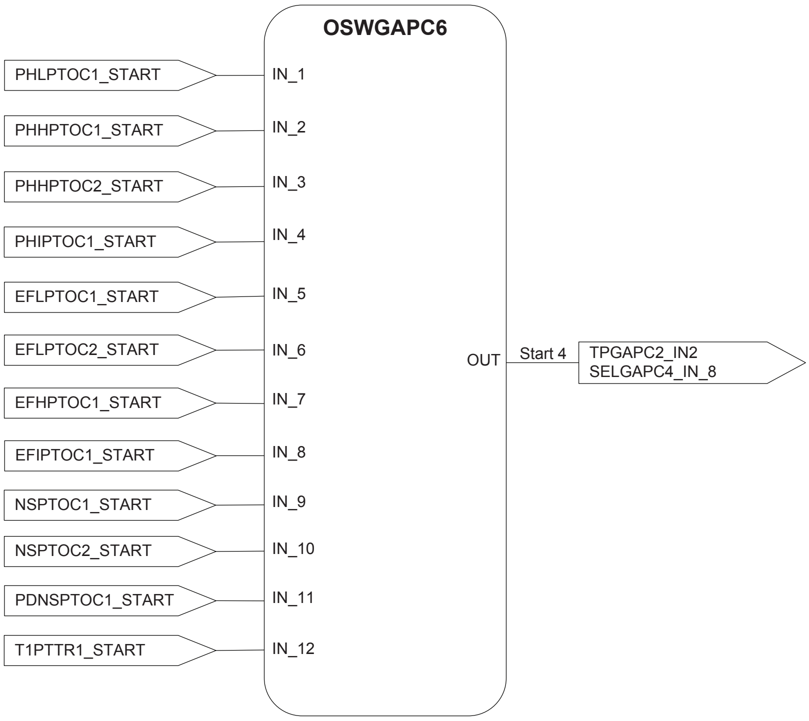


Figure 91: OSWGAPC6

Trip OSWGAPCs

OSWGAPC instances 7...10 are used to configure the protection operate signals which 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 the TPGAPC timer and to SELGAPC4 directly.

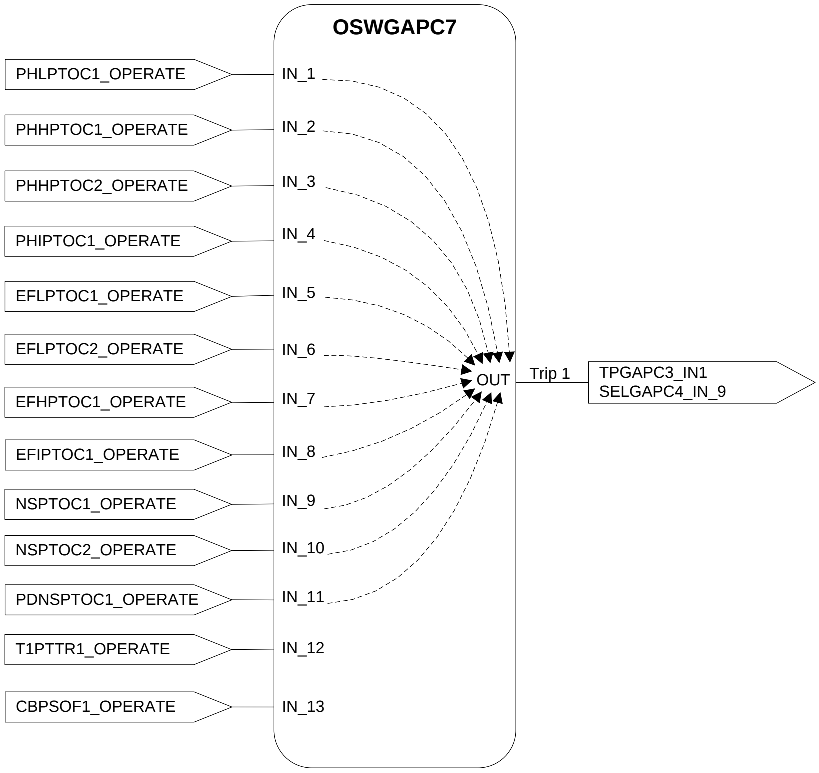


Figure 92: OSWGAPC7

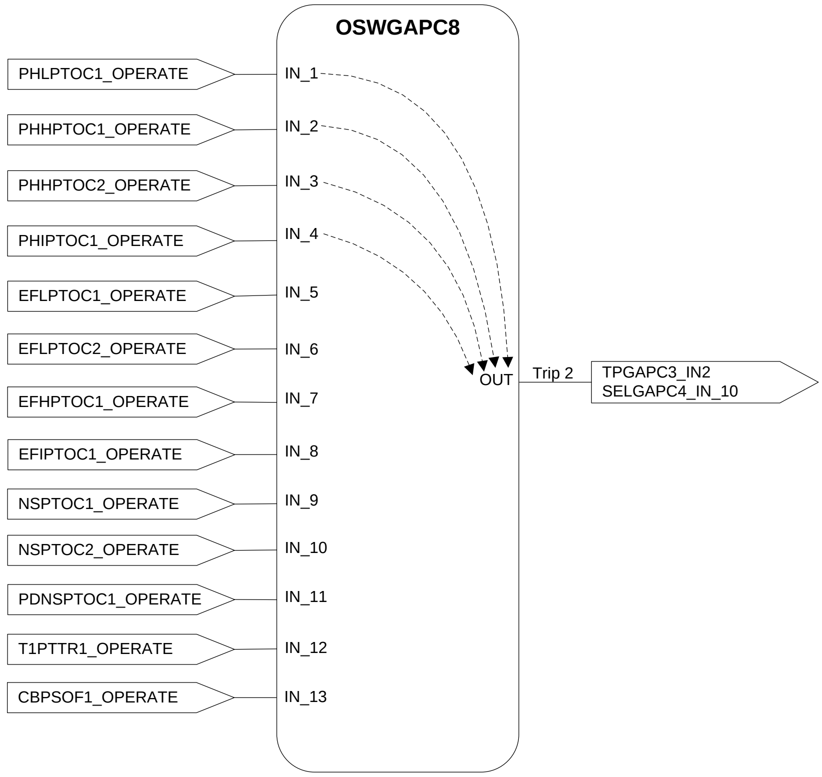


Figure 93: OSWGAPC8

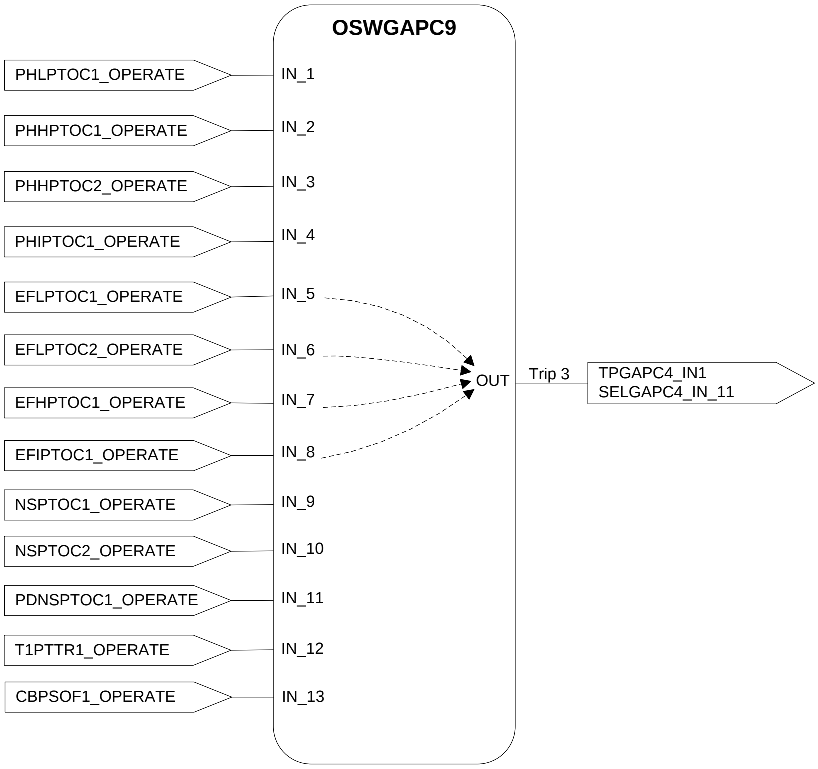


Figure 94: OSWGAPC9

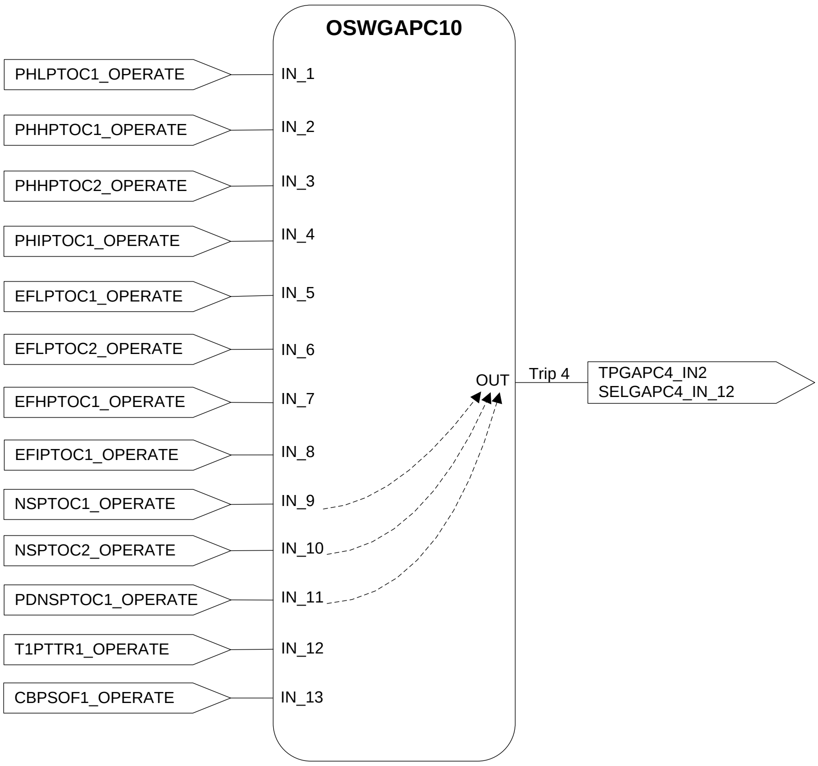


Figure 95: OSWGAPC10

Alarm OSWGAPCs

OSWGAPC instances 11...16 are used to configure the alarm signals which 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.

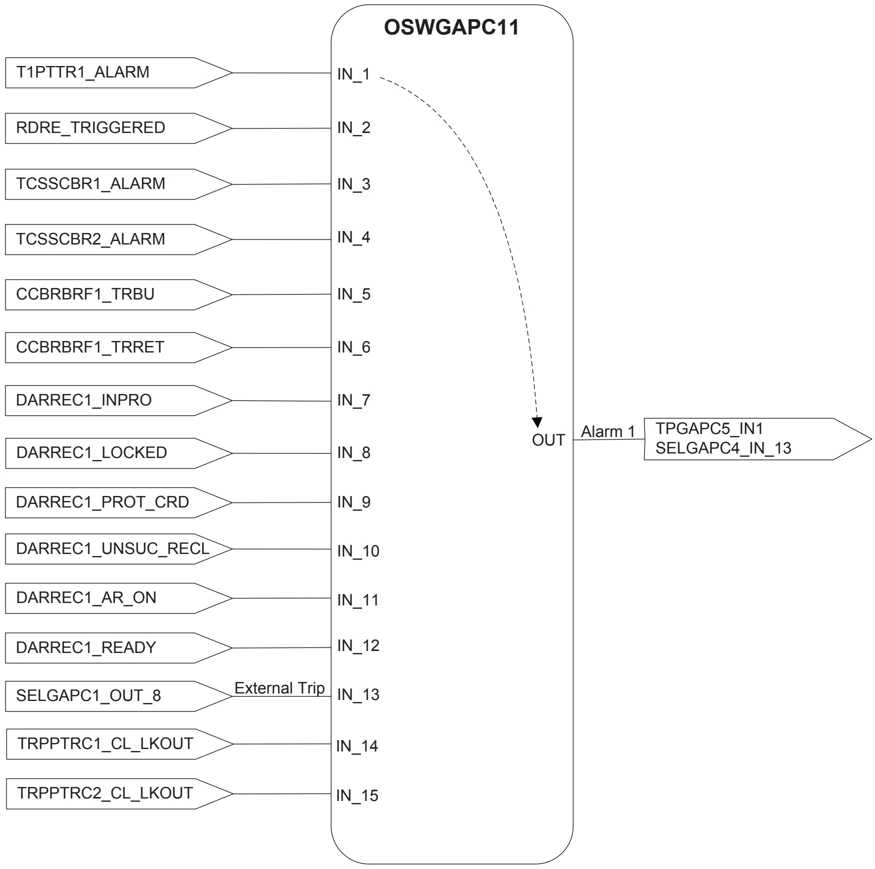


Figure 96: OSWGAPC11

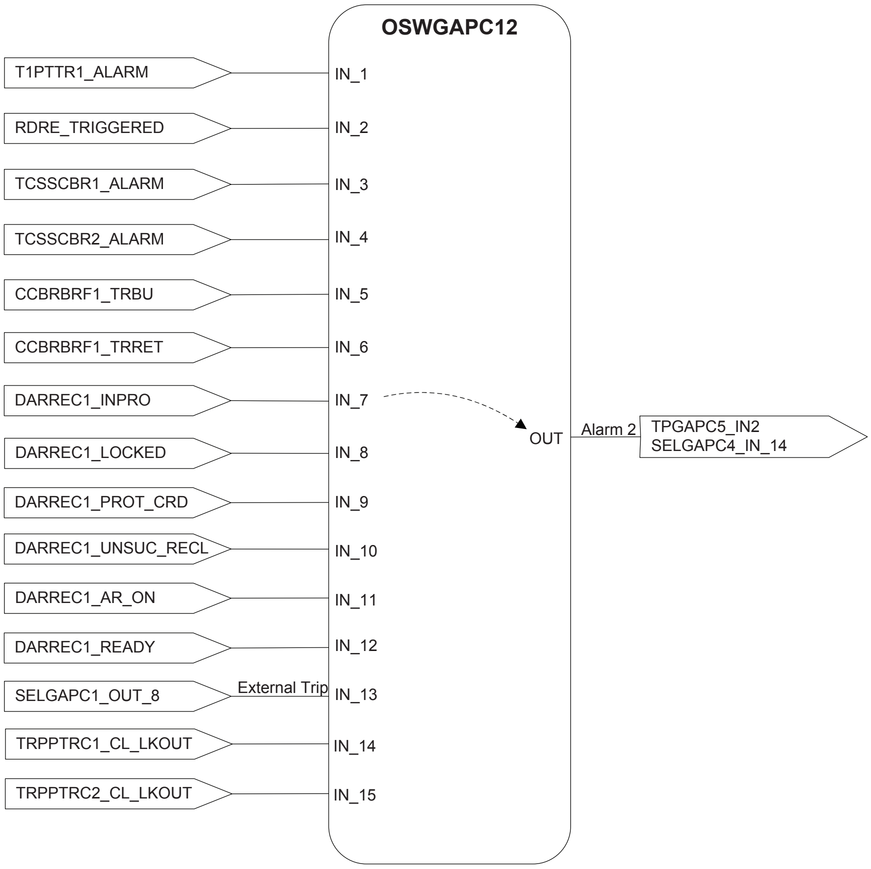


Figure 97: OSWGAPC12

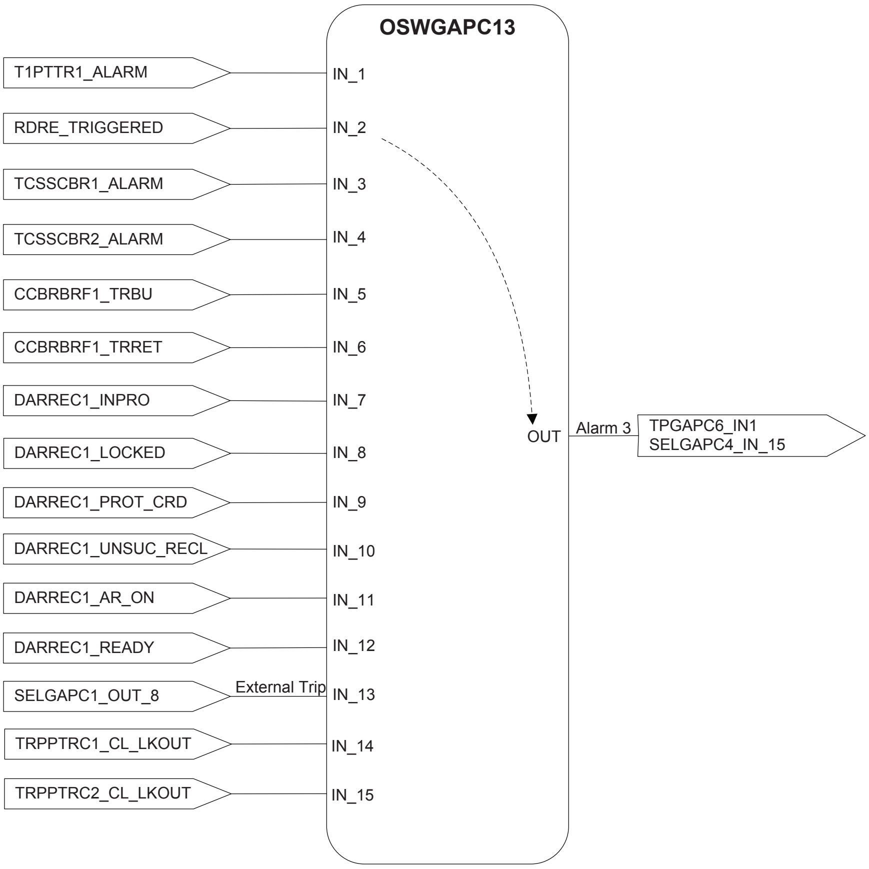


Figure 98: OSWGAPC13

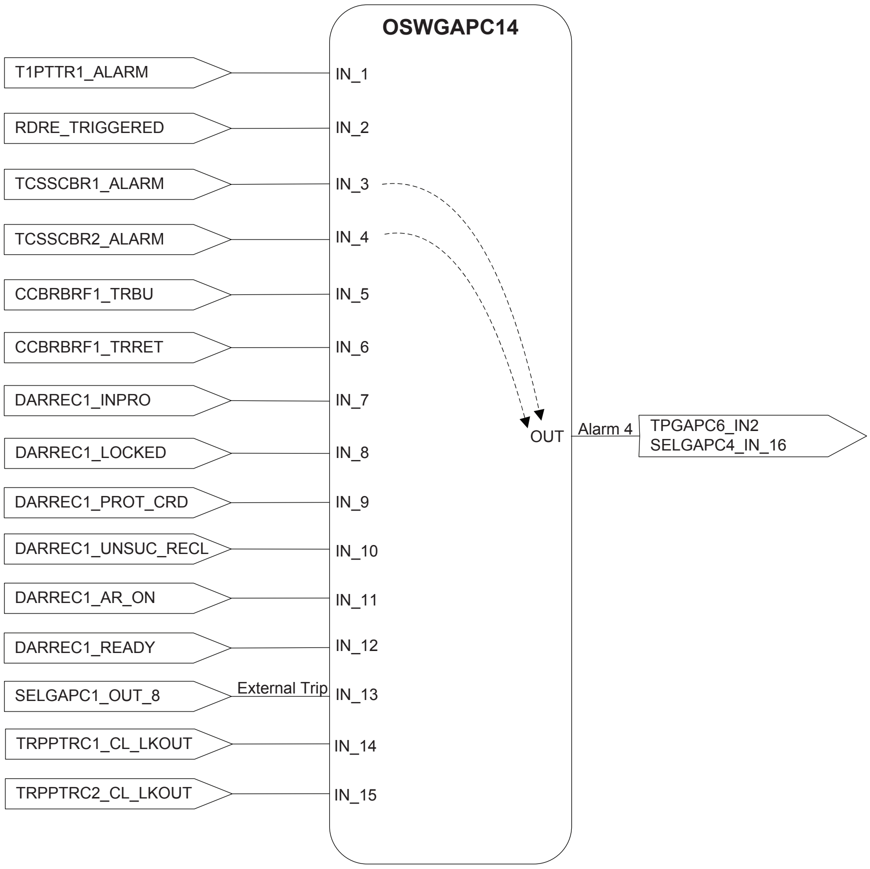


Figure 99: OSWGAPC14

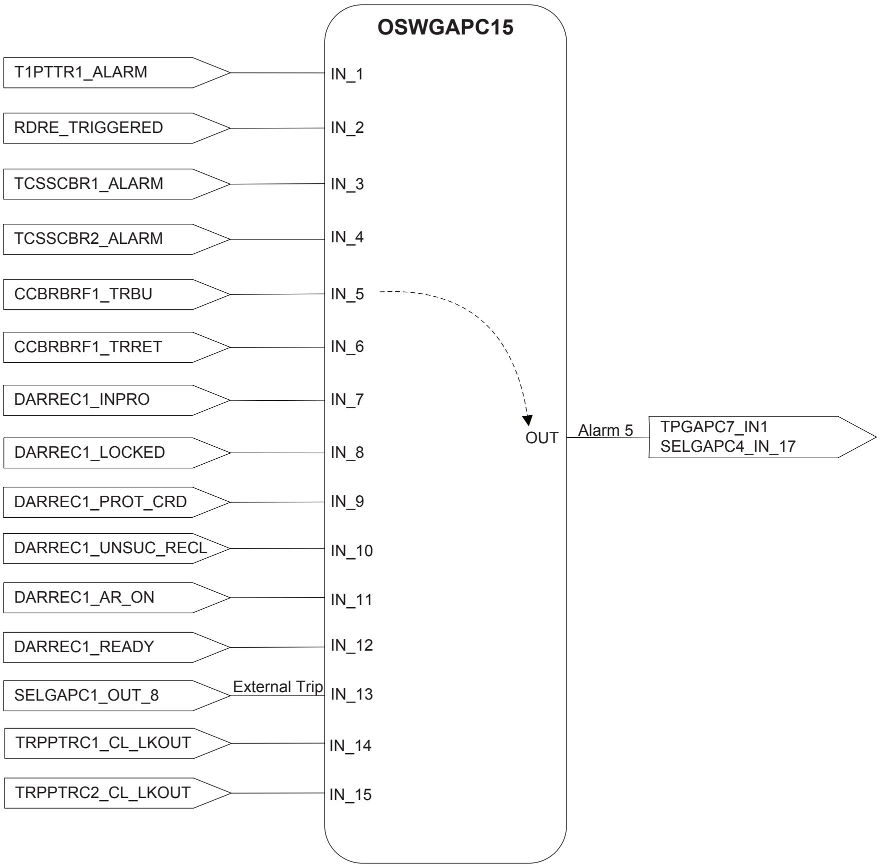


Figure 100: OSWGAPC15

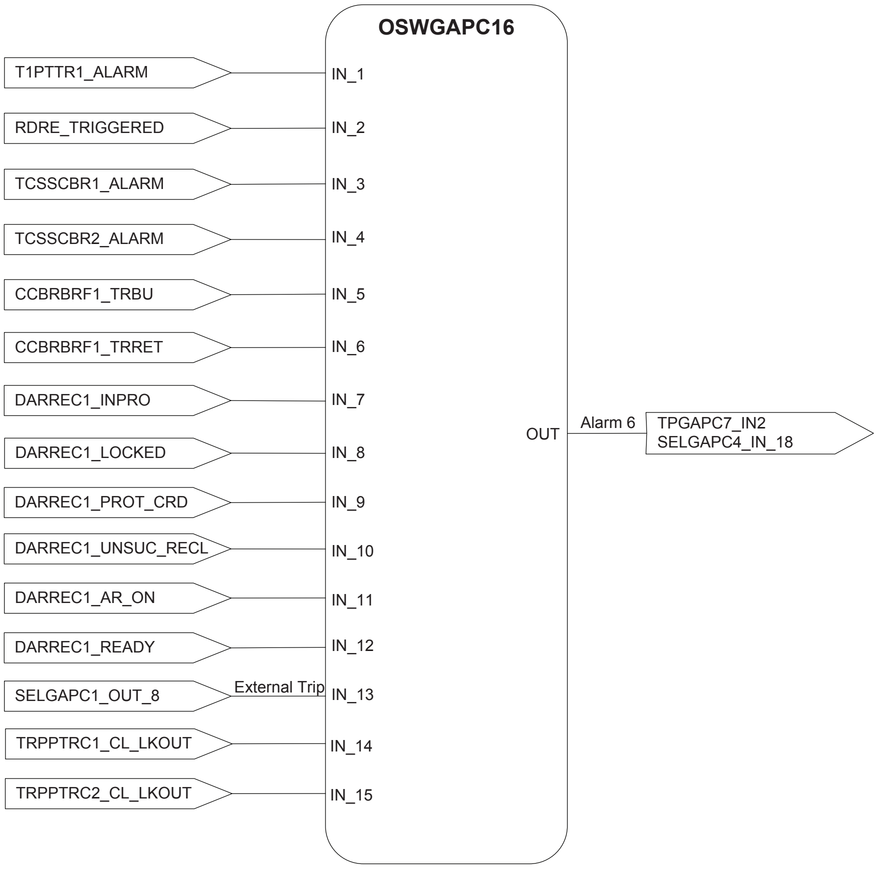


Figure 101: OSWGAPC16

3.5.4.4 GOOSE

In the configuration, there are twenty 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 the protection functions. Signals from these two GOOSERCV_BINs are connected to ISWGAPC9. ISWGAPC9 is used to configure which protection function 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 GOOSE input signal to block the circuit breaker open or close operation.

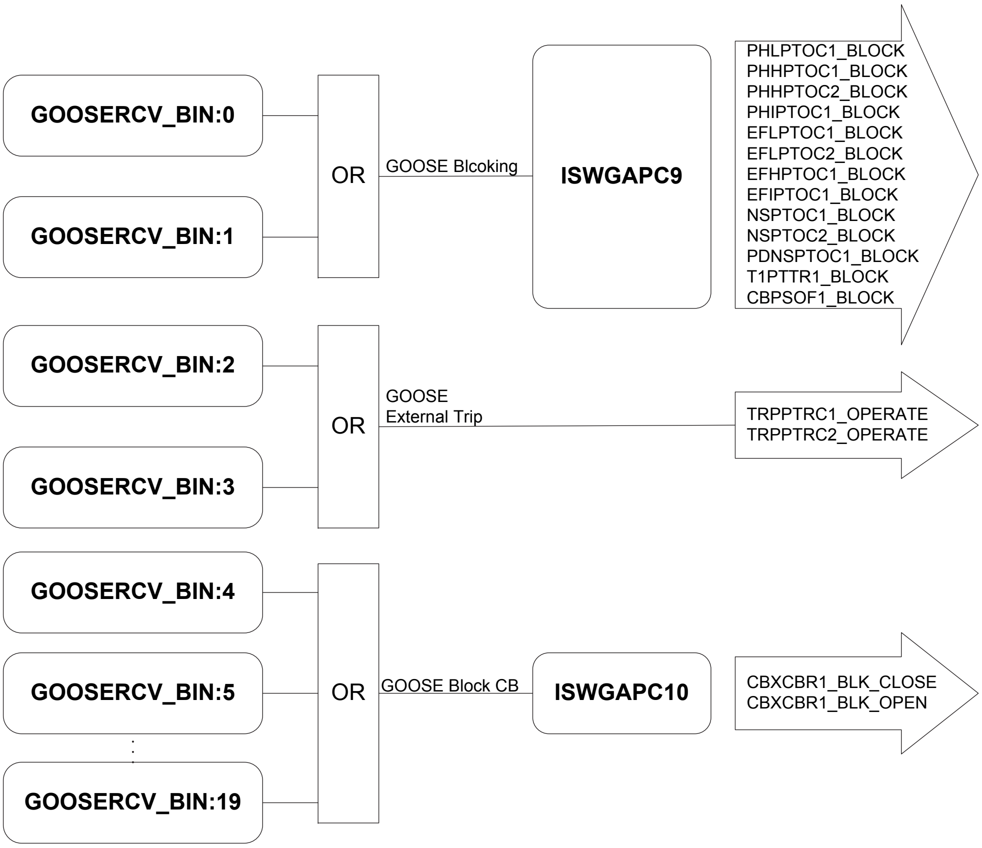


Figure 102: GOOSE overview

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 block inputs of the protection functions.

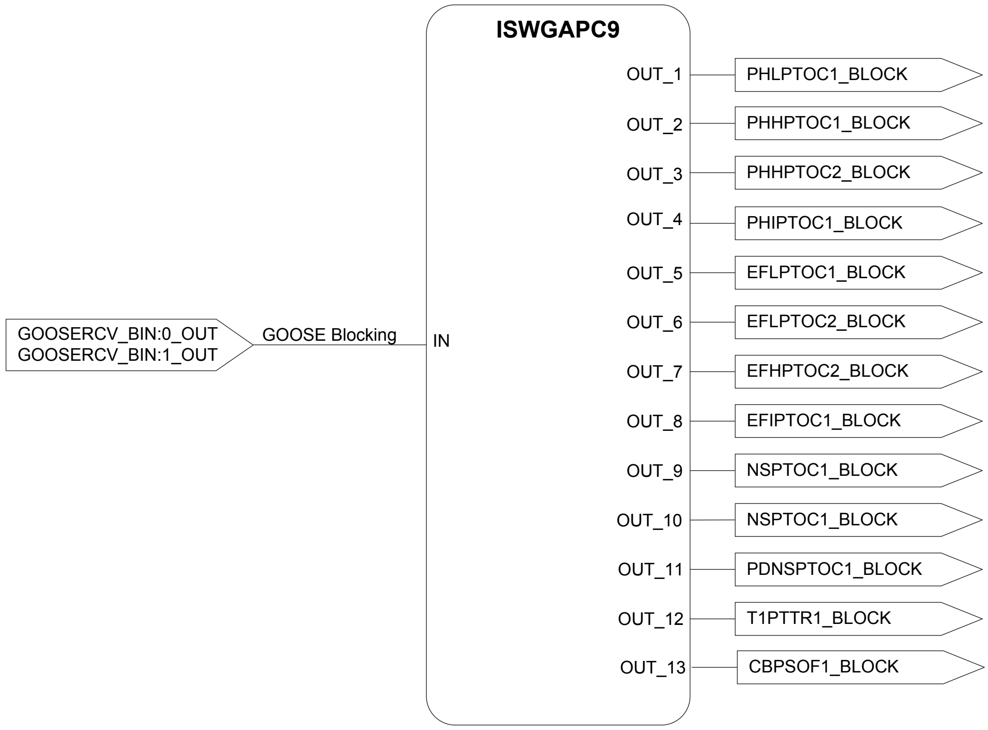


Figure 103: ISWGAPC9

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.

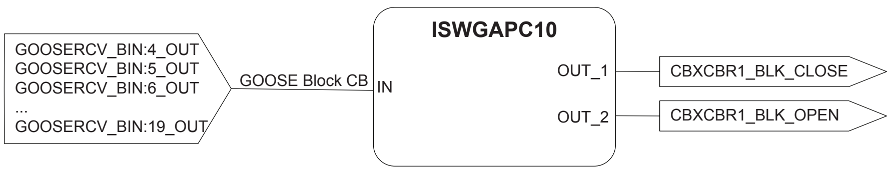


Figure 104: ISWGAPC10

3.6 Configuration C

3.6.1 Applications

Configuration C for directional overcurrent and earth-fault protection is mainly intended for cable and overhead-line feeder applications in isolated and resonant-earthed distribution networks.

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.

3.6.2 Functions

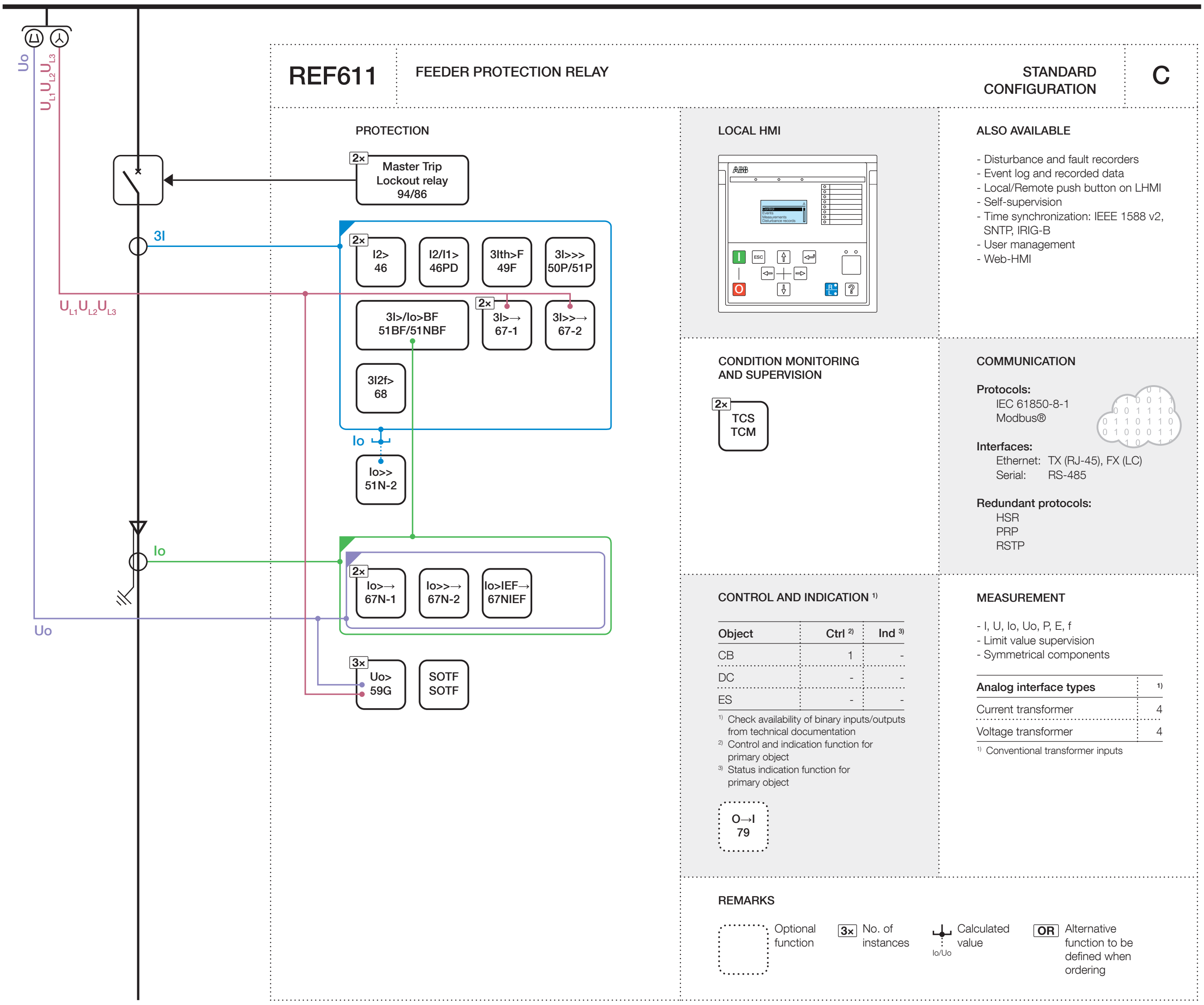


Figure 105: Functionality overview for configuration C

3.6.2.1 Default I/O connections

Table 21: Default connections for binary inputs

Binary input	Description	Connector pins
X120-BI1	Blocking of overcurrent instantaneous stage	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	-	X120:5-6
X130-BI1	-	X130:1-2
X130-BI2	-	X130:3,2
X130-BI3	-	X130:4-5
X130-BI4	-	X130:6,5

Table 22: 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 circuit breaker/trip coil 2	X100:20-24
X100-SO1	General start indication	X100:10-12
X100-SO2	General operate indication	X100:13-15

Table 23: Default connections for LEDs

LED	Description
1	Overcurrent operate
2	Earth fault protection operate
3	Negative-sequence overcurrent/phase discontinuity operate
4	Thermal overload alarm
5	Autoreclose in progress
6	Disturbance recorder triggered
7	Trip circuit supervision alarm
8	Circuit-breaker failure operate

3.6.2.2 Predefined disturbance recorder connections

Table 24: Predefined analog channel setup

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3

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.

3.6.3 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 eight 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. The signal marked with Uo represents the measured residual voltage via open-delta connected voltage transformers.

The EFHPTOC protection function block for double (cross-country) earth-faults uses the calculated residual current originating from the measured phase currents.

3.6.3.1 Functional diagrams for protection

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

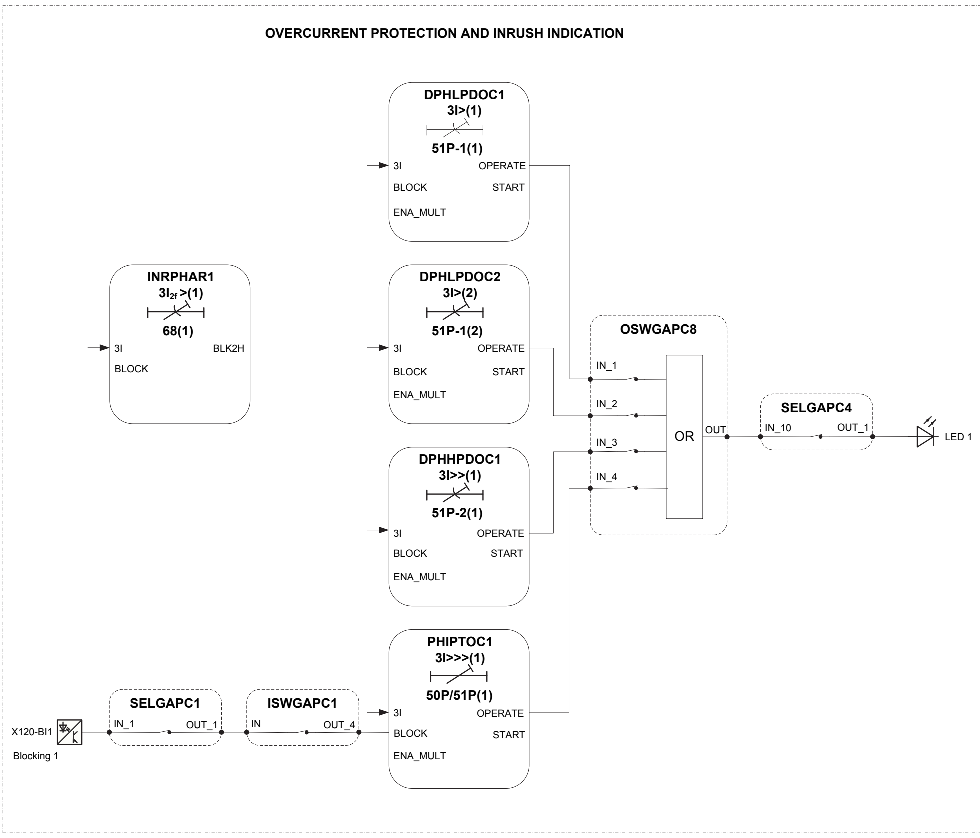


Figure 106: Overcurrent protection

Four overcurrent stages are offered for overcurrent and short-circuit protection. The instantaneous stage PHIPTOC1 can be blocked by energizing the binary input (X120:1-2). The inrush detection block's INRPHAR1 output `BLK2H` enables either blocking the function or multiplying the active settings for any of the described protection function blocks.

All operate signals are connected to the Master Trip and to the alarm LED 1.

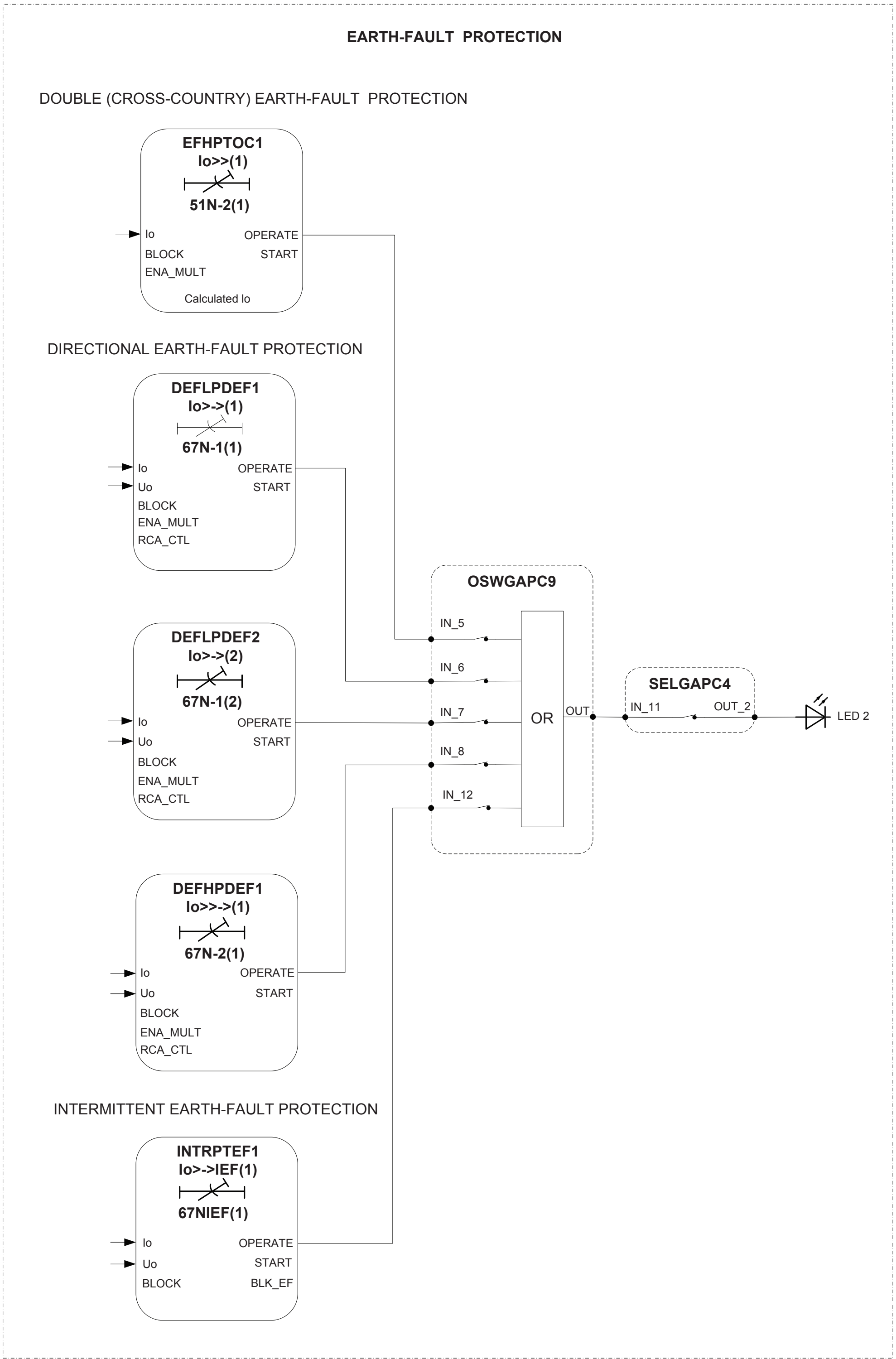


Figure 107: Earth-fault protection

Three stages are offered for directional earth-fault protection. In addition, there is a dedicated protection stage INTRPTEF either for transient-based earth-fault protection or for cable intermittent earth-fault protection in compensated networks.

A dedicated non-directional earth-fault protection block EFHPTOC is intended for protection against double earth-fault situations in isolated or compensated networks. This protection function uses the calculated residual current originating from the phase currents.

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

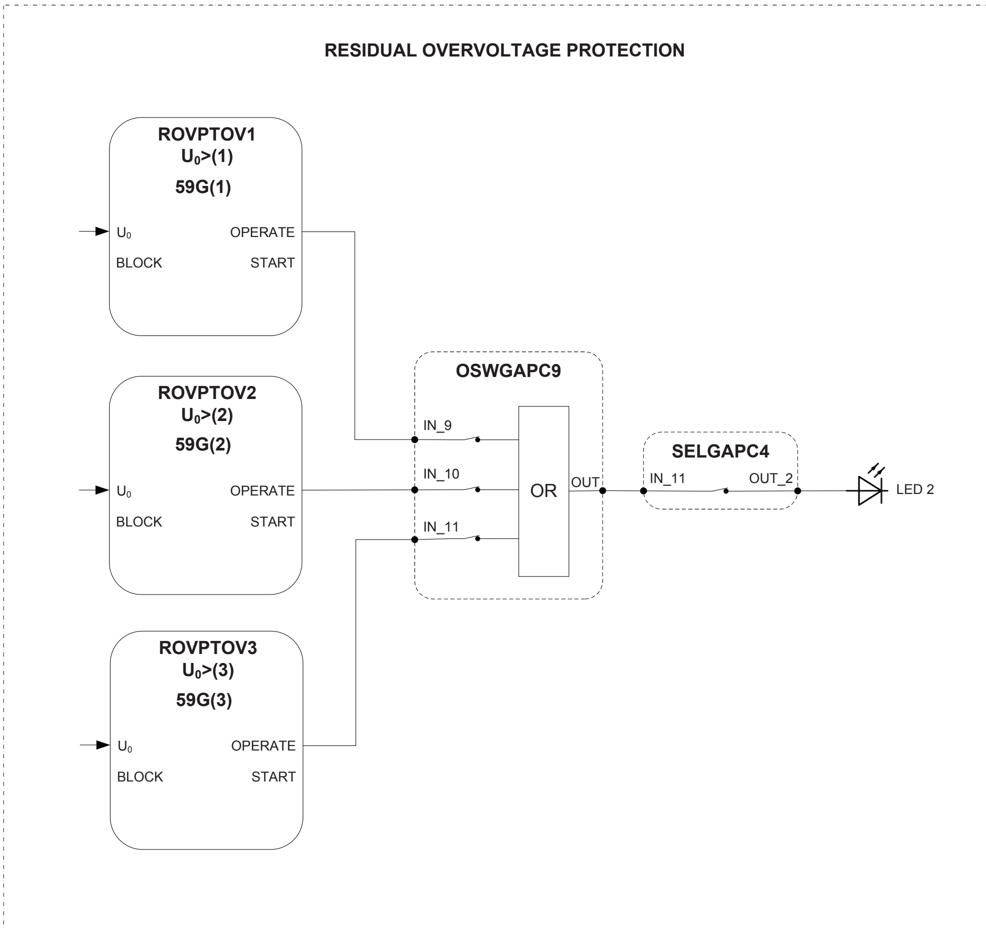


Figure 108: Residual overvoltage protection

The residual overvoltage protection ROVPTOV provides earth-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a non-selective backup protection for the selective directional earth-fault functionality. The operation signal is also connected to alarm LED 2.

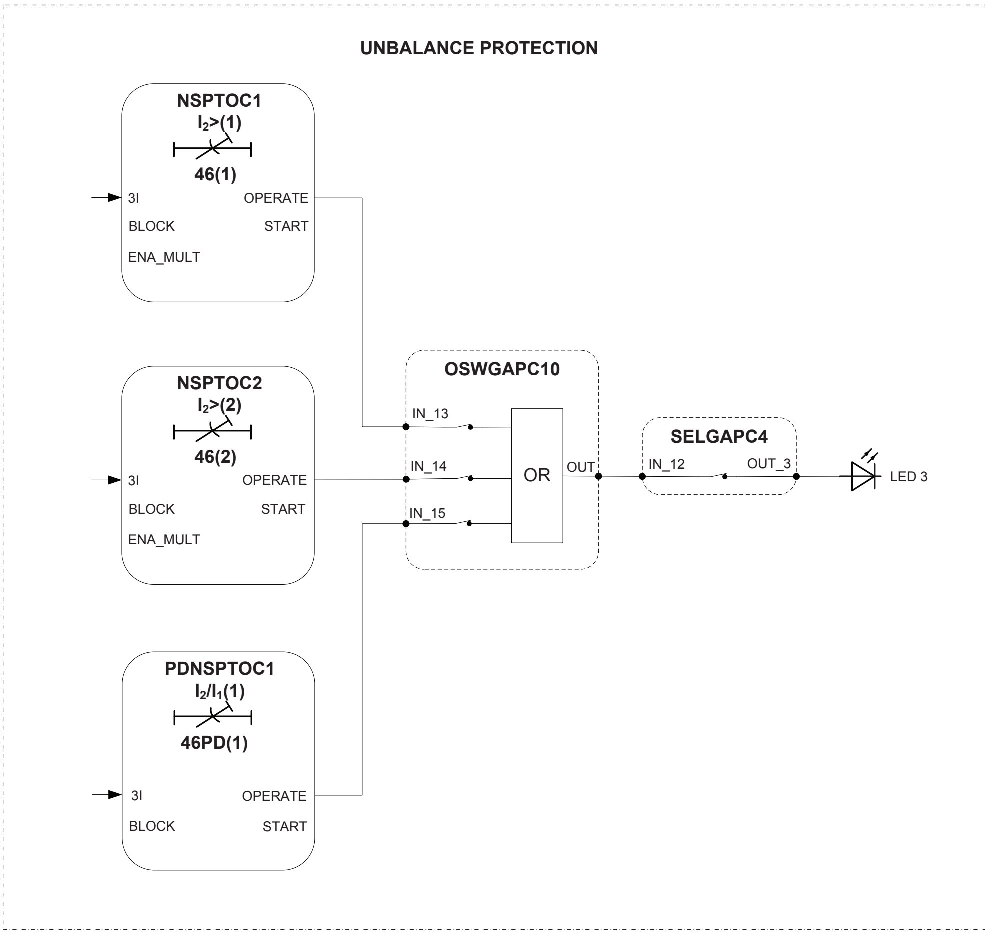


Figure 109: Unbalance protection

Two negative-sequence overcurrent stages NSPTOC1 and NSPTOC2 and one phase discontinuity stage PDNPSTOC1 are offered for unbalance protection. The phase discontinuity protection PDNPSTOC1 provides protection for interruptions in the normal three-phase load supply, for example, in downed conductor situations.

The operate signals of these unbalance protections are connected to the Master Trip and to alarm LED 3.

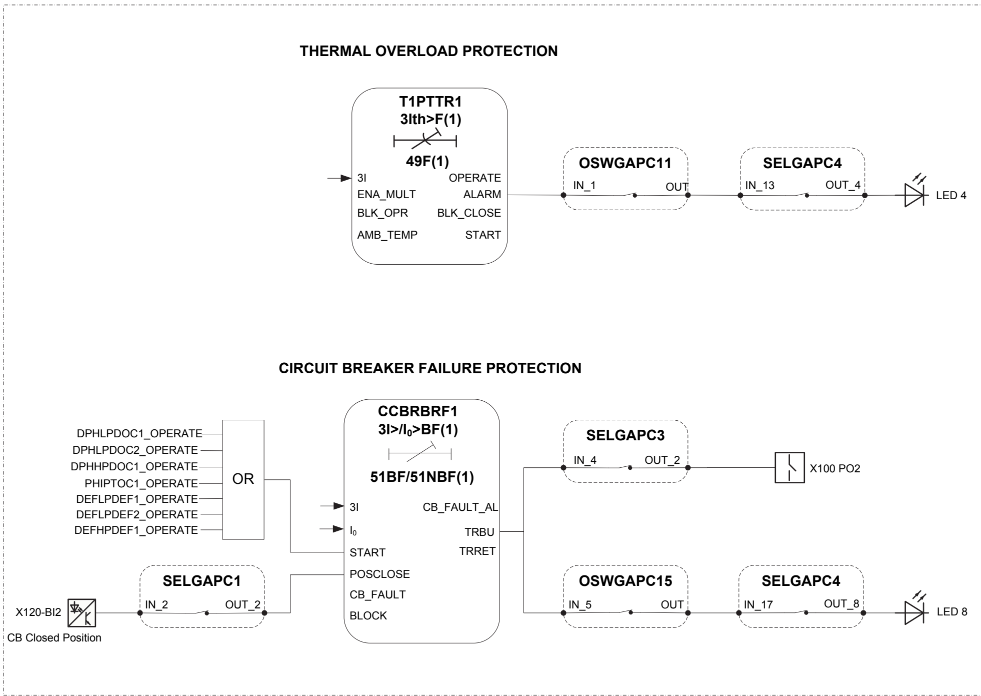


Figure 110: Thermal overload and circuit-breaker failure protection

The thermal overload protection T1PTTR1 provides indication on overload situations. LED 4 is used for the thermal overload protection alarm indication.

The circuit-breaker failure protection CCBRBRF1 is initiated via the start input by a number of different protection stages in the protection relay. The circuit-breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents. The breaker failure protection has two operating outputs: `TRRET` and `TRBU`. The `TRRET` operate output is used for retripping its own breaker through the 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.

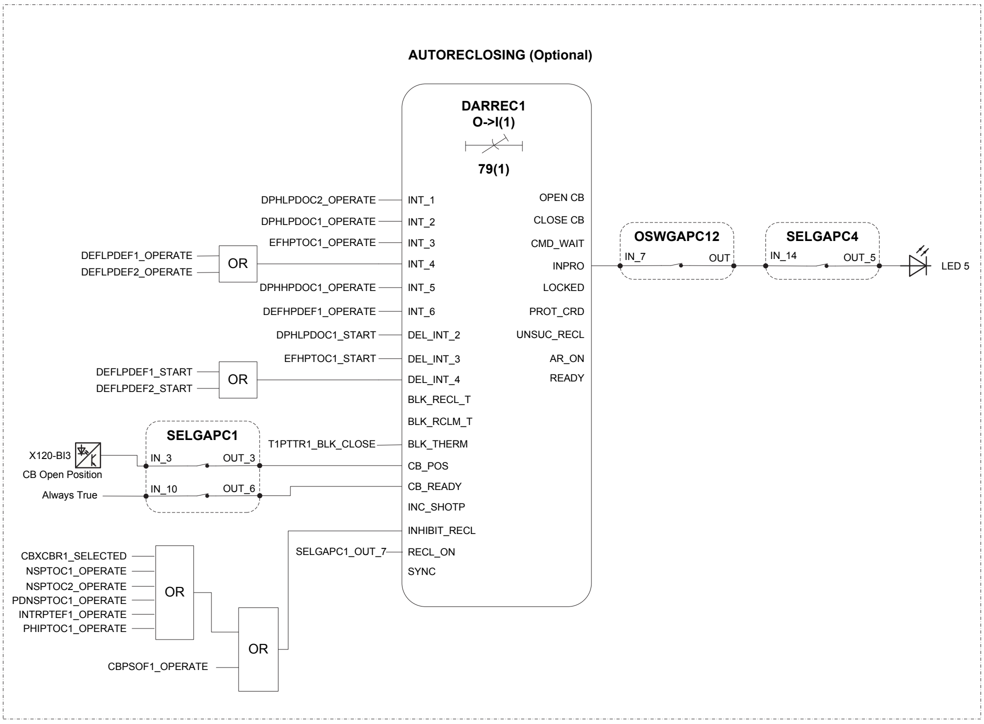


Figure 111: Autoreclosing

Autoreclosing DARREC1 is included as an optional function.

The autoreclose function is configured to be initiated by operate signals from a number of protection stages through the `INT_1...6` inputs and by start signals through the DEL_INT_2…4. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the `INHIBIT_RECL` input. By default, the operations of selected protection functions are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR_SELECTED signal.

The circuit breaker availability for the autoreclose sequence is expressed with the `CB_READY` input in DARREC1. In the configuration, this signal is connected with an always true signal through the SELGAPC1. As a result, the function assumes that the circuit breaker is available all the time.

The autoreclose sequence in progress indication INPRO is connected to the alarm LED 5.

3.6.3.2 Functional diagrams for disturbance recorder and trip circuit supervision

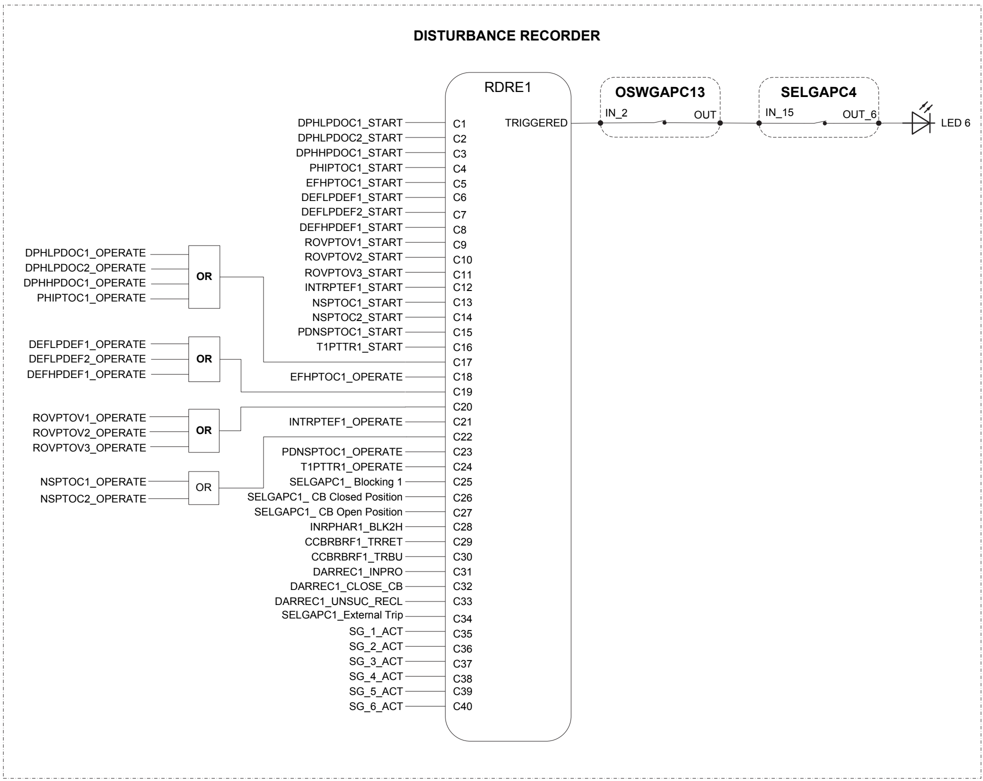


Figure 112: Disturbance recorder

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 autoreclose 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 25: Disturbance recorder binary channel default value

Channel number	Channel ID text	Level trigger mode
Binary channel 1	DPHLPDOC1_START	1=positive or rising
Binary channel 2	DPHLPDOC2_START	1=positive or rising
Binary channel 3	DPHHPDOC1_START	1=positive or rising
Binary channel 4	PHIPTOC1_START	1=positive or rising
Binary channel 5	EFHPTOC1_START	1=positive or rising
Binary channel 6	DEFLPDEF1_START	1=positive or rising
Binary channel 7	DEFLPDEF2_START	1=positive or rising
Binary channel 8	DEFHPDEF1_START	1=positive or rising
Binary channel 9	ROVPTOV1_START	1=positive or rising
Table continues on next page		

Channel number	Channel ID text	Level trigger mode
Binary channel 10	ROVPTOV2_START	1=positive or rising
Binary channel 11	ROVPTOV3_START	1=positive or rising
Binary channel 12	INTRPTEF1_START	1=positive or rising
Binary channel 13	NSPTOC1_START	1=positive or rising
Binary channel 14	NSPTOC2_START	1=positive or rising
Binary channel 15	PDNSPTOC1_START	1=positive or rising
Binary channel 16	T1PTTR1_START	1=positive or rising
Binary channel 17	DPHxPDOC_OPERATE	4=level trigger off
Binary channel 18	EFHPTOC1_OPERATE	4=level trigger off
Binary channel 19	DEFxPDEF_OPERATE	4=level trigger off
Binary channel 20	ROVPTOV_OPERATE	4=level trigger off
Binary channel 21	INTRPTEF1_OPERATE	4=level trigger off
Binary channel 22	NSPTOC1/2_OPERATE	4=level trigger off
Binary channel 23	PDNSPTOC1_OPERATE	4=level trigger off
Binary channel 24	T1PPTR1_OPERATE	4=level trigger off
Binary channel 25	SELGAPC1_Blocking 1	4=level trigger off
Binary channel 26	SELGAPC1_CB_Closed	4=level trigger off
Binary channel 27	SELGAPC1_CB_Open	4=level trigger off
Binary channel 28	INRPHAR1_BLK2H	4=level trigger off
Binary channel 29	CCBRBRF1_TRRET	4=level trigger off
Binary channel 30	CCBRBRF1_TRBU	4=level trigger off
Binary channel 31	DARREC1_INPRO	4=level trigger off
Binary channel 32	DARREC1_CLOSE_CB	4=level trigger off
Binary channel 33	DARREC1_UNSUC_RECL	4=level trigger off
Binary channel 34	SELGAPC1_External Trip	4=level trigger off
Binary channel 35	SG_1_ACT	4=level trigger off
Binary channel 36	SG_2_ACT	4=level trigger off
Binary channel 37	SG_3_ACT	4=level trigger off
Binary channel 38	SG_4_ACT	4=level trigger off
Binary channel 39	SG_5_ACT	4=level trigger off
Binary channel 40	SG_6_ACT	4=level trigger off

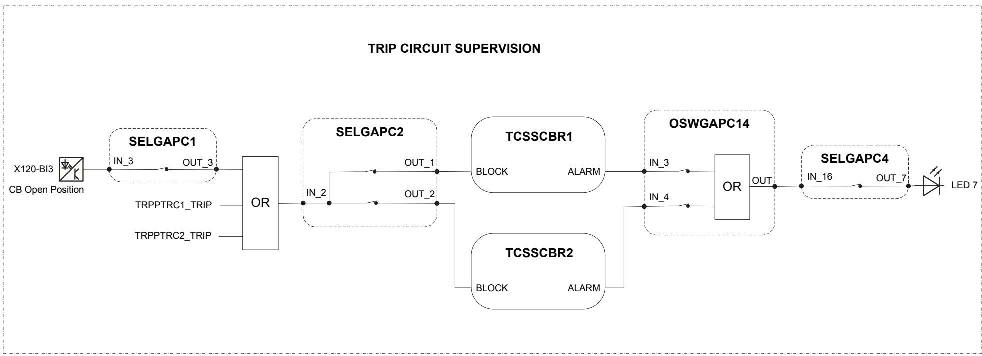


Figure 113: Trip circuit supervision

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.

3.6.3.3 Functional diagrams for control

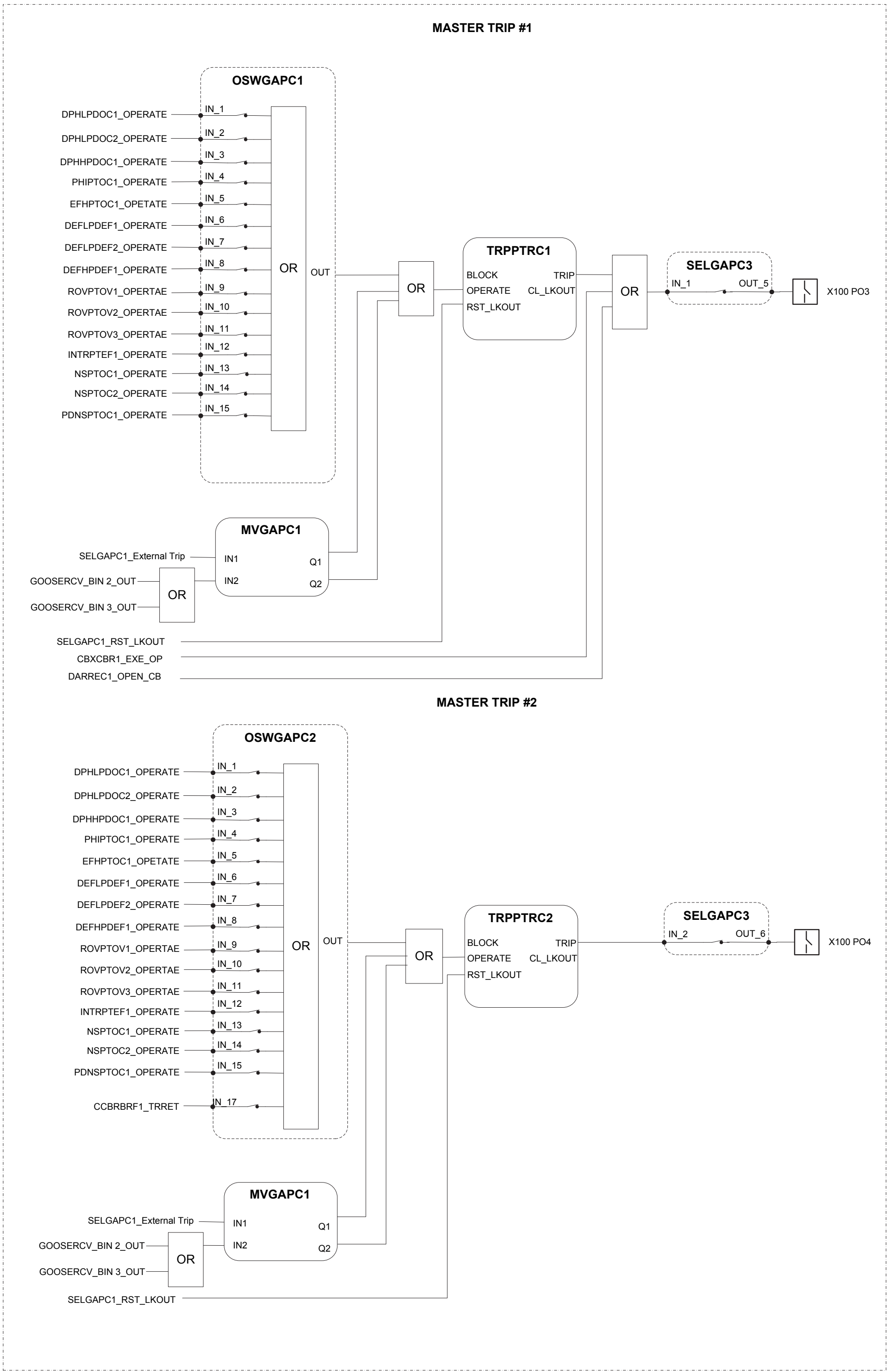


Figure 114: Master trip

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 2 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 the Master Trip. If the lockout operation mode is selected, it is used to enable external reset.

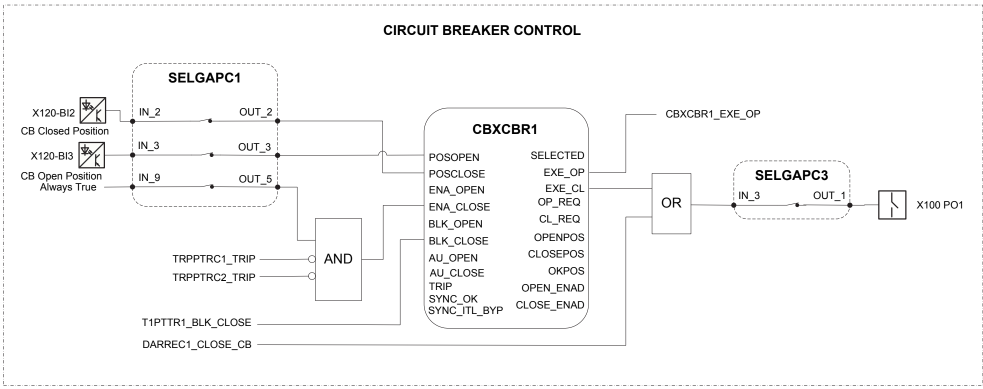


Figure 115: Circuit breaker control

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.

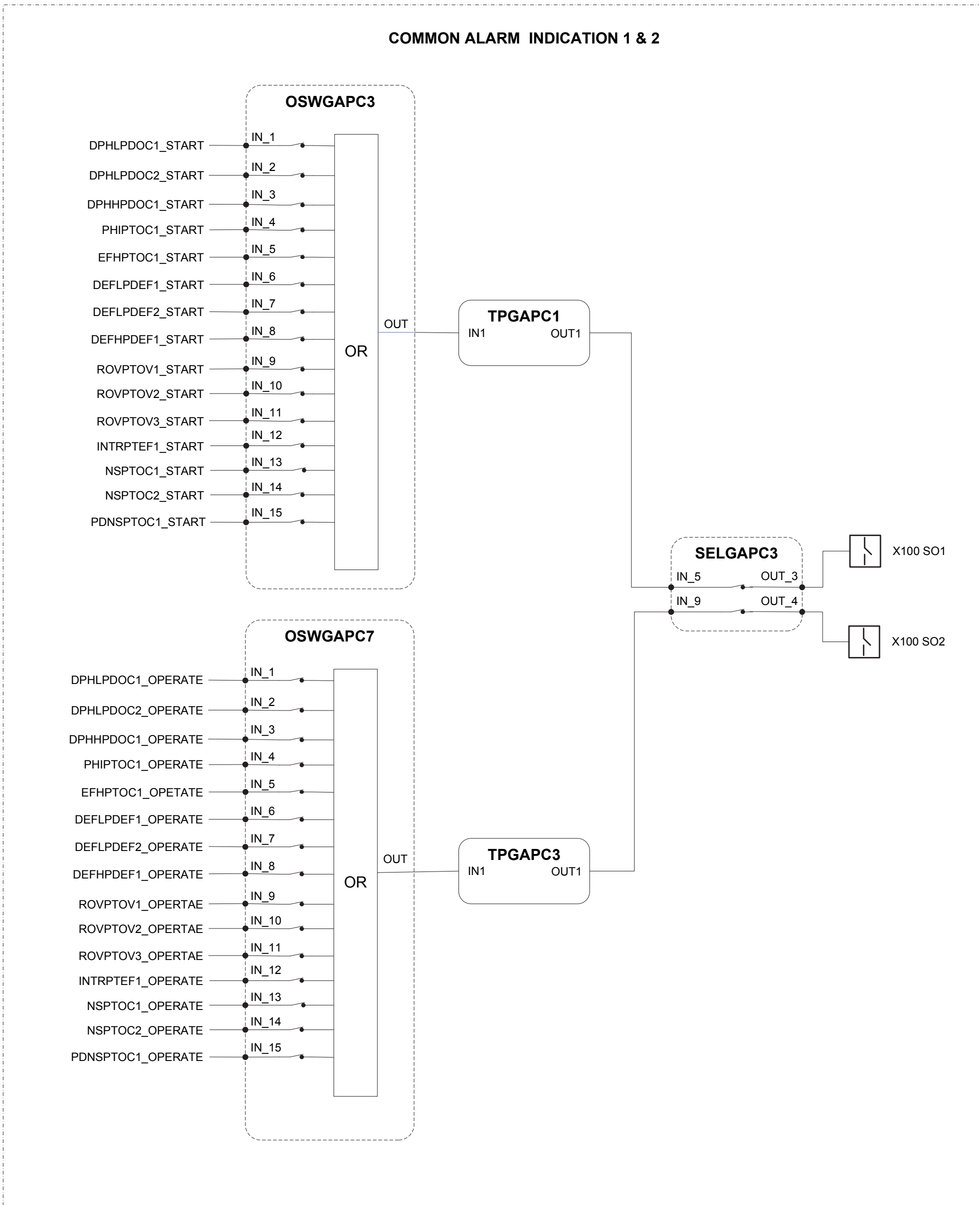


Figure 116: Common alarm indication

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

3.6.4 Switch groups

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

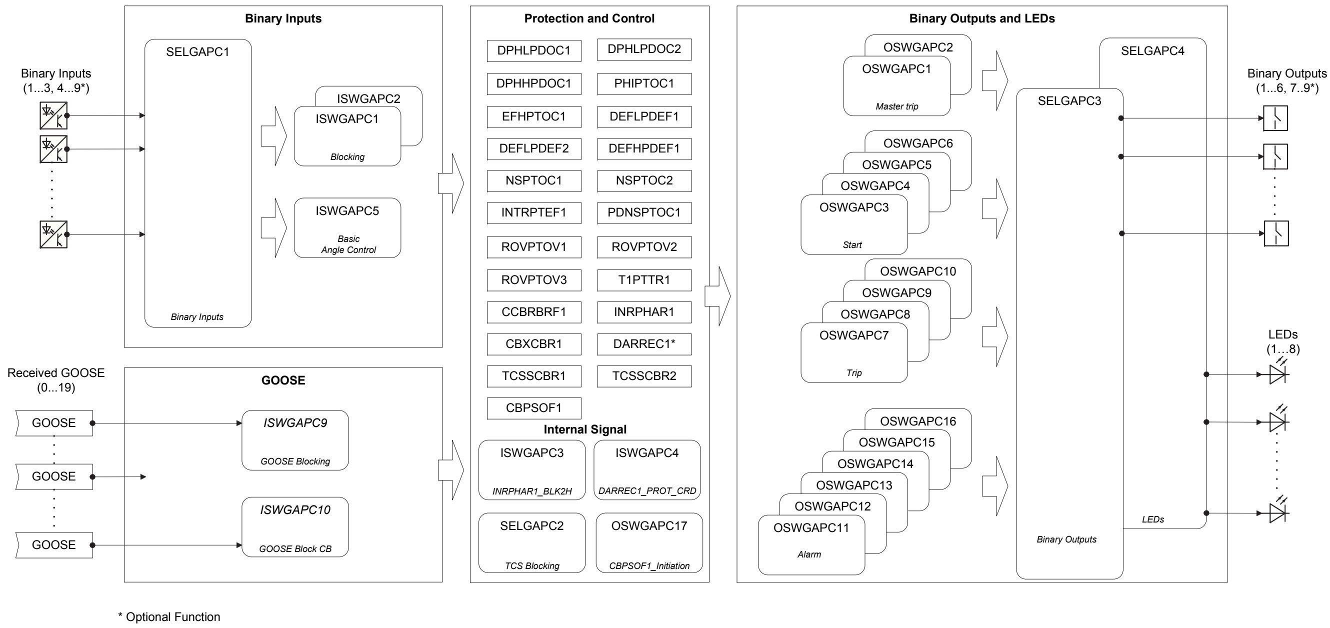


Figure 117: Configuration C switch group overview

3.6.4.1 Binary inputs

The binary inputs group includes one SELGAPC and three 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. ISWGAPC5 is used to control the characteristic angle of DEFxPDEF.

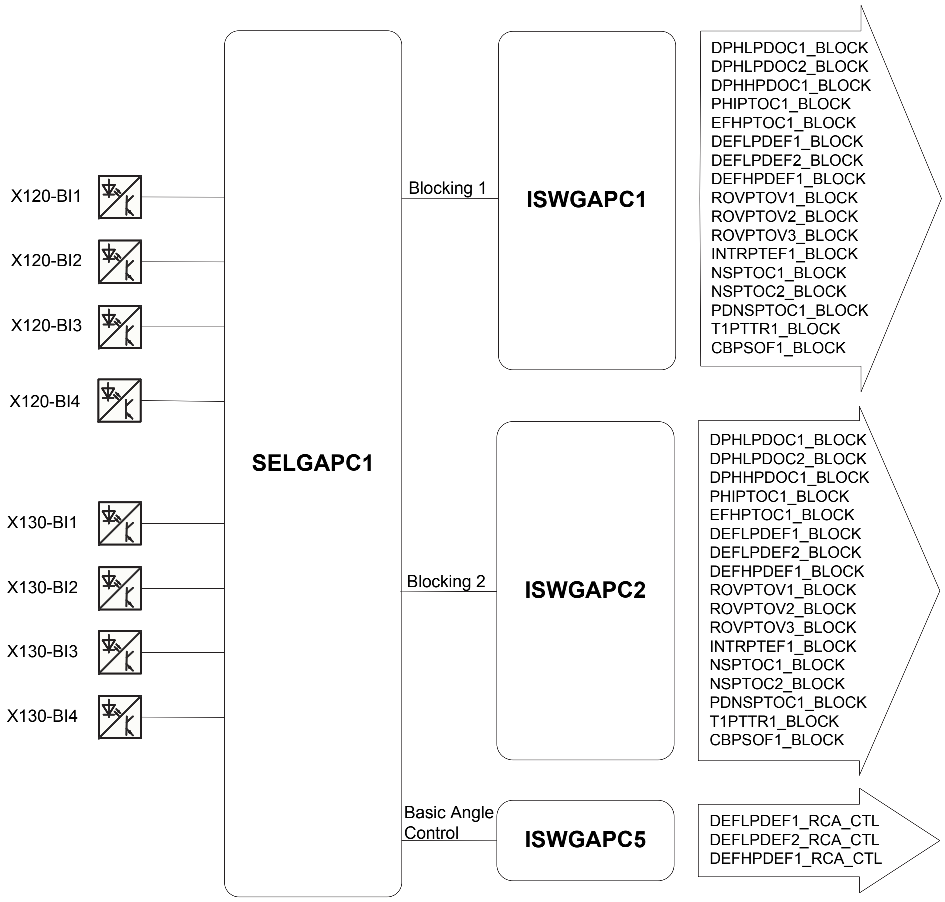


Figure 118: Binary inputs

SELGAPC1

SELGAPC1 has inputs from protection relay binary inputs. IN_1...IN_4 are binary inputs from X120. IN_5...IN_8 are used from four inputs of X130. An always true signal is connected to IN_9. SELGAPC1 outputs are used to route inputs to different functions. By setting SELGAPC1, binary inputs can be configured for different purposes.

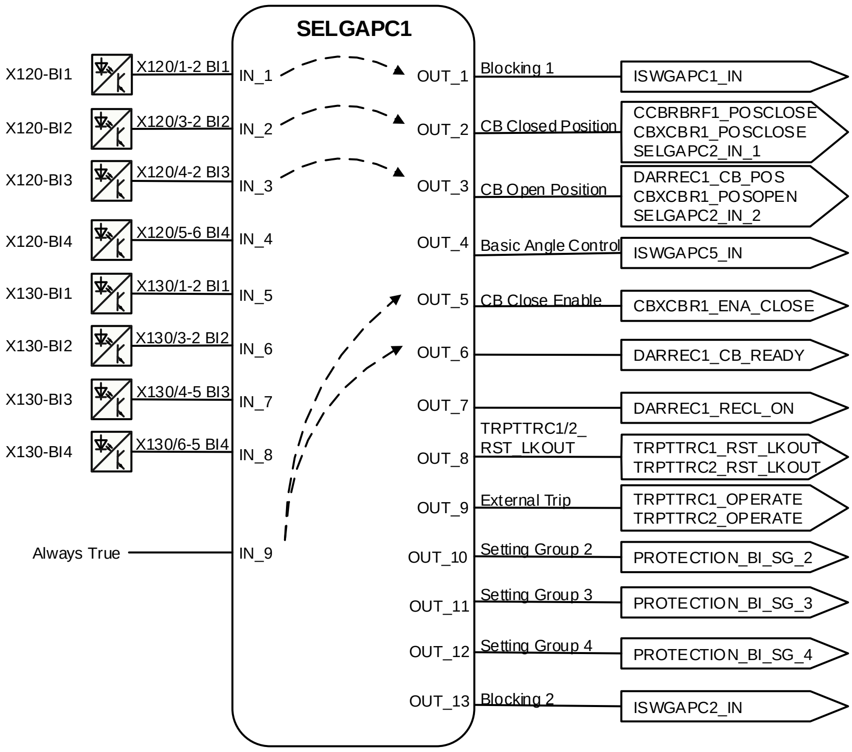


Figure 119: SELGAPC1

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.

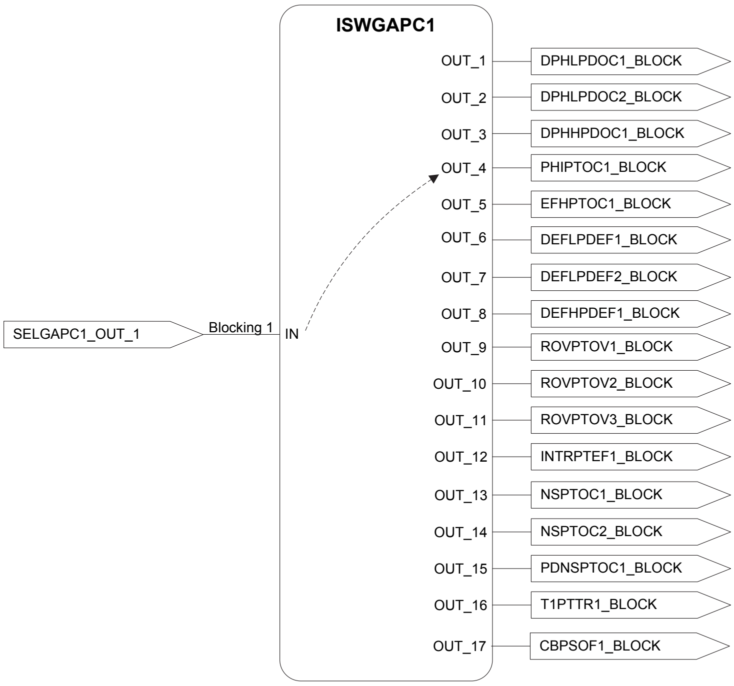


Figure 120: ISWGAPC1

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.

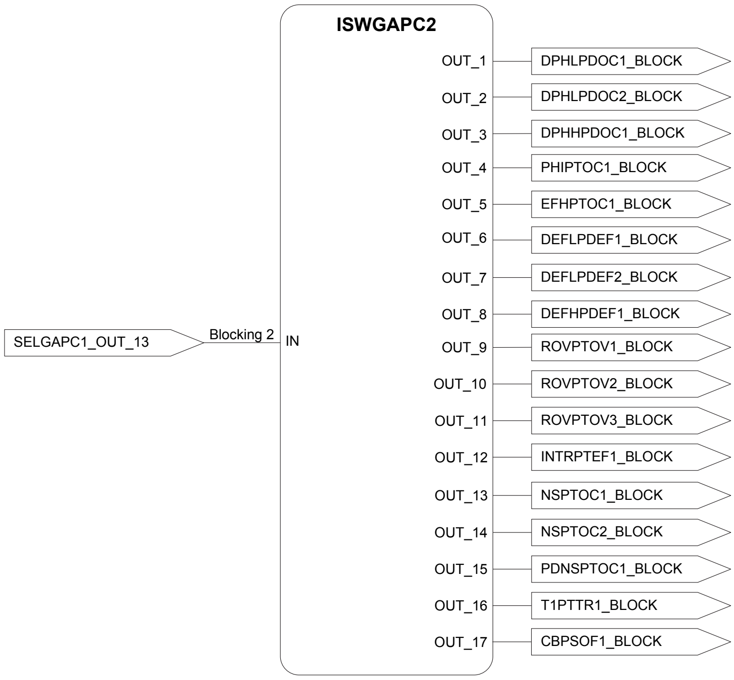


Figure 121: ISWGAPC2

ISWGAPC5

ISWGAPC5 input is used to select which directional earth-fault protection is controlled by ISWGAPC5 input by changing the ISWGAPC5 parameters. ISWGAPC5 input is routed from SELGAPC1 output `OUT_4 Basic Angle Control`. ISWGAPC5 outputs are connected to `RCA_CTL` inputs of directional earth-fault protection functions.

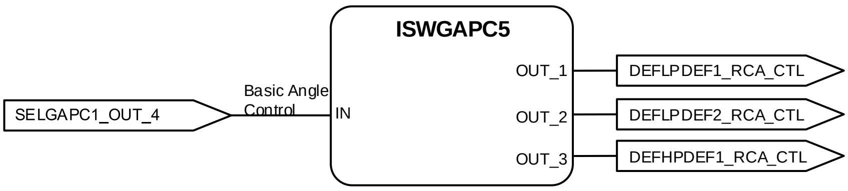


Figure 122: ISWGAPC5

3.6.4.2 Internal signals

The internal signal group is used to configure logic connections between function blocks. There are two ISWGAPC instances, one SELGAPC and one OSWGAPC instance in this group.

ISWGAPC3 is used to configure which protection function enables the current multiplier if the INRPHAR1 function detects inrush. ISWGAPC4 is used to configure the cooperation between the autoreclose function and the protection functions. The autoreclose function DARREC1 can block protection functions according to the application. SELGAPC2 is used to configure TCS blocking from the circuit breaker open or close position. OSWGAPC17 is used for connecting switch onto fault function CBPSOF. The inputs are start signals routed from the protection functions.

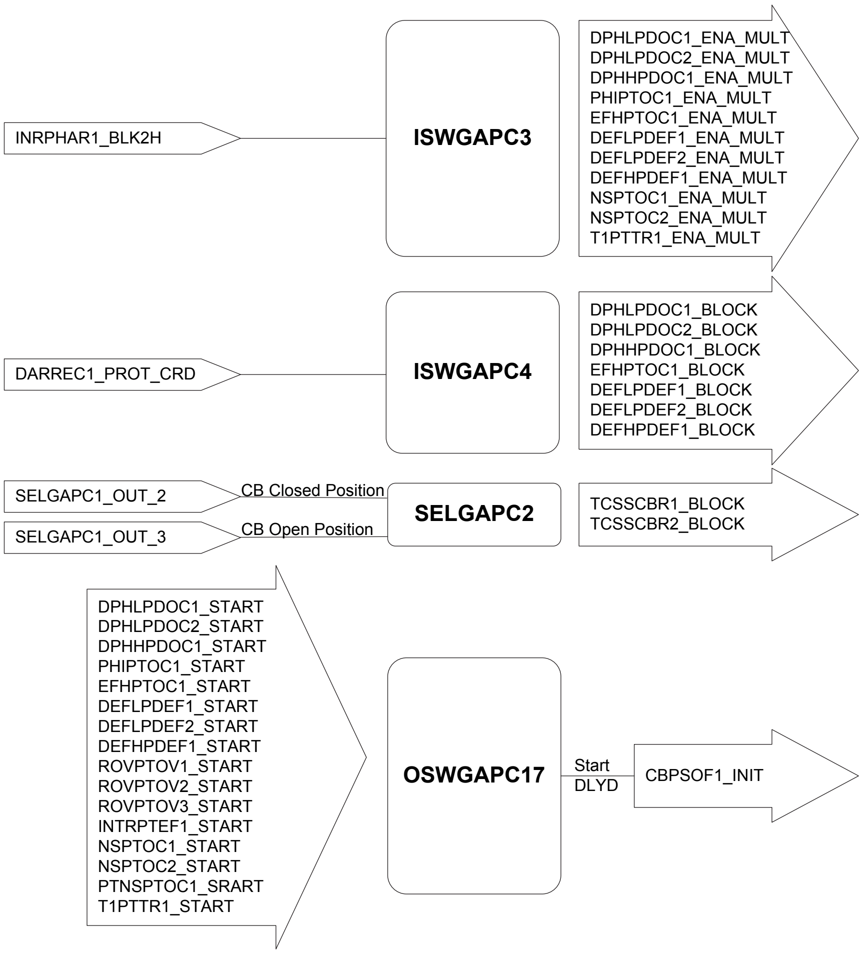


Figure 123: Internal signal

ISWGAPC3

ISWGAPC3 input is used to configure which protection function enables current multiplier while inrush is detected by INRPHAR1 by changing the ISWGAPC3 parameters. ISWGAPC3 input is routed from INRPHAR1 output `BLK2H`. ISWGAPC3 outputs are connected to `ENA_MULT` of the protection functions.

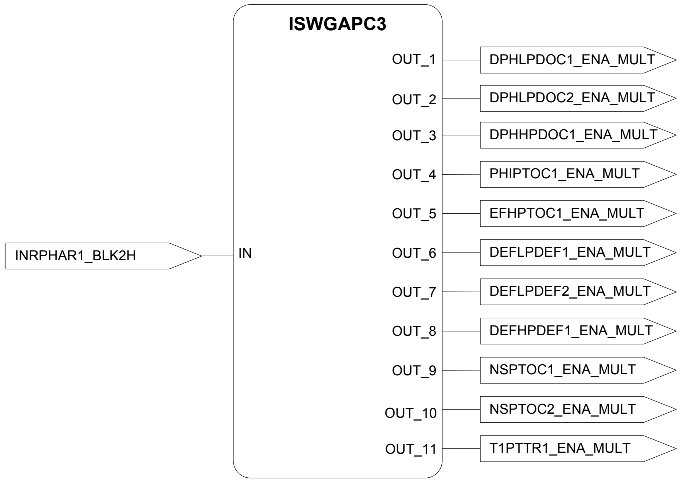


Figure 124: ISWGAPC3

ISWGAPC4

ISWGAPC4 input is used to configure which protection function is blocked by the autoreclosing function by changing the ISWGAPC4 parameters. ISWGAPC4 input is routed from DARREC1 output `PROT_CRD`. ISWGAPC4 outputs are connected to the `BLOCK` inputs of some of the protection functions.

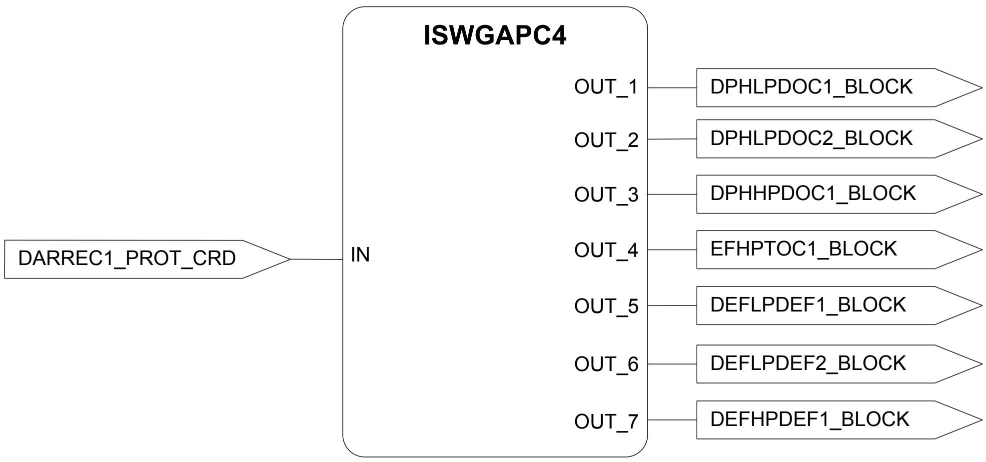


Figure 125: ISWGAPC4

SELGAPC2

SELGAPC2 inputs represent the circuit breaker closed and open position 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 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).

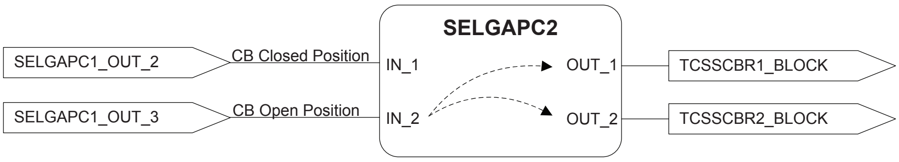


Figure 126: SELGAPC2

OSWGAPC17

OSWGAPC17 is used to route the protection function start signals to the `StartDLYD` input of the switch onto fault function CBPSOF. CBPSOF provides an instantaneous trip or a time delayed trip when closing the breaker while a fault exists. OSWGAPC17 output is connected to CBPSOF function indicating the detected fault.

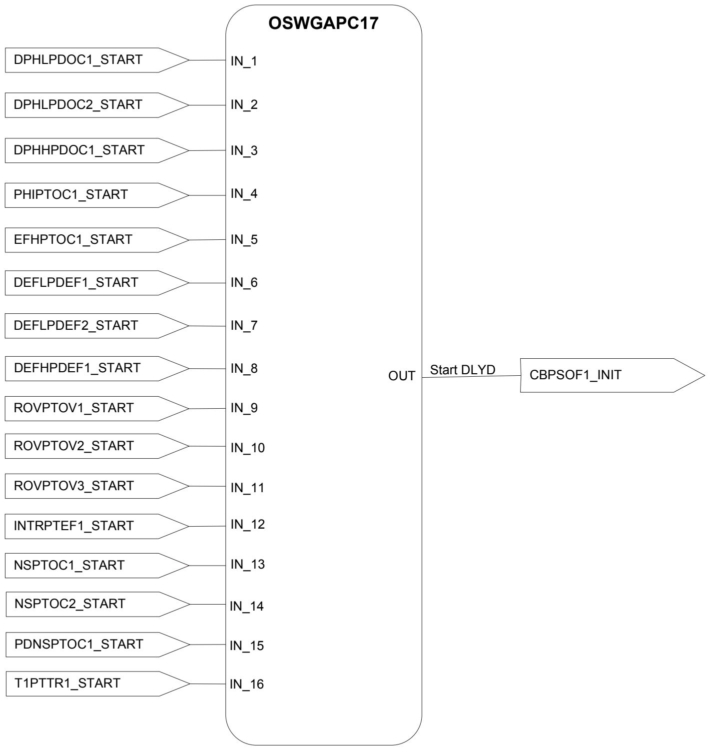


Figure 127: OSWGAPC17

3.6.4.3 Binary outputs and LEDs

In configuration C, signals are routed to binary outputs and LEDs are configured by OSWGAPC. The 16 OSWGAPC instances are categorized in four groups, including two master trip, four start, four trip and six alarm signals. The OSWGAPC output is connected with binary outputs and LEDs via SELGAPC3 and SELGAPC4.

- SELGAPC3 is used to configure OSWGAPC signals to the protection relay's binary outputs. SELGAPC4 is used to configure OSWGAPC signals to LEDs.
- OSWGAPC1 and OSWGAPC2 are used for the Master trip. The inputs are routed from the protection function's operate and the circuit breaker failure's re-trip.
- OSWGAPC3 to OSWGAPC6 are used for the start signal. The inputs are start signals routed from the protection functions.
- OSWGAPC7 to OSWGAPC10 are used for the trip signal. The inputs are operation signals routed from the protection functions.
- OSWGAPC11 to OSWGAPC16 are used for the alarm signal. The inputs are alarm signals routed from the protection and monitoring functions.

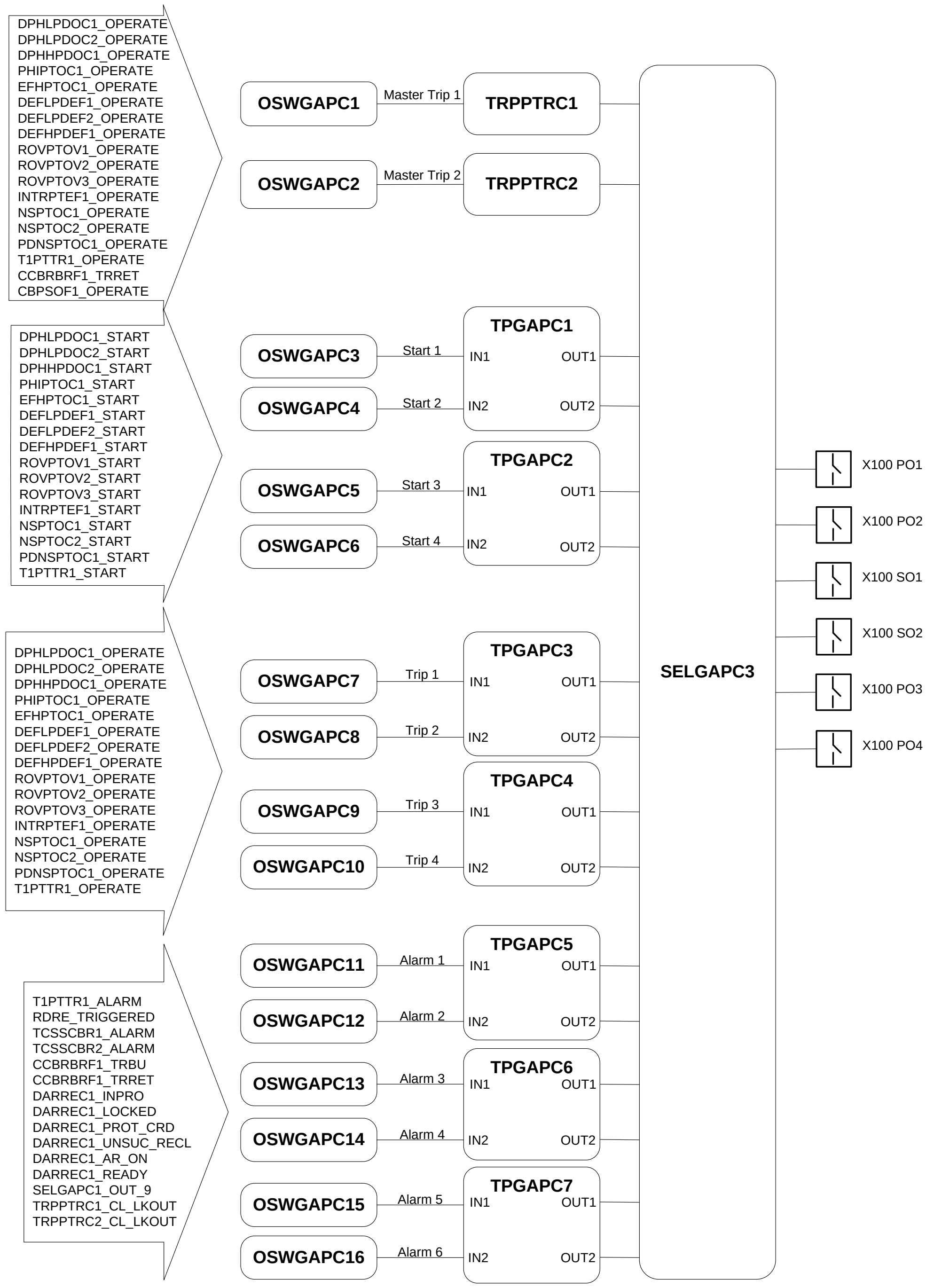


Figure 128: Binary outputs

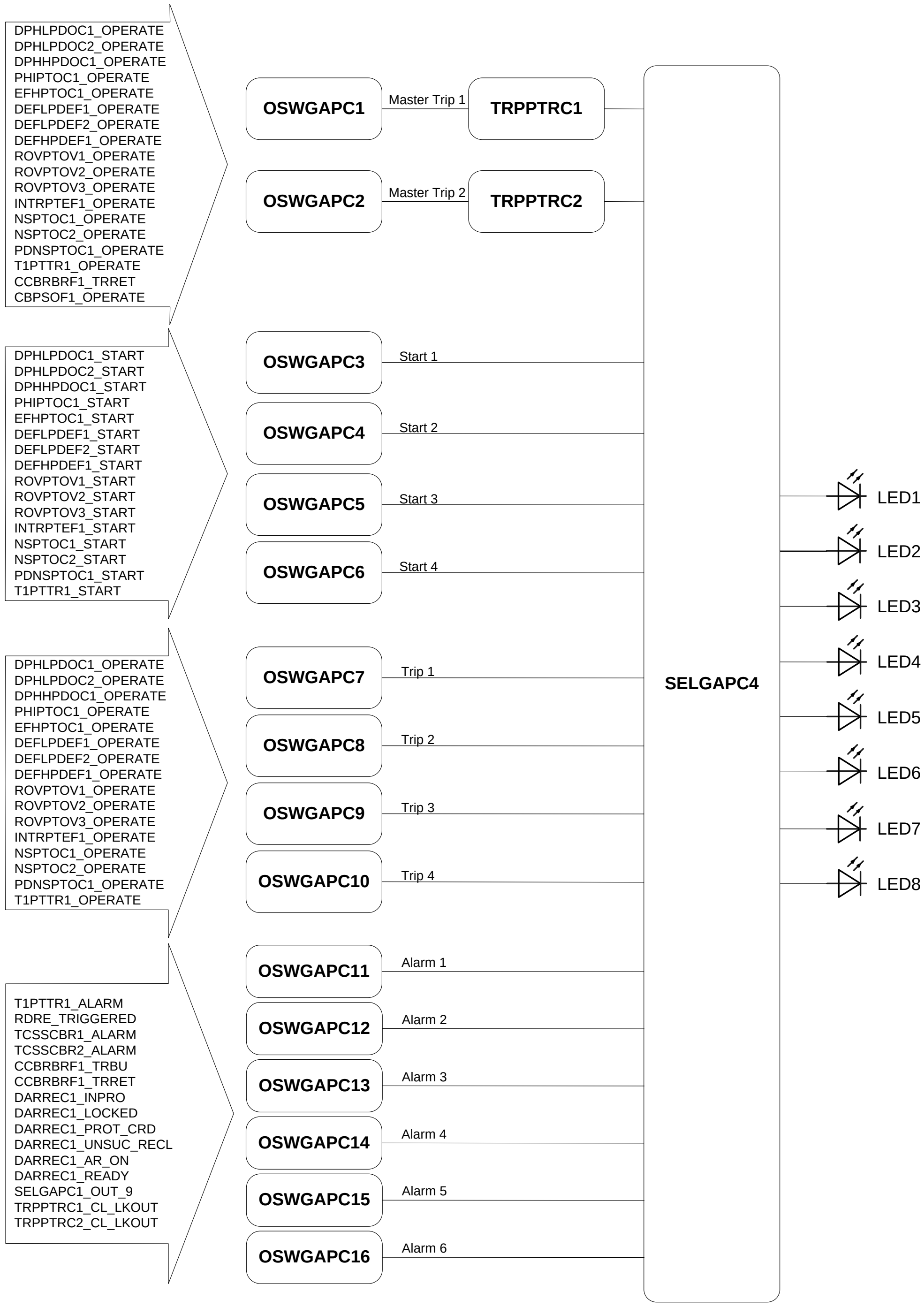


Figure 129: LEDs

SELGAPC3

SELGAPC3 is used to configure the OSWGAPC outputs to the protection relay binary outputs. 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 to X100 binary outputs.

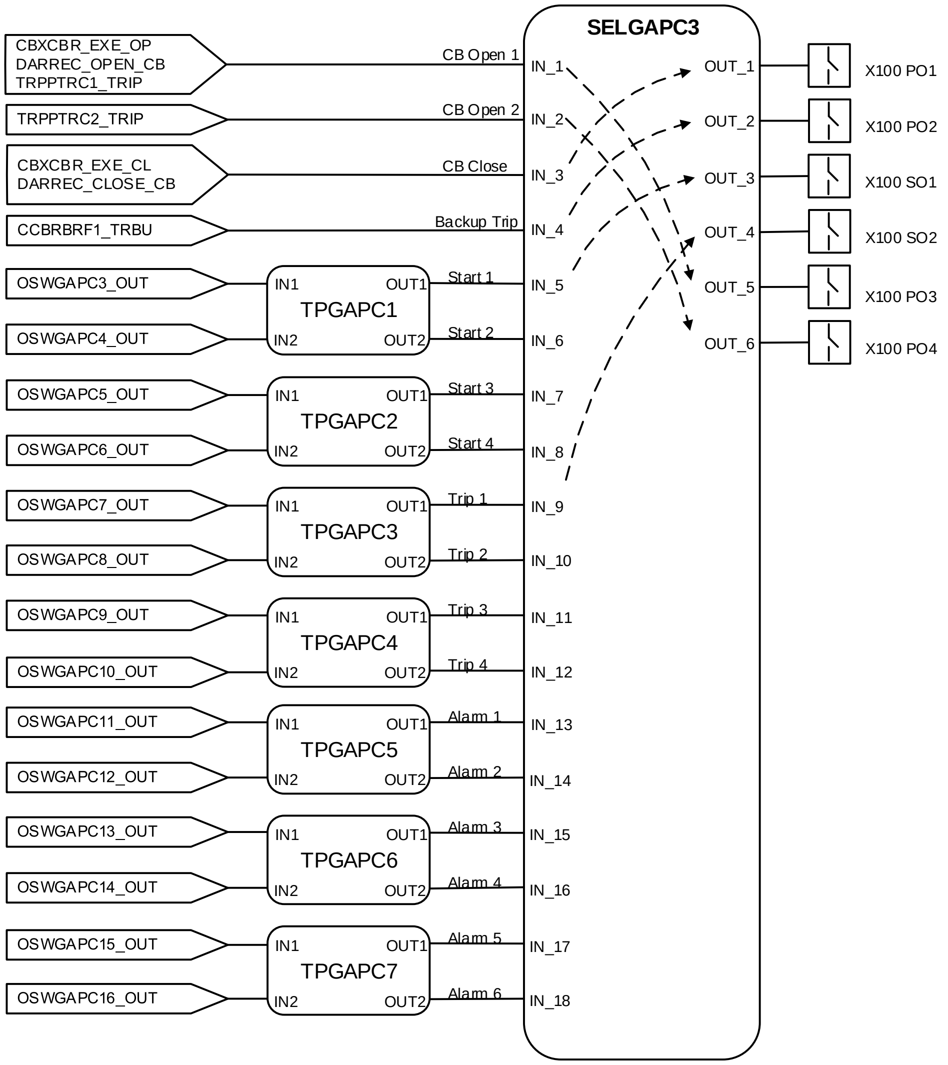


Figure 130: SELGAPC3

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.

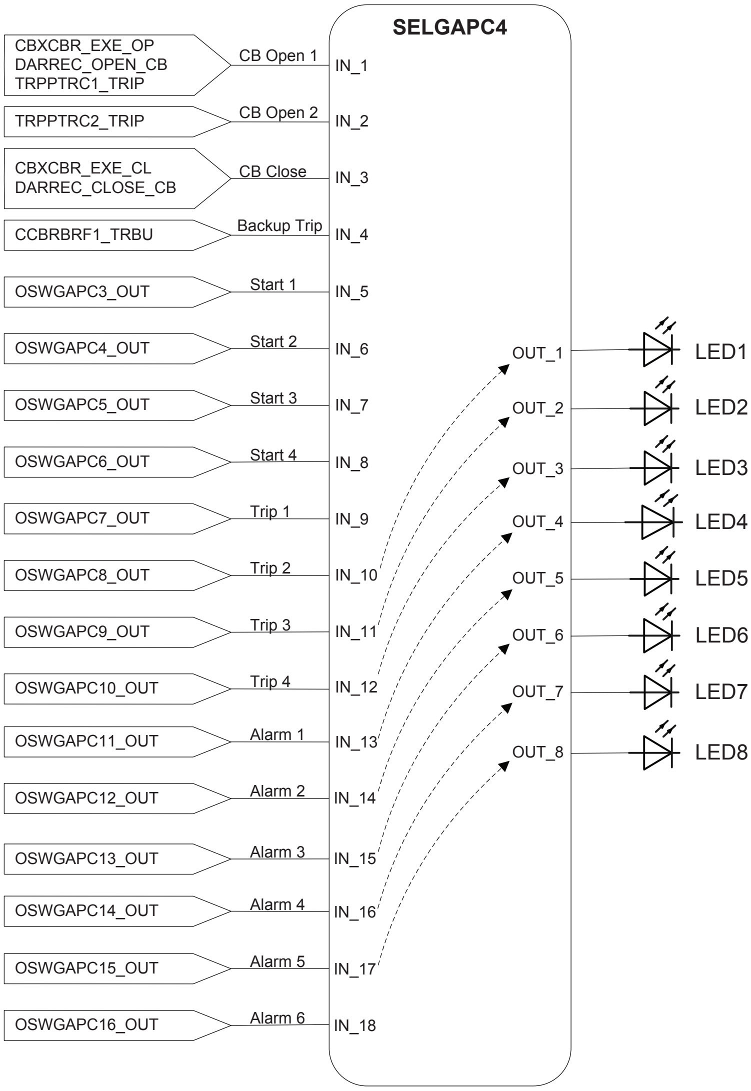


Figure 131: SELGAPC4

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's operate signals. The output is connected to TRPPTRC function. The default connections for OSWGAPC1 and OSWGAPC2 are different.

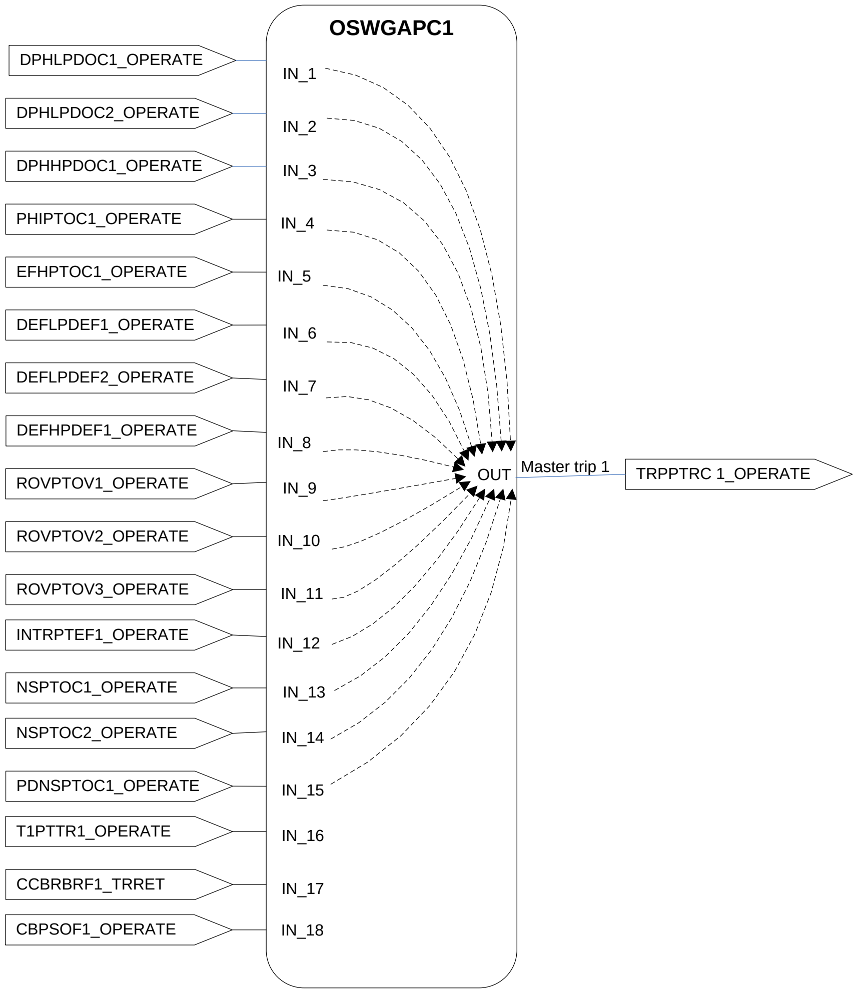


Figure 132: OSWGAPC1

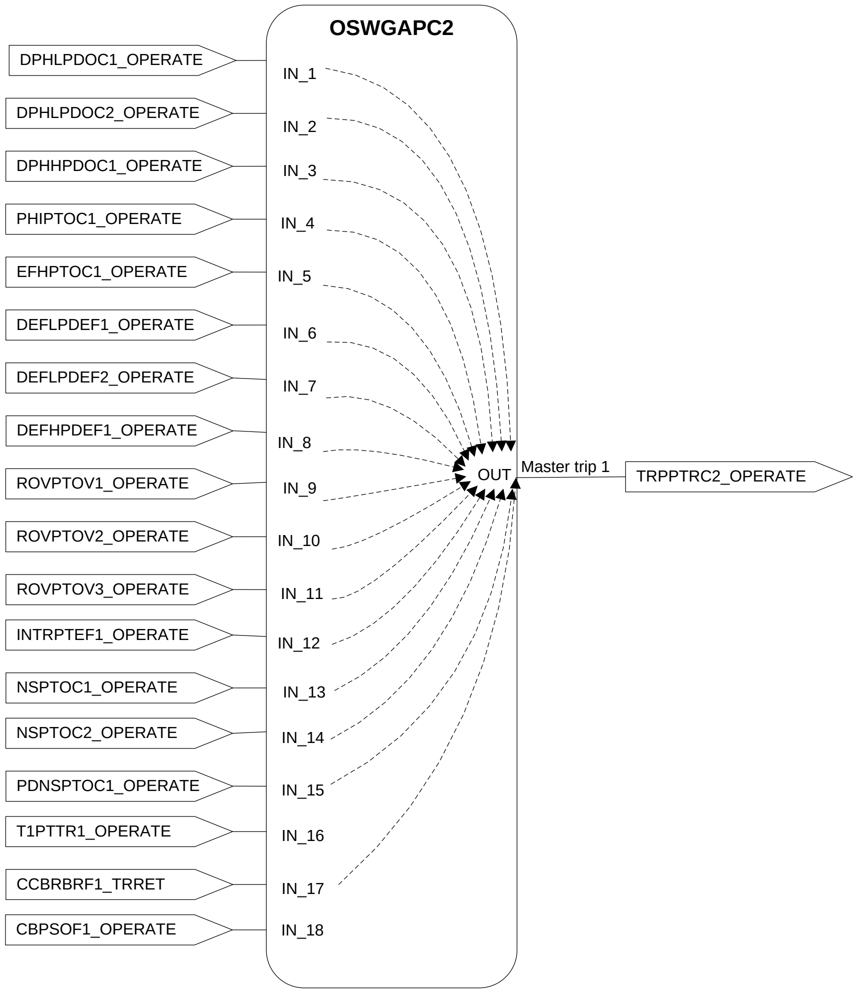


Figure 133: OSWGAPC2

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 routed to SELGAPC4 directly.

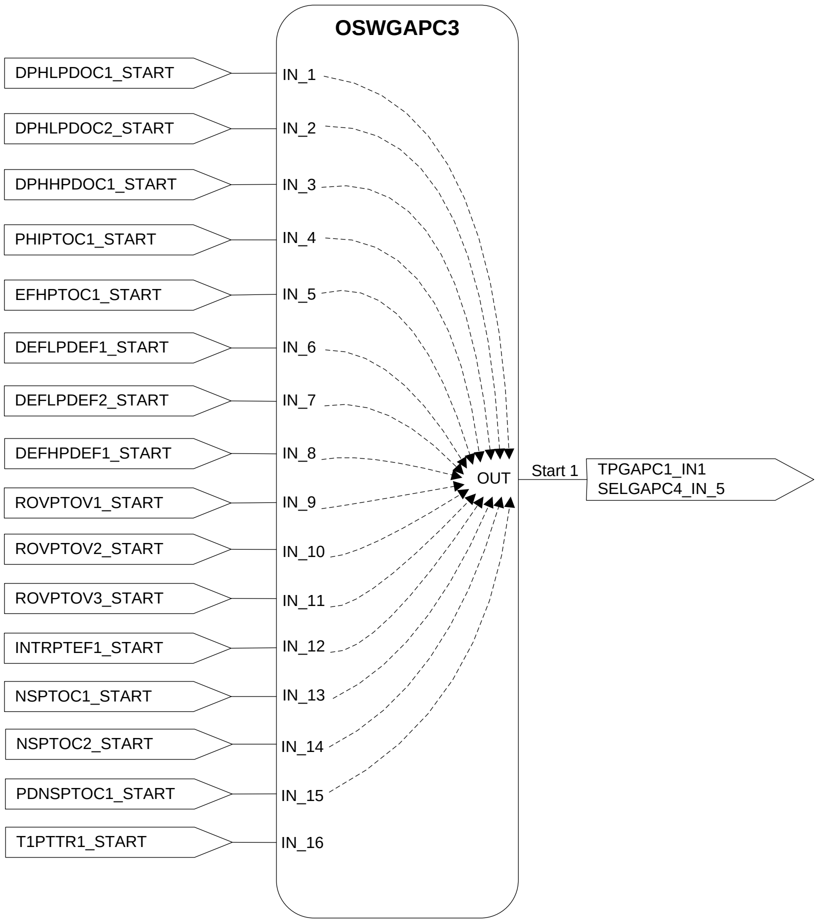


Figure 134: OSWGAPC3

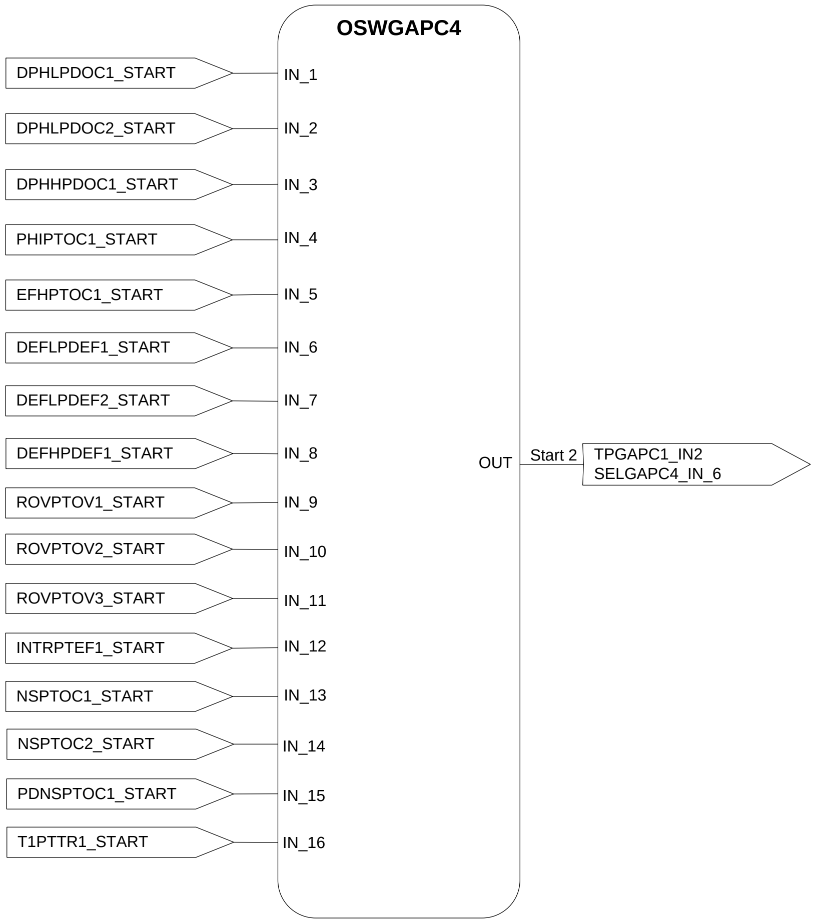


Figure 135: OSWGAPC4

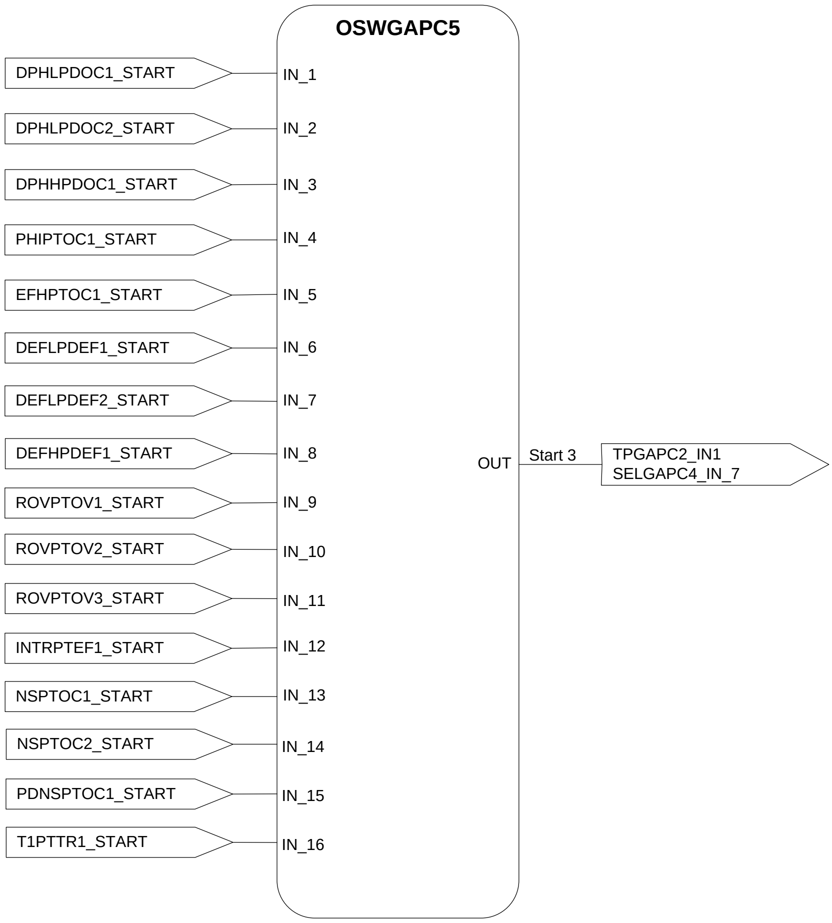


Figure 136: OSWGAPC5

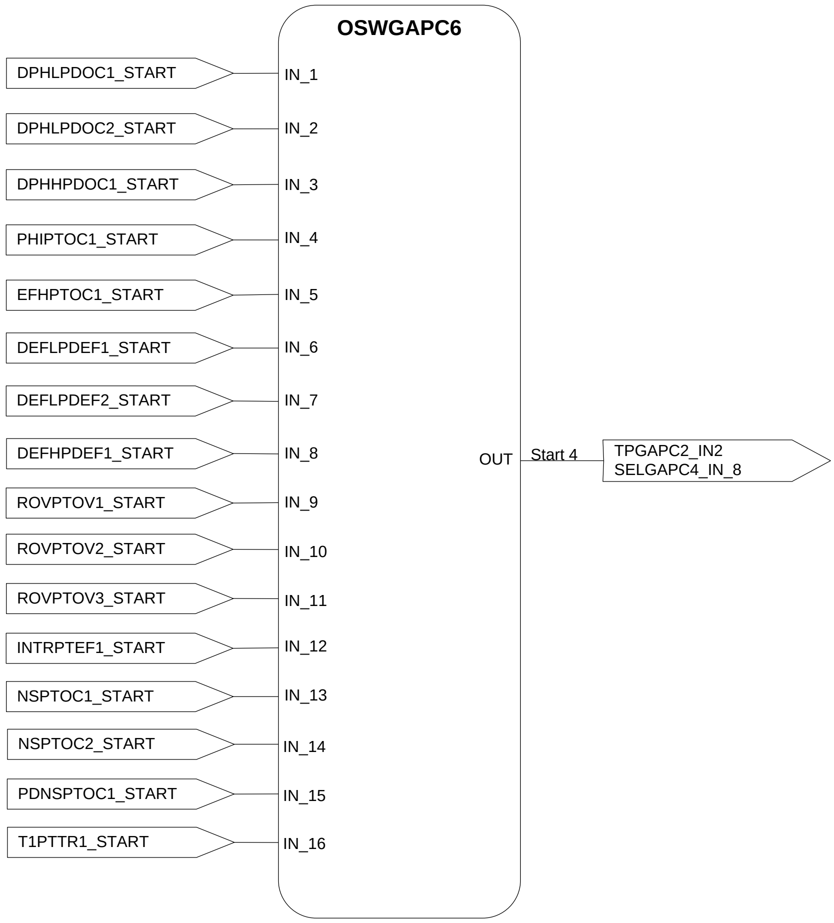


Figure 137: OSWGAPC6

Trip OSWGAPCs

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

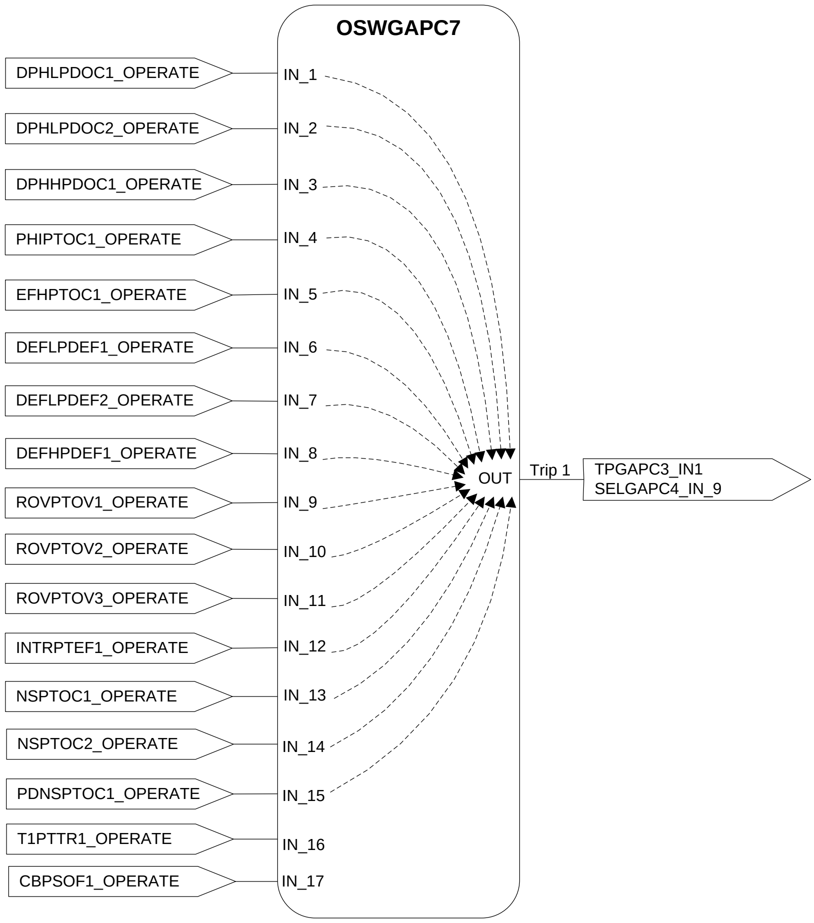


Figure 138: OSWGAPC7

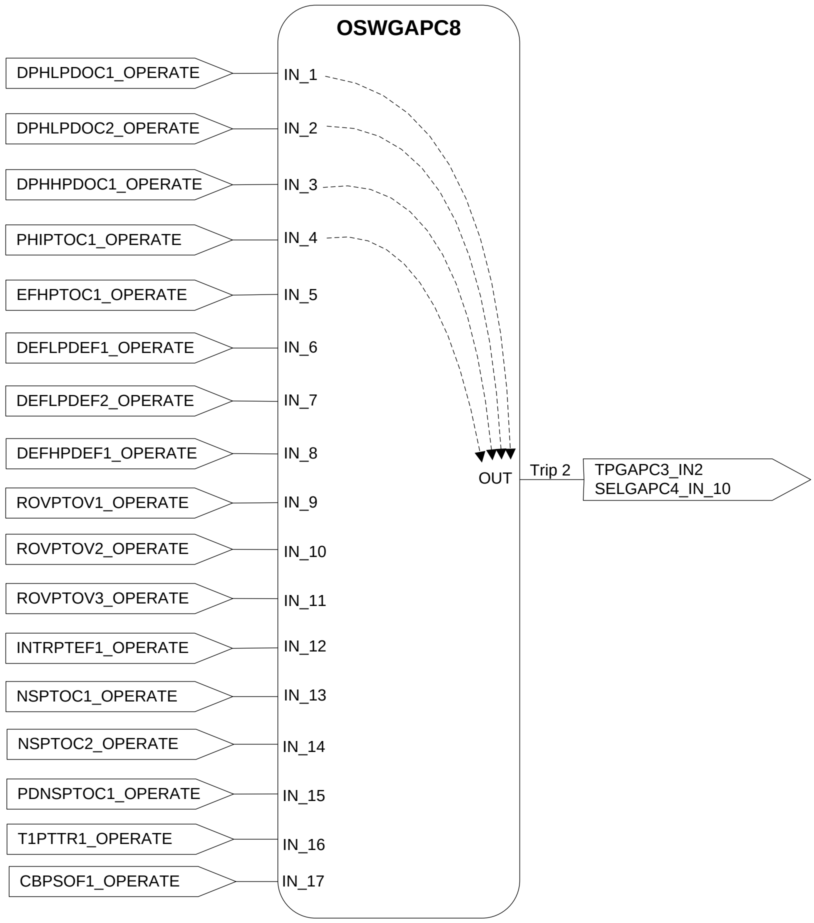


Figure 139: OSWGAPC8

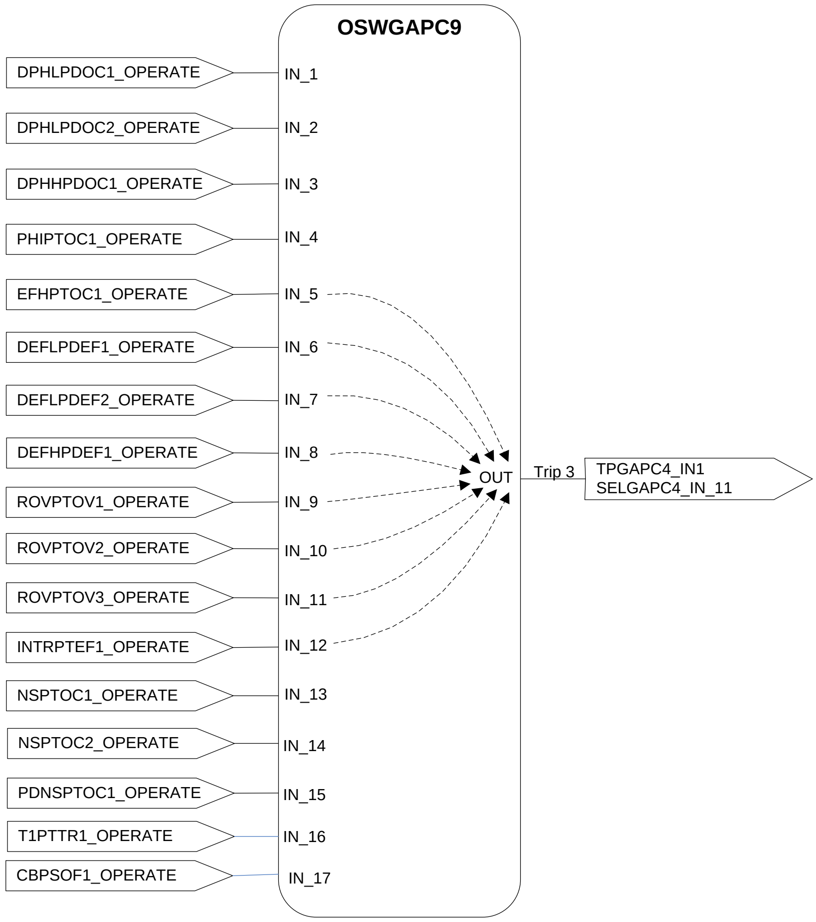


Figure 140: OSWGAPC9

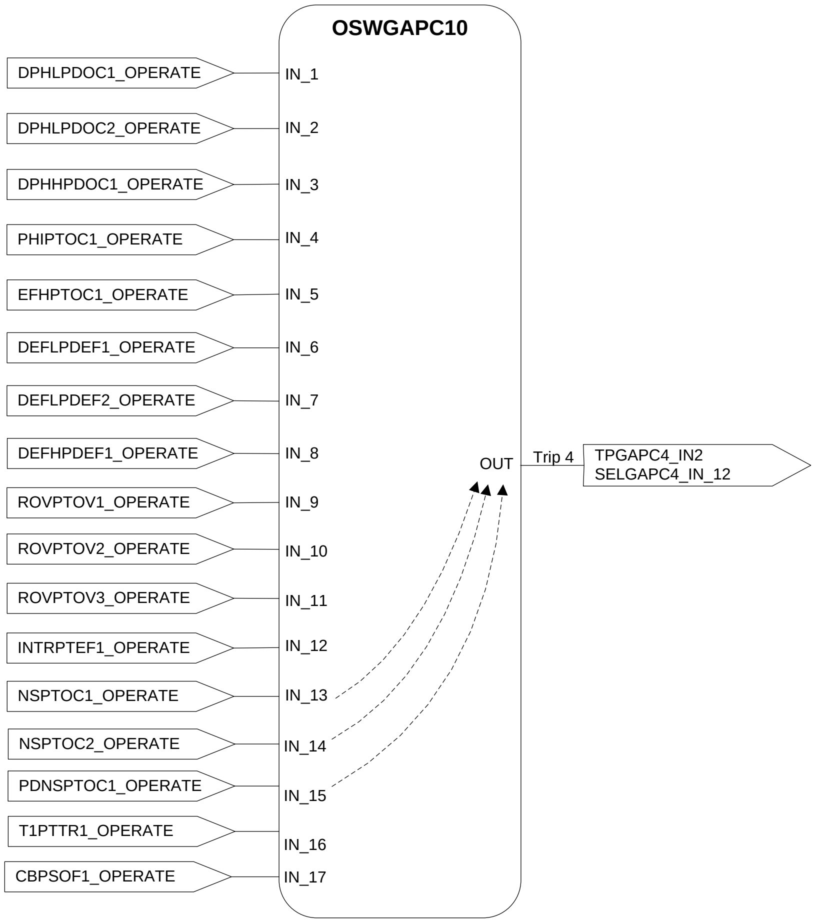


Figure 141: OSWGAPC10

Alarm OSWGAPC11...16

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

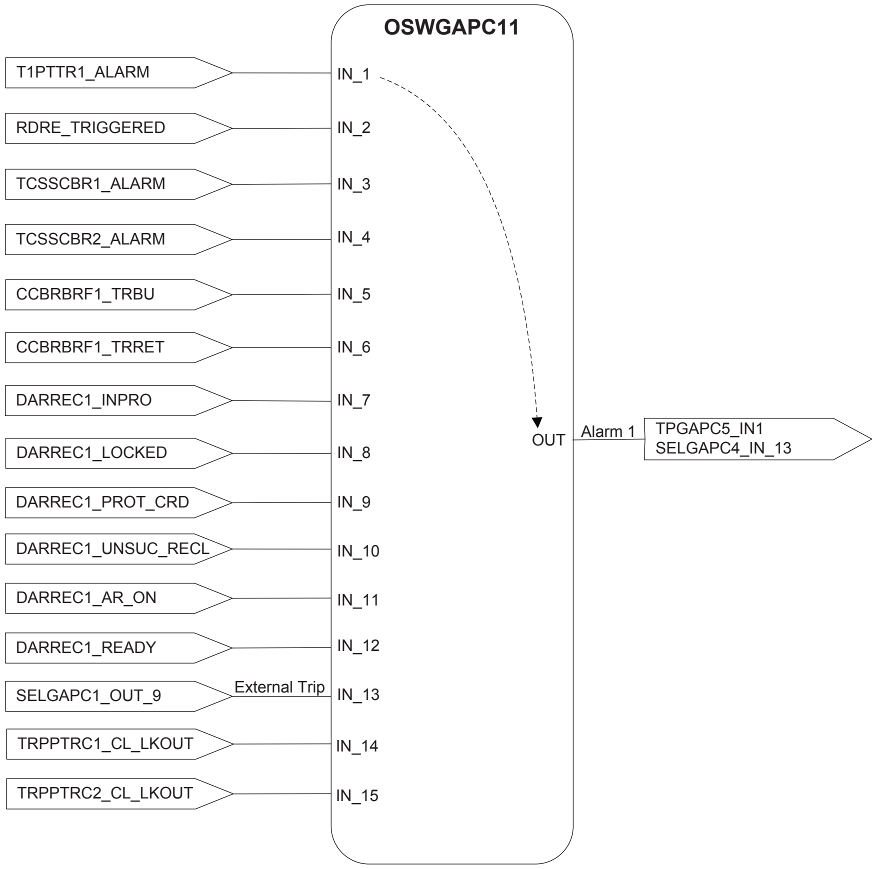


Figure 142: OSWGAPC11

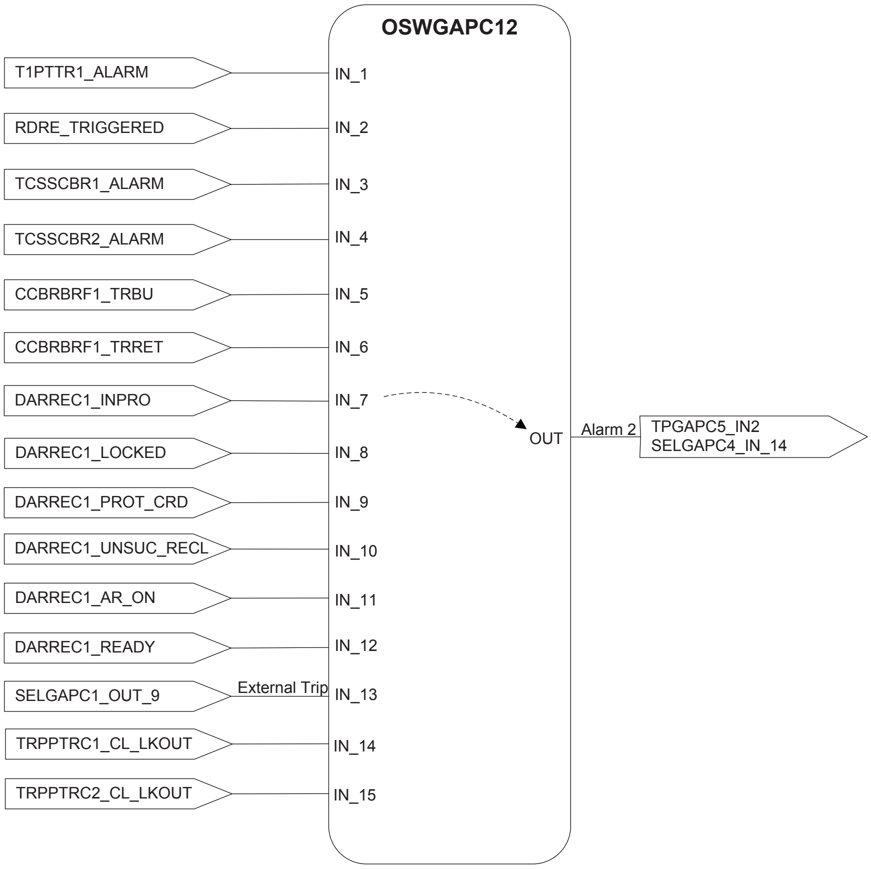


Figure 143: OSWGAPC12

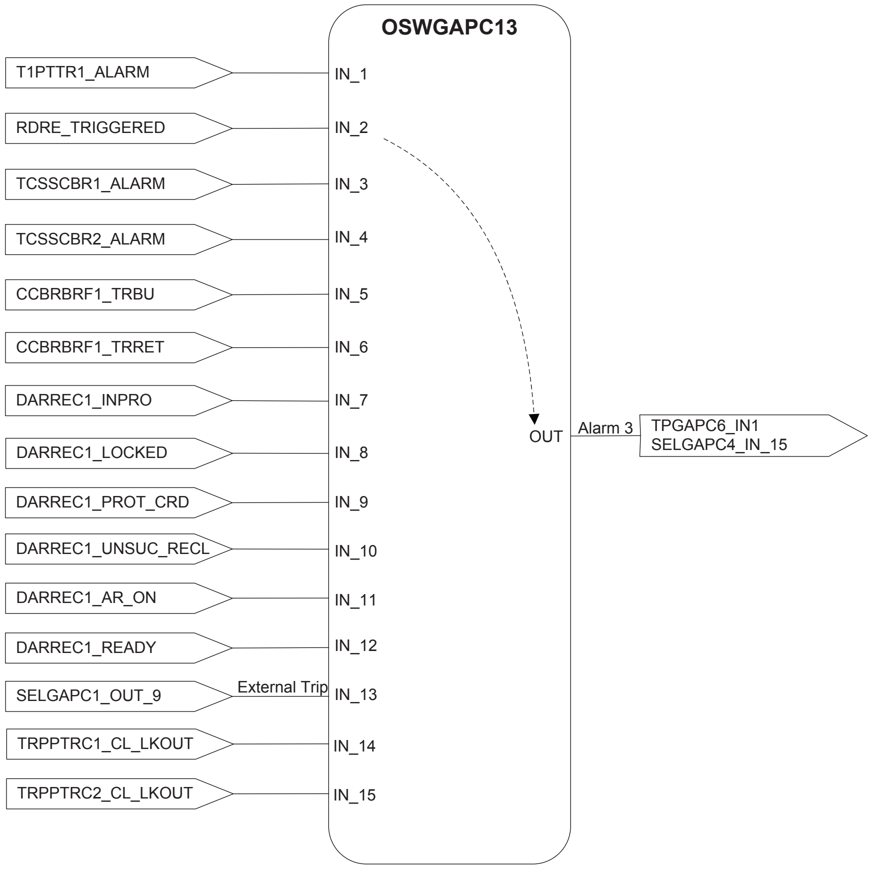


Figure 144: OSWGAPC13

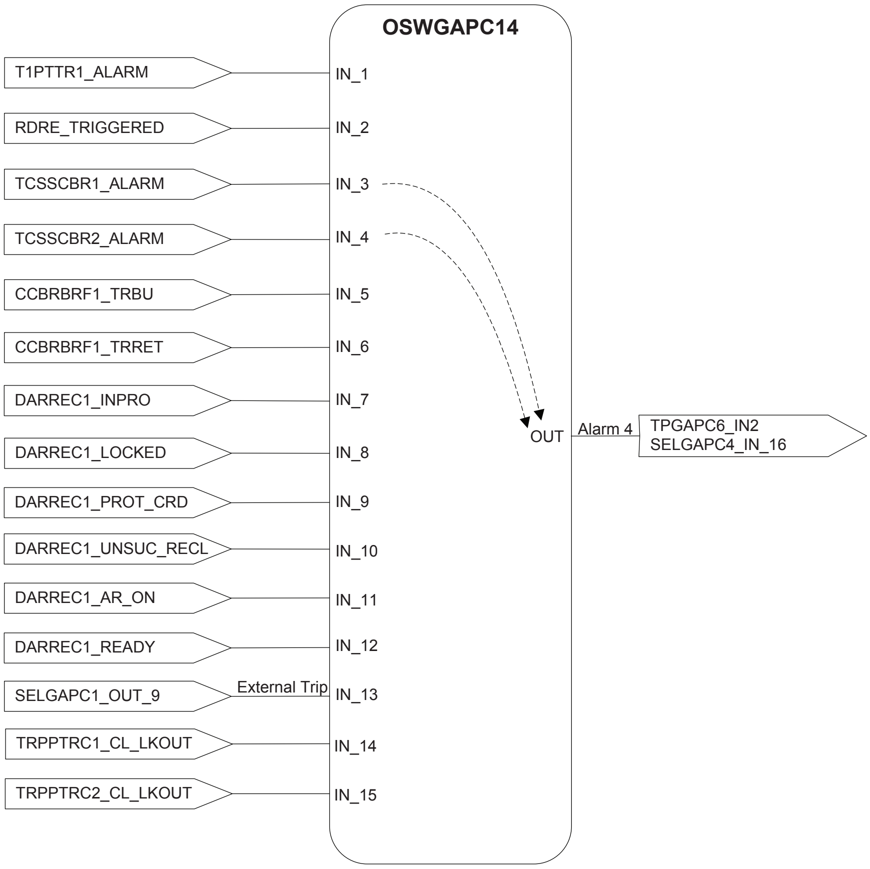


Figure 145: OSWGAPC14

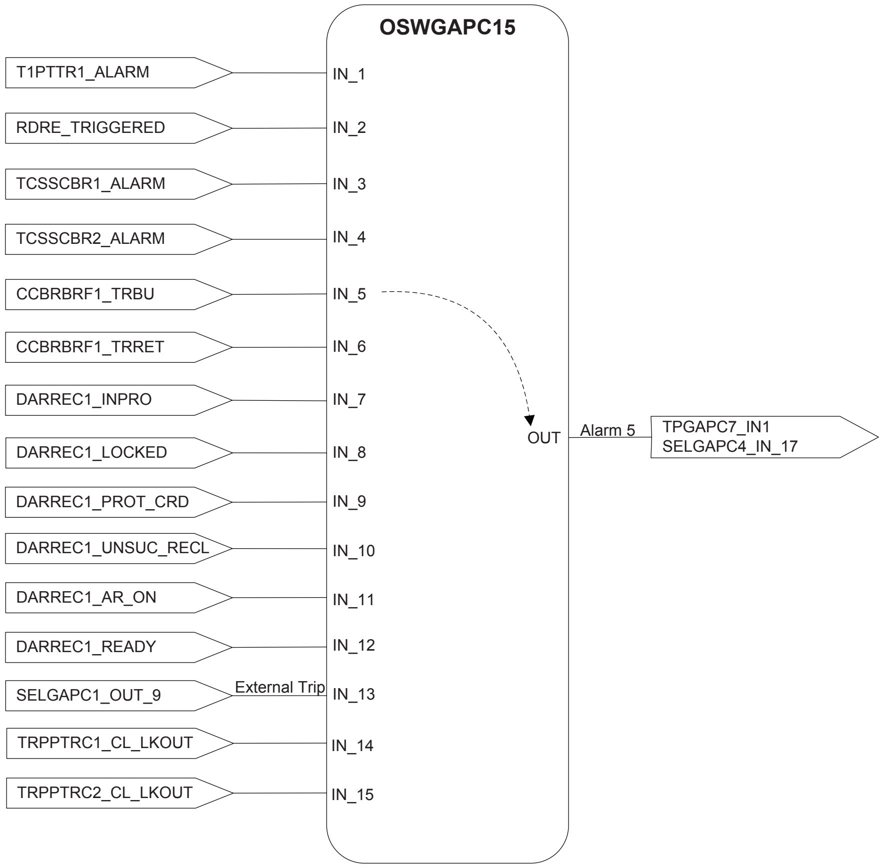


Figure 146: OSWGAPC15

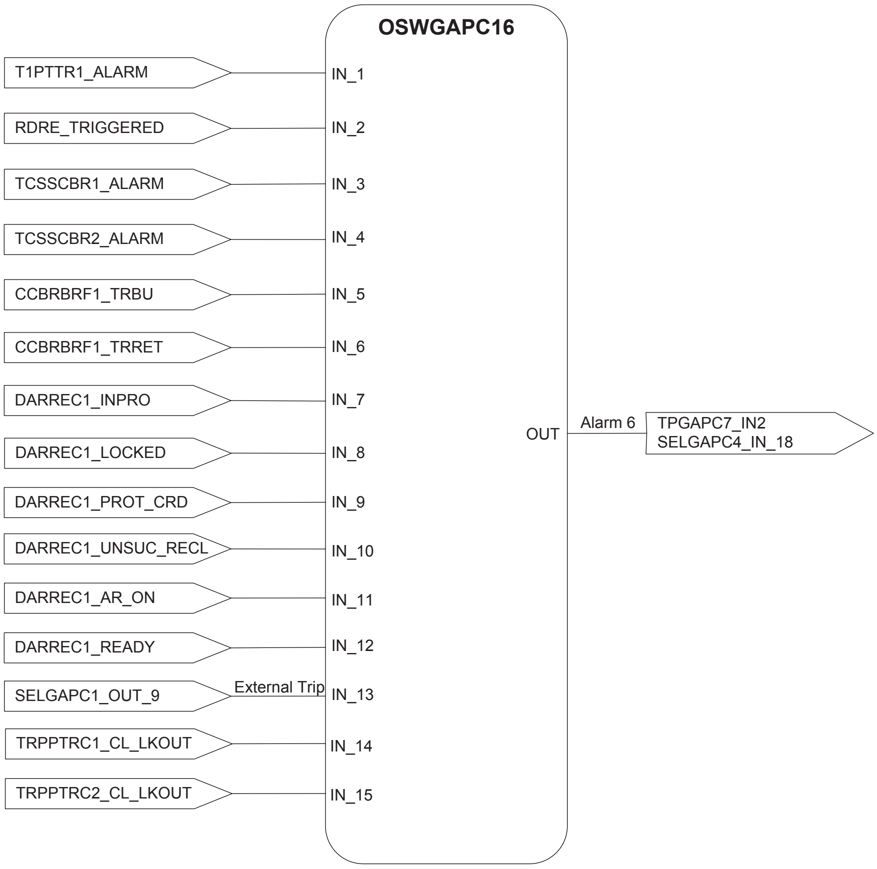


Figure 147: OSWGAPC16

3.6.4.4 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 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.

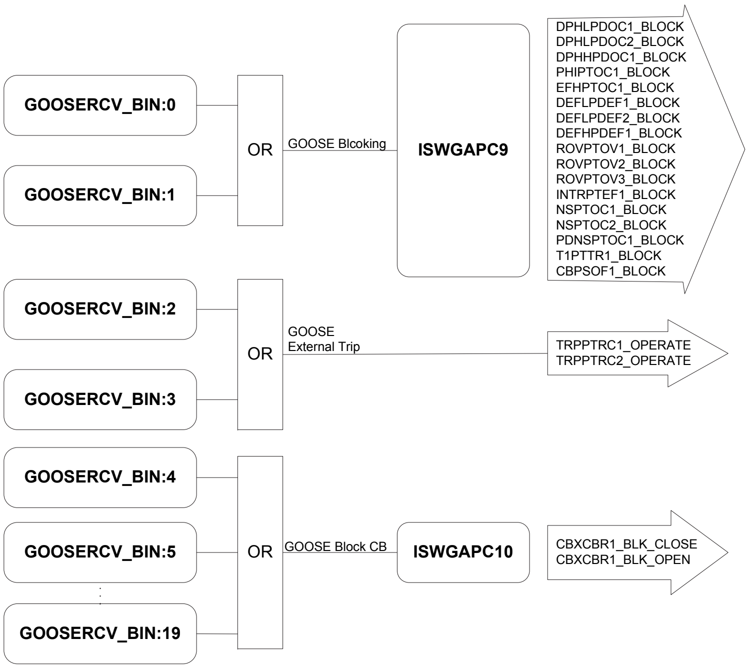


Figure 148: GOOSE overview

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 block inputs of the protection functions.

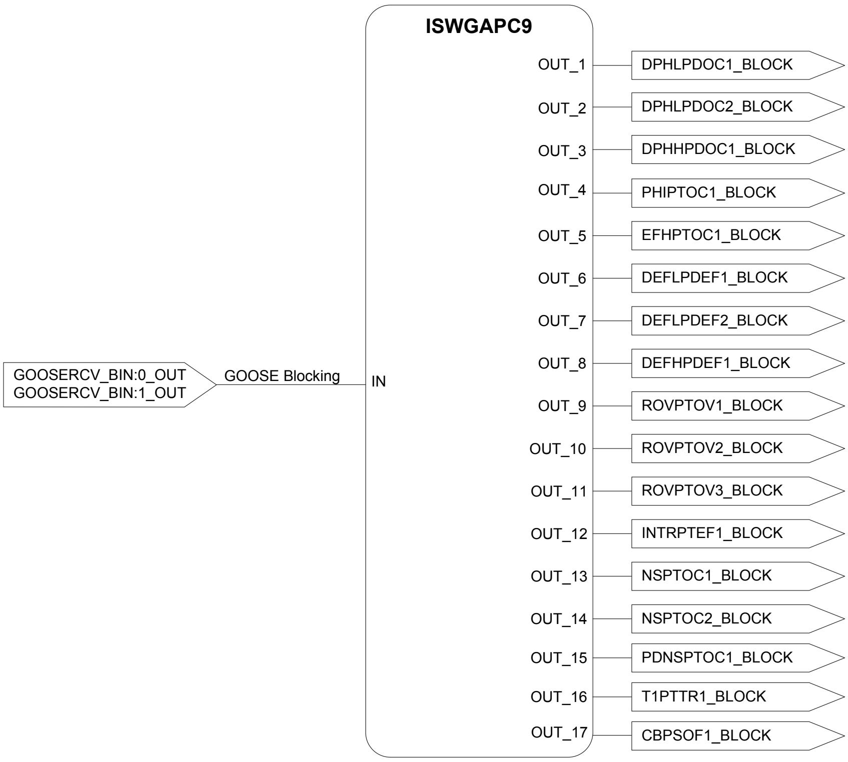


Figure 149: ISWGAPC9

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's close and open operation.

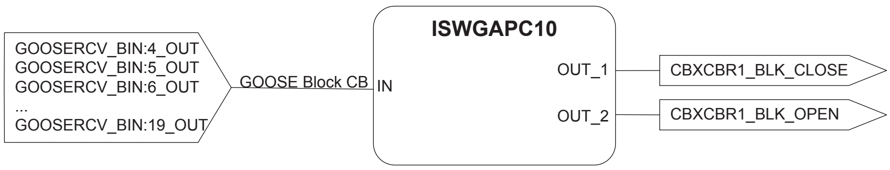


Figure 150: ISWGAPC10

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 26: 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.

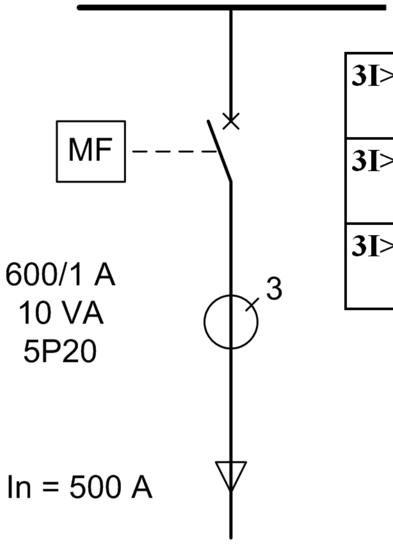
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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.



3I>	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
3I>>	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
3I>>>	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 151: 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 151). 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 151.

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 27: Phase current inputs included in configurations A, B and C

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

5.1.1.2 Residual current

Table 28: Residual current input included in configurations A, B and C

Terminal	Description
X120:13-14	Io

5.1.1.3 Residual voltage

Table 29: Additional residual voltage input included in configuration A

Terminal	Description
X120:5-6	Uo

Table 30: Additional residual voltage input included in configuration C

Terminal	Description
X130:17-18	Uo

5.1.1.4 Phase voltage

Table 31: Phase voltage inputs included in configuration C

Terminal	Description
X130:11-12	U1
X130:13-14	U2
X130:15-16	U3

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 32: 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.

Terminals X120:1-4 are binary input terminals. In the protection relay variant B, there are additional binary inputs X120:5-6 included. Optional BIO-module BIO0006 for slot X130 can be included at the time of order.

Binary inputs of slot X120 are available with configurations A and B.

Table 33: Binary input terminals X120-1...6

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

Binary inputs of slot X130 are optional for configurations A and B.

Table 34: Binary input terminals X130-1...9

Terminal	Description
X130:1	BI1, +
X130:2	BI1, -
X130:2	BI2, -
X130:3	BI2, +
X130:4	BI3, +
X130:5	BI3, -
X130:5	BI4, -
X130:6	BI4, +
X130:7	BI5, +
X130:8	BI5, -
X130:8	BI6, -
X130:9	BI6, +

Binary inputs of slot X130 are available with configuration C.

Table 35: Binary input terminals X130:1-8 with AIM0006 module

Terminal	Description
X130:1	BI1, +
X130:2	BI1, -
X130:3	BI2, +
X130:4	BI2, -
X130:5	BI3, +
X130:6	BI3, -
X130:7	BI4, +
X130:8	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 36: 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 or SO1, SO2 and SO3 in slot X130 (optional) 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 37: 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

Output contacts of slot X130 are available in the optional BIO module (BIO0006).

Output contacts of slot X130 are optional for configurations A and B.

Table 38: Output contacts X130:10...18

Terminal	Description
X130:10	SO1, common
X130:11	SO1, NO
X130:12	SO1, NC
X130:13	SO2, common

Table continues on next page

Terminal	Description
X130:14	SO2, NO
X130:15	SO2, NC
X130:16	SO3, common
X130:17	SO3, NO
X130:18	SO3, NC

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 39: 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.
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
REF611	Feeder 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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