RELION® 615 SERIES

Generator and Interconnection Protection
REG615 ANSI

Application Manual

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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 standards EN 50263 and 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 and ANSI C37.90. This product complies with the UL 508 certification.

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

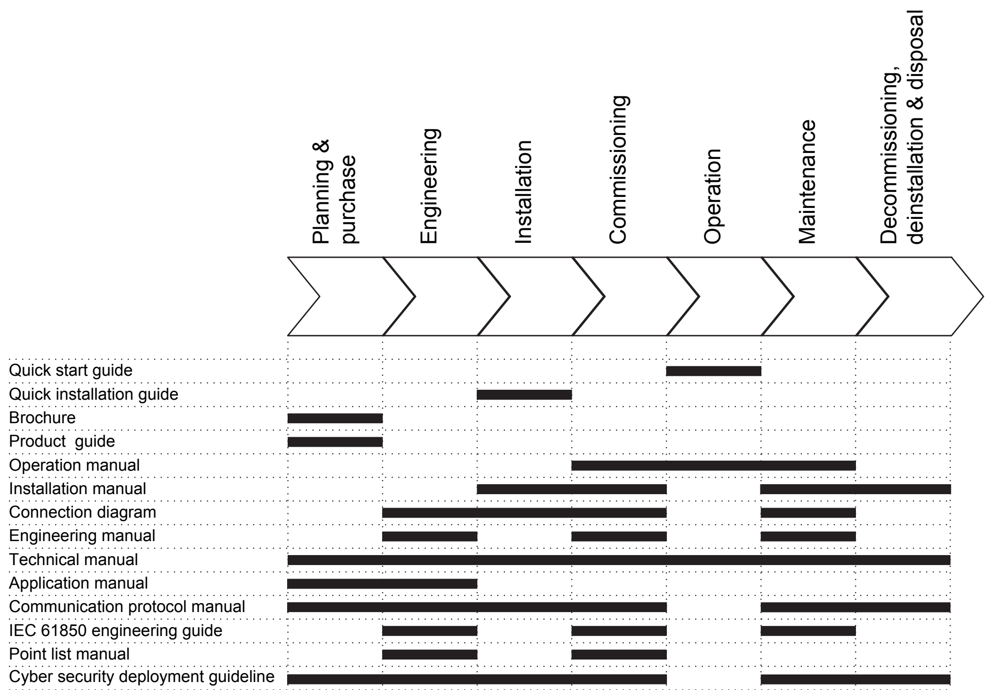


Figure 1: The intended use of documents during the product life cycle

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/2018-02-26	5.0 FP1	First release
B/2019-05-08	5.0 FP1	Content updated
C/2019-06-07	5.0 FP1	Content updated
D/2019-06-13	5.0 FP1	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	1MAC057386-MB
DNP3 Communication Protocol Manual	1MAC052479-MB
IEC 61850 Engineering Guide	1MAC053584-RG
Engineering Manual	1MAC108982-MB
Installation Manual	1MAC051065-MB
Operation Manual	1MAC054853-MB
Technical Manual	1MAC059074-MB
Cyber Security Deployment Guideline	1MAC052704-HT

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 "Enabled" and "Disabled".
- Input/output messages and monitored data names are shown in Courier font.
  When the function picks up, the `PICKUP` output is set to TRUE.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned, the dimension is in mm.
- 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	ANSI/C37.2-2008
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	50P-1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P-3

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67/51P-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67/50P-1
Three-phase voltage-dependent overcurrent protection	PHPVOC1	3I(U)> (1)	51V
Non-directional ground-fault protection, high stage	EFHPTOC1	Io>> (1)	50G-1
Directional ground-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67/51N-1
	DEFLPDEF2	Io> -> (2)	67/51N-2
Directional ground-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67/50N-1
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G
	ROVPTOV2	Uo> (2)	59N-1
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27-1
	PHPTUV2	3U< (2)	27-2
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59-1
	PHPTOV2	3U> (2)	59-2
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U-1
	PSPTUV2	U1< (2)	47U-2
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47-1
	NSPTOV2	U2> (2)	47-2
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81-1
	FRPFRQ2	f>/f<,df/dt (2)	81-2
	FRPFRQ3	f>/f<,df/dt (3)	81-3
	FRPFRQ4	f>/f<,df/dt (4)	81-4
	FRPFRQ5	f>/f<,df/dt (5)	81-5
	FRPFRQ6	f>/f<,df/dt (6)	81-6
Overexcitation protection	OEPVPH1	U/f> (1)	24
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T-1
Negative-sequence overcurrent protection for machines	MNSPTOC1	I2>M (1)	46M-1
	MNSPTOC2	I2>M (2)	46M-2
Motor differential protection	MPDIF1	3dI>M	87G-1
Numerically stabilized low-impedance restricted ground-fault protection	LREFPNDF1	dIoLo> (1)	87LOZREF
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	50BF-1
Three-phase inrush detector	INRPHAR1	3I2f> (1)	INR-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Master trip	TRPPTRC1	Master Trip (1)	86/94-1
	TRPPTRC2	Master Trip (2)	86/94-2
	TRPPTRC3	Master Trip (3)	86/94-3
	TRPPTRC4	Master Trip (4)	86/94-4
	TRPPTRC5	Master Trip (5)	86/94-5
	TRPPTRC6	Master Trip (6)	86/94-6
Arc protection	ARCSARC1	ARC (1)	AFD-1
	ARCSARC2	ARC (2)	AFD-2
	ARCSARC3	ARC (3)	AFD-3
Multipurpose protection	MAPGAPC1	MAP (1)	MAP-1
	MAPGAPC2	MAP (2)	MAP-2
	MAPGAPC3	MAP (3)	MAP-3
	MAPGAPC4	MAP (4)	MAP-4
	MAPGAPC5	MAP (5)	MAP-5
	MAPGAPC6	MAP (6)	MAP-6
	MAPGAPC7	MAP (7)	MAP-7
	MAPGAPC8	MAP (8)	MAP-8
	MAPGAPC9	MAP (9)	MAP-9
	MAPGAPC10	MAP (10)	MAP-10
	MAPGAPC11	MAP (11)	MAP-11
	MAPGAPC12	MAP (12)	MAP-12
	MAPGAPC13	MAP (13)	MAP-13
	MAPGAPC14	MAP (14)	MAP-14
	MAPGAPC15	MAP (15)	MAP-15
	MAPGAPC16	MAP (16)	MAP-16
	MAPGAPC17	MAP (17)	MAP-17
	MAPGAPC18	MAP (18)	MAP-18
Third harmonic-based stator ground-fault protection	H3EFPSEF1	dUo>/Uo3H (1)	27/59THN
Underpower protection	DUPPDPR1	P< (1)	32U-1
	DUPPDPR2	P< (2)	32U-2
Reverse power/directional overpower protection	DOPPDPR1	P>/Q> (1)	32R-32
	DOPPDPR2	P>/Q> (2)	32R-32
	DOPPDPR3	P>/Q> (3)	32R-32
Three-phase underexcitation protection	UEXPDIS1	X< (1)	40-1
Three-phase underimpedance protection	UZPDIS1	Z<G (1)	21G-1
Out-of-step protection	OOSRPSB1	OOS (1)	78-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQI-1
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQVPH-1
Voltage variation	PHQVVR1	PQMU (1)	PQSS-1
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB-1
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	52-1
Disconnector control	DCXSWI1	I <-> O DCC (1)	29DS-1
	DCXSWI2	I <-> O DCC (2)	29DS-2
Grounding switch control	ESXSWI1	I <-> O ESC (1)	29GS-1
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	52-TOC
	DCSXSWI2	I <-> O DC (2)	29DS-1
	DCSXSWI3	I <-> O DC (3)	29DS-2
Grounding switch indication	ESSXSWI1	I <-> O ES (1)	29GS-1
	ESSXSWI2	I <-> O ES (2)	29GS-2
Synchronism and energizing check	SECRSYN1	SYNC (1)	25
Condition monitoring			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	52CM-1
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM-1
	TCSSCBR2	TCS (2)	TCM-2
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60-1
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM-1
Measurement			
Load profile record	LDPRLRC1	LOADPROF (1)	LoadProf
Three-phase current measurement	CMMXU1	3I (1)	IA, IB, IC
	CMMXU2	3I (2)	IA, IB, IC (2)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0
Residual current measurement	RESCMMXU1	Io (1)	IG
Three-phase voltage measurement	VMMXU1	3U (1)	VA, VB, VC
	VMMXU2	3U (2)	VA, VB, VC (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	VG-1
	RESVMMXU2	Uo (2)	VG-2
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0
Single-phase power and energy measurement	SPEMMXU1	SP, SE	SP, SE-1
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRECEIVER	SMVRECEIVER	SMVRECEIVER
Other			
Minimum pulse timer	TPGAPC1	TP (1)	62TP-1
	TPGAPC2	TP (2)	62TP-2
	TPGAPC3	TP (3)	62TP-3
	TPGAPC4	TP (4)	62TP-4
Minimum pulse timer (second resolution)	TPSGAPC1	TPS (1)	62TPS-1
Minimum pulse timer (minute resolution)	TPMGAPC1	TPM (1)	62TPM-1
Pulse timer	PTGAPC1	PT (1)	62PT-1
	PTGAPC2	PT (2)	62PT-2
Time delay off	TOFGAPC1	TOF (1)	62TOF-1
	TOFGAPC2	TOF (2)	62TOF-2
	TOFGAPC3	TOF (3)	62TOF-3
	TOFGAPC4	TOF (4)	62TOF-4
Time delay on	TONGAPC1	TON (1)	62TON-1
	TONGAPC2	TON (2)	62TON-2
	TONGAPC3	TON (3)	62TON-3
	TONGAPC4	TON (4)	62TON-4
Set-reset	SRGAPC1	SR (1)	SR-1
	SRGAPC2	SR (2)	SR-2
	SRGAPC3	SR (3)	SR-3
	SRGAPC4	SR (4)	SR-4
Move	MVGAPC1	MV (1)	MV-1
	MVGAPC2	MV (2)	MV-2
Generic control point	SPCGAPC1	SPC (1)	SPC-1
	SPCGAPC2	SPC (2)	SPC-2
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4-1
	SCA4GAPC2	SCA4 (2)	SCA4-2
	SCA4GAPC3	SCA4 (3)	SCA4-3
	SCA4GAPC4	SCA4 (4)	SCA4-4
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4-1

Table continues on next page

Function	IEC 61850	IEC 60617	ANSI/C37.2-2008
Generic up-down counters	UDFCNT1	UDCNT (1)	CTR-1
	UDFCNT2	UDCNT (2)	CTR-2
	UDFCNT3	UDCNT (3)	CTR-3
	UDFCNT4	UDCNT (4)	CTR-4

Section 2 REG615 overview

2.1 Overview

REG615 is a dedicated generator and interconnection protection relay designed for the different power generation applications. REG615 is available in two standard configurations denoted C and D. Standard configurations C and D are designed for the protection, control, measurement and supervision of small or medium size generators used in diesel, gas, hydroelectric, combined heat and power (CHP), and steam power plants. REG615 is a member of ABB's Relion® product family and part of its 615 protection and control product series. The 615 series protection relays are characterized by their compactness and withdrawable unit design.

Re-engineered from the ground up, the 615 series has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices. Once the standard configuration relay has been given the application-specific settings, it can directly be put into service.

The generator protection relay provides main protection for small size power generators. The generator protection relay is also used as back-up protection for medium size generators in power applications, where an independent and redundant protection system is required. The interconnection protection relay provides main protection fulfilling the grid codes to connect distributed generation with the power grid.

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, Modbus® and DNP3.

2.1.1 Product version history

Product version	Product history
5.0 FP1	Product released

2.1.2 PCM600 and relay connectivity package version

- Protection and Control IED Manager PCM600 2.8 or later
- REG615 Connectivity Package Ver.5.1 or later

- Parameter Setting
- Signal Monitoring
- Event Viewer
- Disturbance Handling
- Application Configuration
- Signal Matrix
- Graphical Display Editor
- Communication Management
- IED User Management
- IED Compare
- Firmware Update
- Fault Record tool
- Load Record Profile
- Lifecycle Traceability
- Configuration Wizard
- Label Printing
- IEC 61850 Configuration
- IED Configuration Migration

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 features

- Arc protection
- Modbus TCP/IP or RTU/ASCII
- DNP3 TCP/IP or serial
- Power quality functions
- RTD/mA measurement
- IEC 61850-9-2 LE
- IEEE 1588 v2 time synchronization

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	Details
Plug-in unit	-	HMI	Large (10 lines, 20 characters) with SLD
	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
	X110	Optional BIO module	Only with configurations C and D: 8 binary inputs 4 SO contacts
			Only with configurations C and D: 8 binary inputs 3 high-speed SO contacts
	X120	AI/BI module	Only with configuration C: 3 phase current inputs (1/5 A) 1 residual current input (1/5 A) 3 binary inputs
			Only with configuration C: 3 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)] 3 binary inputs
			Only with configuration D: 6 phase current inputs (1/5 A) 1 residual current input (1/5 A)
			Only with configuration D: 6 phase current inputs (1/5 A) 1 residual current input (0.2/1 A)[1)]

Table continues on next page

Main unit	Slot ID	Content	Details
Case	X130	Optional AI/BI module	Only with configurations C and D: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 4 binary inputs Additionally with configuration N: 1 reference voltage input for SECRSYN1 (60...210 V)
		Optional AI/RTD/mA module	Only with configurations C and D: 3 phase voltage inputs (60...210 V) 1 residual voltage input (60...210 V) 1 generic mA input 2 RTD sensor inputs Additionally with configuration N: 1 reference voltage input for SECRSYN1 (60...210 V)
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

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

The rated input levels are selected in the software of the protection relay for phase current and ground current. The binary input thresholds 18...176 V DC are selected by adjusting the protection relay's parameter settings.

The optional BIO module can be added in the protection relay to all standard configurations.

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

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

Table 3: Input/output overview

Std. conf.	Order code digit		Analog channels		Binary channels			
	5-6	7-8	CT	VT	BI	BO	RTD	mA
C	AE/AF	AG	4	5	16	4 PO + 6 SO	-	-
		FC	4	5	16	4 PO + 2 SO + 3 HSO	-	-
	FE/FF	AD	4	5	12	4 PO + 6 SO	2	1
		FE	4	5	12	4 PO + 2 SO + 3 HSO	2	1

Table continues on next page

Std. conf.	Order code digit		Analog channels		Binary channels			
	5-6	7-8	CT	VT	BI	BO	RTD	mA
D	BC/BD	AD	7	5	12	4 PO + 6 SO	-	-
		FE	7	5	12	4 PO + 2 SO + 3 HSO	-	-
	BE/BF	BA	7	5	8	4 PO + 6 SO	2	1
		FD	7	5	8	4 PO + 2 SO + 3 HSO	2	1

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.

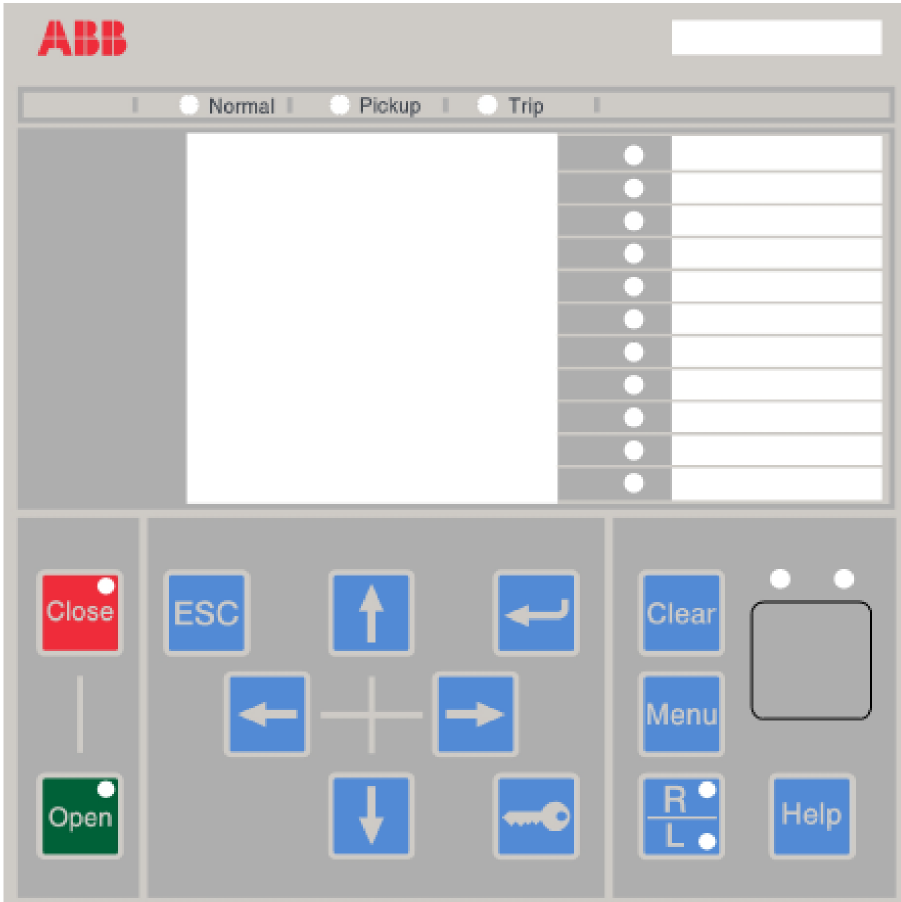


Figure 2: Example of the LHMI

2.4.1 Display

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

Table 4: Large display

Character size1)	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20

1) Depending on the selected language

The display view is divided into four basic areas.

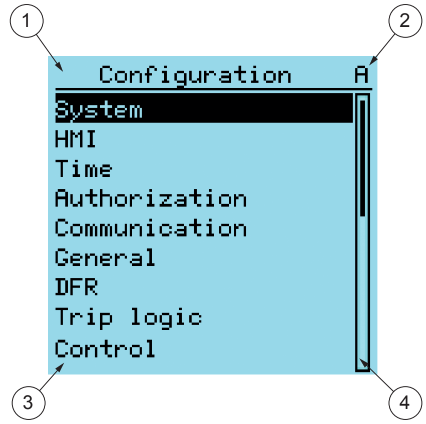


Figure 3: Display layout

1 Header

2 Icon

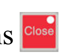
3 Content

4 Scroll bar (displayed when needed)

2.4.2 LEDs

The LHMI includes three protection indicators above the display: Normal, Pickup and Trip.

There are 11 matrix programmable LEDs on front of the LHMI. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

There are two additional LEDs which are embedded into the control buttons 

and 

. They represent the status of breaker 1 (CBXCBR1).

2.4.3 Keypad

The LHMI keypad contains push buttons which are used to navigate in different views or menus. Using the push buttons, open or close commands can be given to objects 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.

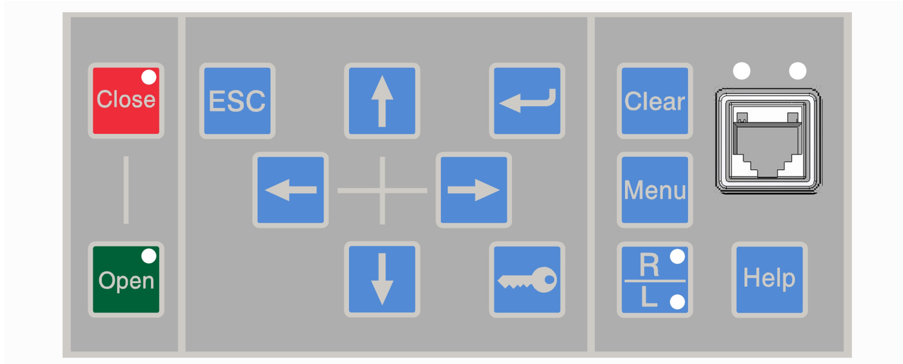


Figure 4: LHMI keypad with object control, navigation and command push buttons and RJ-45 communication port

2.5 Web HMI

The WHMI allows secure access to the protection relay via a Web browser. The supported Web browser versions are Internet Explorer 9.0, 10.0 and 11.0. 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 11.0.

WHMI is disabled by default.WHMI is enabled by default.

WHMI offers several functions.

- Programmable LEDs and event lists
- System supervision
- Parameter settings
- Measurement display
- DFR records
- Fault records
- Load profile record
- Phasor diagram
- Single-line diagram
- Importing/Exporting parameters
- Report summary

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

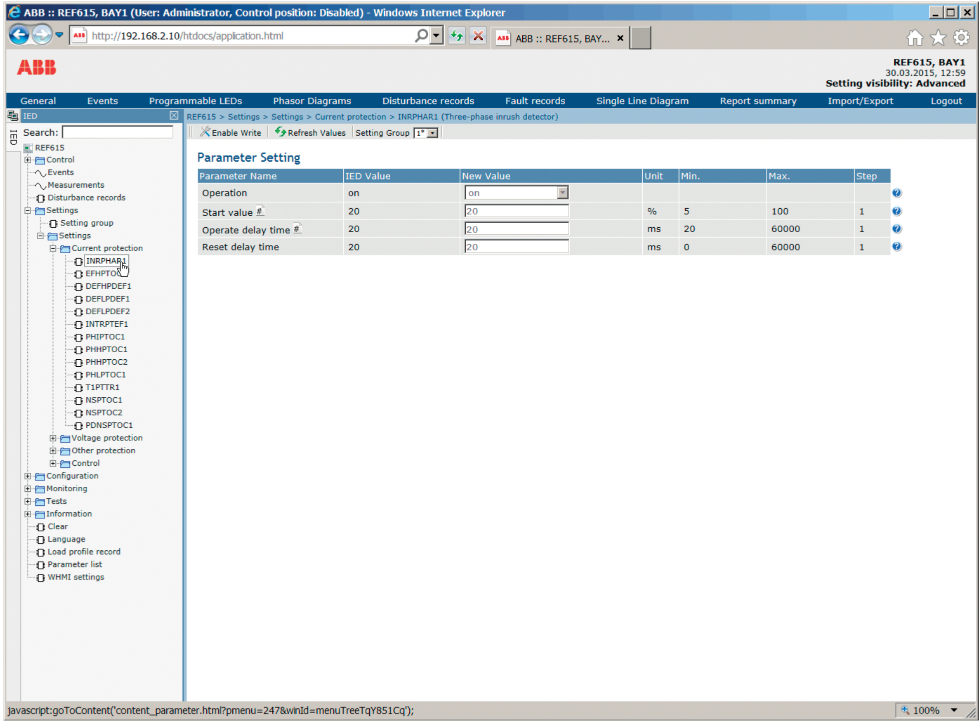


Figure 5: Example view of the WHMI

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.

2.6 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 5: 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 DFRs and load profile record • Changing system settings such as IP address, serial baud rate or DFR 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.

2.7 Communication

The protection relay supports a range of communication protocols including IEC 61850, IEC 61850-9-2 LE, Modbus® and DNP3. 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 protection relay utilizes Ethernet communication extensively for different purposes. The exact services depend on the ordered product variant and enabled functionality. HSR/PRP is available in 615 series Ver.5.0 FP1 ANSI.

HSR/PRP availability depends on the product ordering information. See the Rear communication modules chapter for information on HSR/PRP supported COM cards.

Table 6: TCP and UDP ports used for different services

Service	Port
File Transfer Protocol (FTP and FTPS)	20, 21
IEC 61850	102
Web Server HTTP	80
Web Server HTTPS	443
Simple Network Time Protocol (SNTP)	123
Modbus TCP	502
DNP TCP	20000

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and DFR records can be accessed using the IEC 61850 protocol. Oscillographic files are available to any Ethernet-based application in the standard COMTRADE 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. Furthermore, the protection relay supports sending and receiving of analog values using GOOSE messaging. 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 simultaneously report events to five different clients on the station bus.

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).

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.

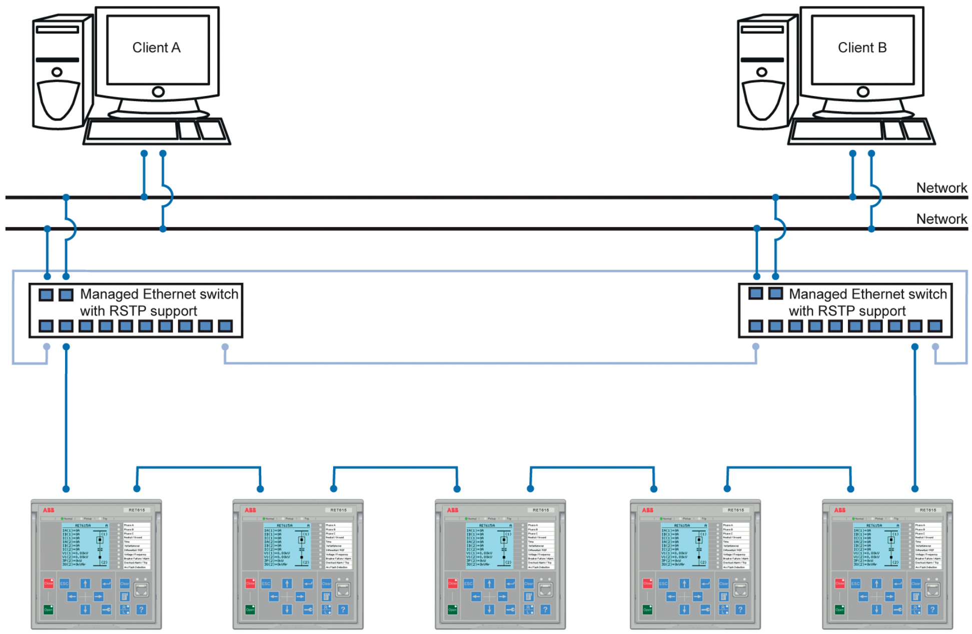


Figure 6: Self-healing Ethernet ring solution

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 615 series protection relays. However, RED615 supports this option only over fiber optics.

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.

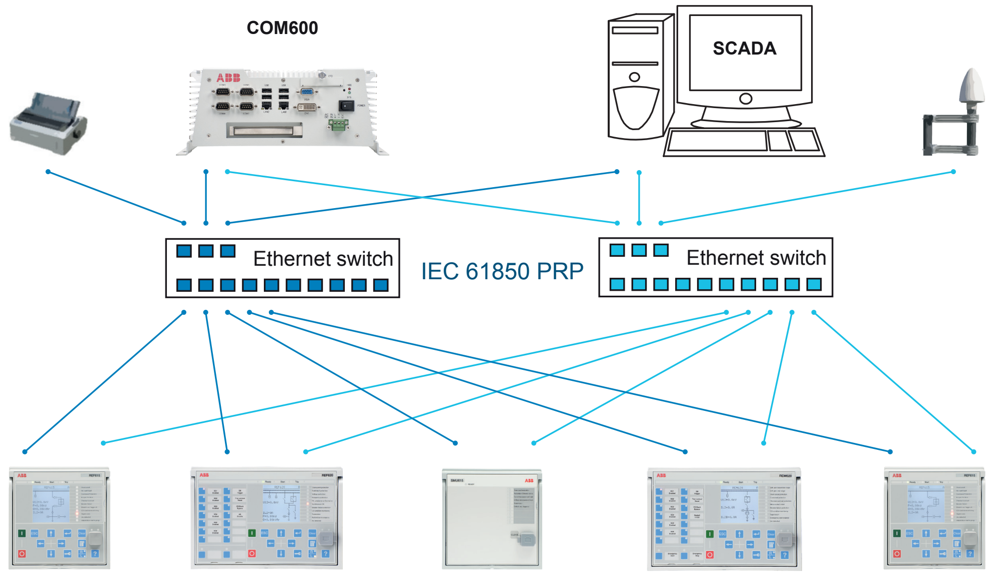


Figure 7: PRP solution

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.

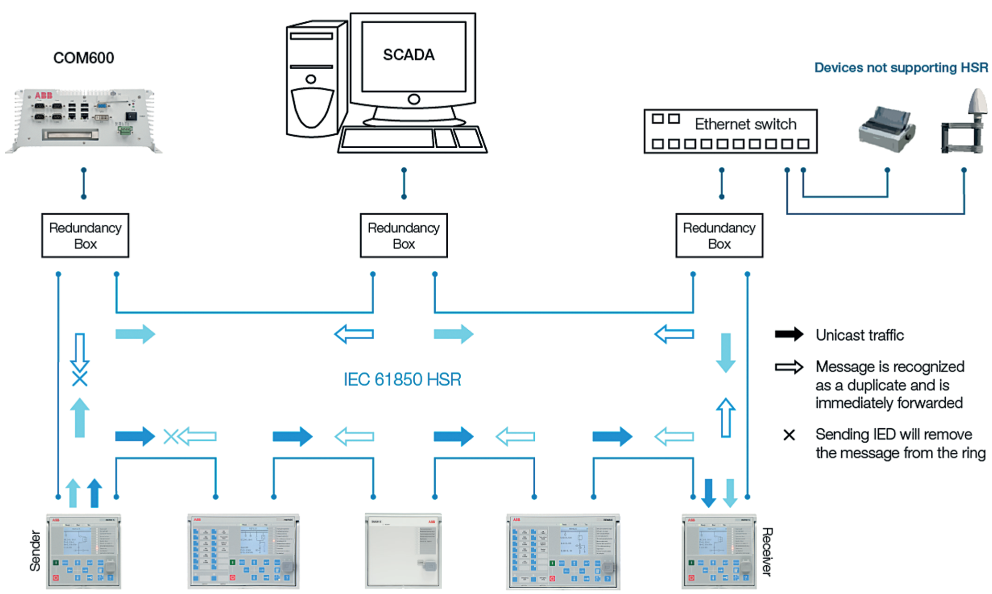


Figure 8: HSR solution

Section 3 REG615 standard configurations

3.1 Standard configurations

REG615 is available with two alternative standard configurations. The standard signal configuration can be altered by means of the signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions using various logical elements, including timers and flip-flops. By combining protection functions with logic function blocks, the relay configuration can be adapted to user-specific application requirements.

The protection relay is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. Some of the supported functions in REG615 must be added with the Application Configuration tool to be available in the Signal Matrix tool and in the relay. The positive measuring direction of directional protection functions is towards the busbar.

Table 7: Standard configurations

Description	Std. conf.
Generator protection with 100% stator ground-fault protection	C
Generator protection with generator differential and directional overcurrent protection and synchro-check	D

Table 8: Supported functions

Function	IEC 61850	ANSI	C	D
Protection				
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	51P	1	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	50P	1	1
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P		1^{TR}
Three-phase directional overcurrent protection, high stage	DPHHPDOC	67/50P		1^{TR}

Table continues on next page

Function	IEC 61850	ANSI	C	D
Three-phase voltage-dependent overcurrent protection	PHPVOC	51V	1	1
Non-directional ground-fault protection, high stage	EFHPTOC	50G	1	1
Directional ground-fault protection, low stage	DEFLPDEF	67/51N	2	2
Directional ground-fault protection, high stage	DEFHPDEF	67/50N	1	1
Residual overvoltage protection	ROVPTOV	59G	1	1
		59N	1	1
Three-phase undervoltage protection	PHPTUV	27	2	2
Three-phase overvoltage protection	PHPTOV	59	2	2
Positive-sequence undervoltage protection	PSPTUV	47U	2	2
Negative-sequence overvoltage protection	NSPTOV	47	2	2
Frequency protection	FRPFRQ	81	6	4
Overexcitation protection	OEPVPH	24	1	1
Three-phase thermal overload protection, two time constants	T2PTTR	49T	1	1
Negative-sequence overcurrent protection for machines	MNSPTOC	46M	2	2
Motor differential protection	MPDIF	87G		1
Numerically stabilized low-impedance restricted ground-fault protection	LREFPNDF	87LOZREF		1
Circuit breaker failure protection	CCBRBRF	50BF	1[1)]	1[1)]
Three-phase inrush detector	INRPHAR	INR	1	1
Master trip	TRPPTRC	86/94	2 (3)[2)] 1	2 (3)[2)] 1
Arc protection	ARCSARC	AFD	(3)[1)]	(3)[1)]
Multipurpose protection	MAPGAPC	MAP	18	18
Third harmonic-based stator ground-fault protection	H3EFPSEF	27/59THN	1	
Underpower protection	DUPPDPR	32U	2	2
Reverse power/directional overpower protection	DOPPDPR	32R-32	3	2
Three-phase underexcitation protection	UEXPDIS	40	1	1
Three-phase underimpedance protection	UZPDIS	21G	1	
Out-of-step protection	OOSRPSB	78	1	1
Power quality				
Table continues on next page				

Function	IEC 61850	ANSI	C	D
Current total demand distortion	CMHAI	PQI	(1)[3)]	(1)[3)]
Voltage total harmonic distortion	VMHAI	PQVPH	(1)[3)]	(1)[3)]
Voltage variation	PHQVVR	PQSS	(1)[3)]	(1)[3)]
Voltage unbalance	VSQVUB	PQVUB	(1)[3)]	(1)[3)]
Control				
Circuit-breaker control	CBXCBR	52	1	1
Disconnector control	DCXSWI	29DS	2	2
Grounding switch control	ESXSWI	29GS	1	1
Disconnector position indication	DCSXSWI	52-TOC	1	1
		29DS	2	2
Grounding switch indication	ESSXSWI	29GS	2	2
Synchronism and energizing check	SECRSYN	25		1
Condition monitoring				
Circuit-breaker condition monitoring	SSCBR	52CM	1	1
Trip circuit supervision	TCSSCBR	TCM	2	2
Fuse failure supervision	SEQSPVC	60	1	1
Runtime counter for machines and devices	MDSOPT	OPTM	1	1
Measurement				
Load profile record	LDPRLRC	LoadProf	1	1
Three-phase current measurement	CMMXU	IA, IB, IC	1	1 1^{TR}
Sequence current measurement	CSMSQI	I1, I2, I0	1	1
Residual current measurement	RESCMMXU	IG	1	1
Three-phase voltage measurement	VMMXU	VA, VB, VC	1	1 1^{TR}
Residual voltage measurement	RESVMMXU	VG	2	1
Sequence voltage measurement	VSMSQI	V1, V2, V0	1	1^{TR}
Single-phase power and energy measurement	SPEMMXU	SP, SE	1	1^{TR}
Three-phase power and energy measurement	PEMMXU	P, E	1	1^{TR}
RTD/mA measurement	XRGGIO130	X130 (RTD)	(1)	(1)
Frequency measurement	FMMXU	f	1	1^{TR}
IEC 61850-9-2 LE sampled value sending[4)]	SMVSENDER	SMVSENDER	(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing)[4)]	SMVRECEIVER	SMVRECEIVER	(1)	(1)
Table continues on next page				

Function	IEC 61850	ANSI	C	D
Frequency adaptivenes (10...70 Hz)			1	1
Other				
Minimum pulse timer (2 pcs)	TPGAPC	62TP	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1	1
Pulse timer (8 pcs)	PTGAPC	62PT-1	2	2
Time delay off (8 pcs)	TOFGAPC	62TOF	4	4
Time delay on (8 pcs)	TONGAPC	62TON	4	4
Set-reset (8 pcs)	SRGAPC	SR	4	4
Move (8 pcs)	MVGAPC	MV	2	2
Generic control point (16 pcs)	SPCGAPC	SPC	2	2
Analog value scaling	SCA4GAPC	SCA4	4	4
Integer value move	MVI4GAPC	MVI4	1	1
Generic up-down counters	UDFCNT	CTR	4	4
1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration. () = Optional TR = The function block is to be used on the terminal side in the application.				

1) Calculated I0 is always used
2) Master Trip included and connected to corresponding HSO in the configuration only when BIO0007 module is used. If additionally the ARC option is selected, then AFD is connected in the configuration to the corresponding Master Trip input.
3) Power quality option includes Current total demand distortion, Voltage total harmonic distortion and Voltage variation.
4) Only available with COM0031...0037

3.1.1 Addition of control functions for primary devices and the use of binary inputs and outputs

If extra control functions intended for controllable primary devices are added to the configuration, additional binary inputs and/or outputs are needed to complement the standard configuration.

If the number of inputs and/or outputs in a standard configuration is not sufficient, it is possible either to modify the chosen standard configuration in order to release some binary inputs or binary outputs which have originally been configured for other purposes, or to integrate an external input/output module, for example RIO600, to the protection relay.

The external I/O module’s binary inputs and outputs can be used for the less time-critical binary signals of the application. The integration enables releasing some initially reserved binary inputs and outputs of the protection relay’s standard configuration.

The suitability of the protection relay’s binary outputs which have been selected for primary device control should be carefully verified, for example make and carry and breaking capacity. If the requirements for the primary device control circuit are not met, using external auxiliary relays should be considered.

3.2 Connection diagrams

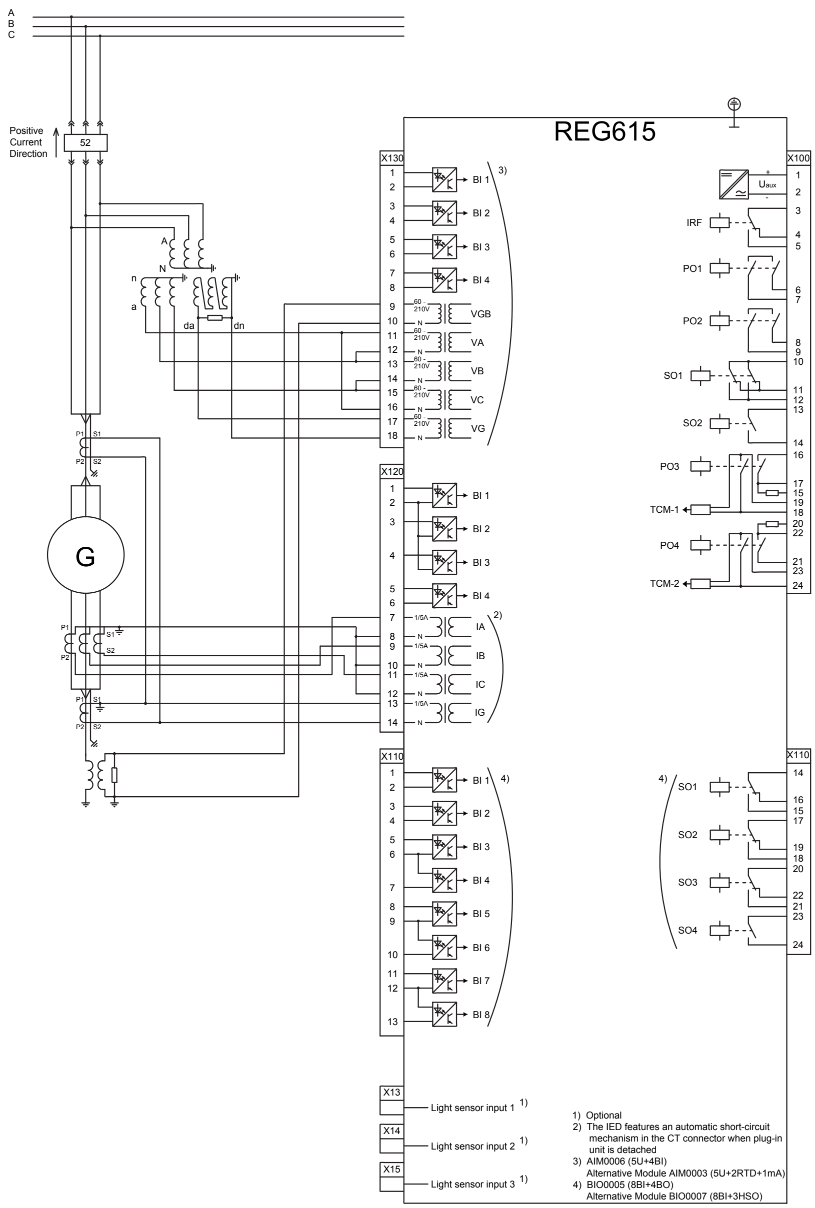


Figure 9: Connection diagram for the C configuration

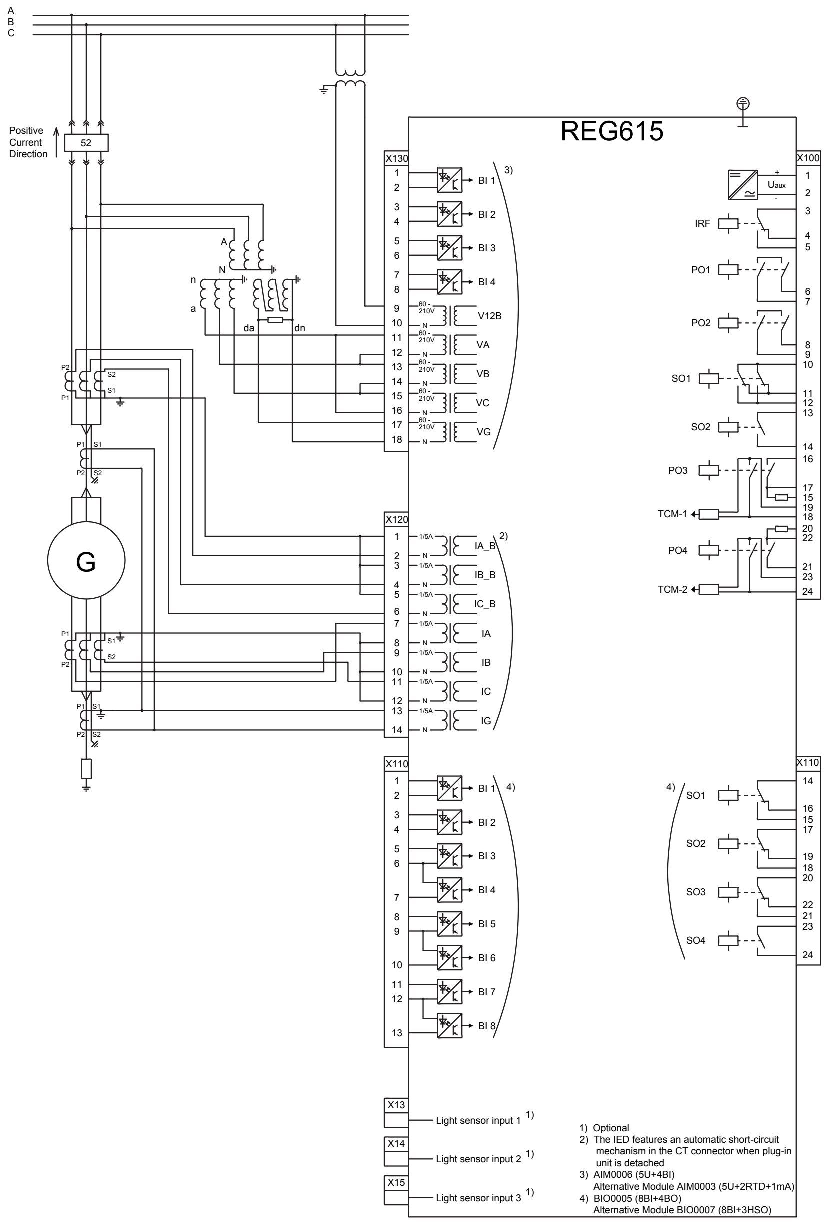


Figure 10: Connection diagram for the D configuration

3.3 Standard configuration C

3.3.1 Applications

The standard configuration with power protection, 100% stator ground-fault protection with third harmonic-based stator ground-fault protection, overcurrent and directional ground-fault protection, voltage and frequency based protection, underexcitation, underimpedance and out-of-step protection is mainly intended for the main protection of a small size synchronous power generator or as backup protection for a medium size synchronous power generator.

The protection relay with a standard 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.

3.3.2 Functions

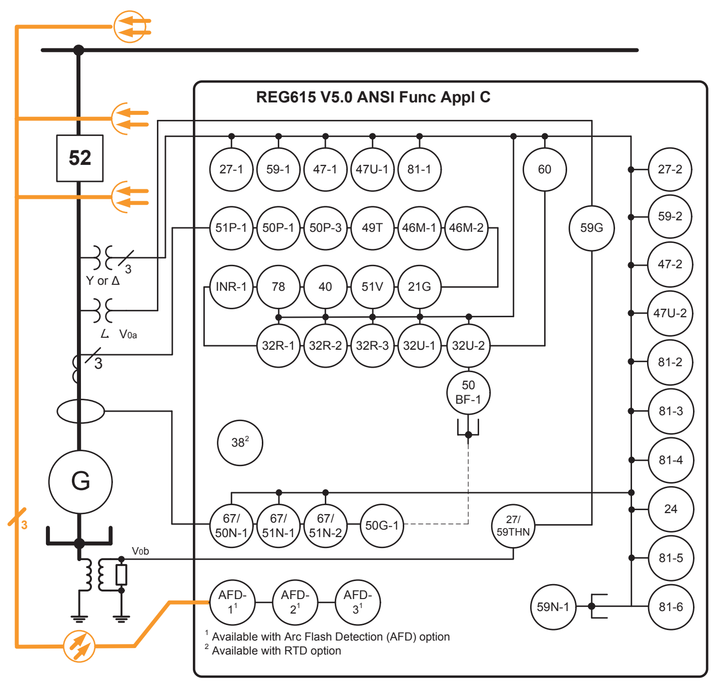


Figure 11: Functionality overview for standard configuration C

3.3.2.1 Default I/O connections

Table 9: Default connections for analog inputs

Analog input	Description	Connector pins
IA	Phase A current	X120:7-8
IB	Phase B current	X120:9-10
IC	Phase C current	X120:11-12
IG	Residual current IG	X120:13-14
VGB	Residual voltage VG2	X130:9-10
VA	Phase voltage VA	X130:11-12
VB	Phase voltage VB	X130:13-14
VC	Phase voltage VC	X130:15-16
VG	Residual voltage VG	X130:17-18

Table 10: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	Terminal VT secondary MCB open	X110:1-2	X110:1,5
X110-BI2	Neutral VT secondary MCB open	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	Circuit breaker closed position indication	X110:11-12	X110:8,10
X110-BI8	Circuit breaker open position indication	X110:13-12	X110:9-10
X120-BI1	-	X120:1-2	
X120-BI2	-	X120:3-2	
X120-BI3	-	X120:4-2	
X120-BI4	-	X120:5-6	
X130-BI1	External trip 1	X130:1-2	
X130-BI2	External trip 2	X130:3-4	
X130-BI3	Lockout reset	X130:5-6	
X130-BI4	Field excitation open indication	X130:7-8	

Table 11: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Generator circuit breaker trip 2	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	Prime mover shutdown	X100:10-11,(12)
X100-SO2	General protection operate indication	X100:13-14
X100-PO3	Generator circuit breaker open command/trip 1	X100:15-19
X100-PO4	Field excitation circuit breaker open command	X100:20-24
X110-SO1	Overcurrent protection trip alarm	X110:14-16
X110-SO2	Ground-fault protection trip alarm	X110:17-19
X110-SO3	Voltage or frequency protection trip alarm	X110:20-22
X110-SO4	Thermal overload and negative phase-sequence trip alarm	X110:23-24
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 12: Default connections for LEDs

LED	Default usage	ID	Label description
1	Under impedance protection trip	LED_UnderImpedance	Underimpedance
2	Power protection trip	LED_DirOverpowerProt	Power
3	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
4	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
5	Under excitation protection trip	LED_UnderExcitation	Under excitation
6	Voltage or frequency protection trip	LED_VoltageOrFrequencyProt	Voltage / Frequency Prot.
7	Negative sequence overcurrent or thermal overload protection trip	LED_NPSOrThermalOverload_1	Neg. Seq./Thermal Ovld.
8	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
9	Supervision alarms	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Circuit breaker failure protection trip	LED_BreakerFailure_1	Breaker failure

3.3.2.2 Default disturbance recorder settings

Table 13: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	Io
5	Uo
6	U1
7	U2
8	U3
9	UoB
10	-
11	-
12	-

Table 14: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHIPTOC1 - pickup	Positive or Rising
4	PHPVOC1 - pickup	Positive or Rising
5	DEFLPDEF1 - pickup	Positive or Rising
6	DEFLPDEF2 - pickup	Positive or Rising
7	DEFHPDEF1 - pickup	Positive or Rising
8	EFHPTOC1 - pickup	Positive or Rising
9	MNSPTOC1 - pickup	Positive or Rising
10	MNSPTOC2 - pickup	Positive or Rising
11	PHPTUV1 - pickup	Positive or Rising
12	PHPTUV2 - pickup	Positive or Rising
13	H3EFPSEF1 - pickup	Positive or Rising
14	PHPTOV1 - pickup	Positive or Rising
15	PHPTOV2 - pickup	Positive or Rising
16	FRPFRQ1 - pickup	Positive or Rising
17	FRPFRQ2 - pickup	Positive or Rising
18	FRPFRQ3 - pickup	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
19	FRPFRQ4 - pickup	Positive or Rising
20	OEPVPH1 - pickup	Positive or Rising
21	UZPDIS1 - pickup	Positive or Rising
22	UEXPDIS1 - pickup	Positive or Rising
23	ROVPTOV1 - pickup	Positive or Rising
24	ROVPTOV2 - pickup	Positive or Rising
25	NSPTOV1 - pickup	Positive or Rising
26	NSPTOV2 - pickup	Positive or Rising
27	PSPTUV1 - pickup	Positive or Rising
28	PSPTUV2 - pickup	Positive or Rising
29	DUPPDPR1 - pickup	Positive or Rising
30	DUPPDPR2 - pickup	Positive or Rising
31	DOPPDPR1 - pickup	Positive or Rising
32	DOPPDPR2 - pickup	Positive or Rising
33	DOPPDPR3 - pickup	Positive or Rising
34	T2PTTR1 - pickup	Positive or Rising
35	CCBRBRF1 - trret	Level trigger off
36	CCBRBRF1 - trbu	Level trigger off
37	PHxPTOC/PHPVOC1 - trip	Level trigger off
38	EFHPTOC1/DEFxPDEF - trip	Level trigger off
39	MNSPTOC - trip	Level trigger off
40	PHPTUV - trip	Level trigger off
41	H3EFPSEF1 - trip	Level trigger off
42	PHPTOV - trip	Level trigger off
43	FRPFRQ - trip	Level trigger off
44	OEPVPH1 - trip	Level trigger off
45	UZPDIS1 - trip	Level trigger off
46	UEXPDIS1 - trip	Level trigger off
47	ROVPTOV/NSPTOV/PSPTUV - trip	Level trigger off
48	INRPHAR1 - blk2h	Level trigger off
49	DUPPDPR/DOPPDPR - trip	Level trigger off
50	T2PTTR1 - trip	Level trigger off
51	SEQSPVC1- fusef 3ph	Level trigger off
52	SEQSPVC1- fusef u	Level trigger off
53	X130BI1 - Ext trip1	Positive or Rising
54	X130BI2 - Ext trip2	Positive or Rising

Table continues on next page

Channel	ID text	Level trigger mode
55	X130BI4 - Field Excitation open	Positive or Rising
56	X110BI7 - CB closed	Level trigger off
57	X110BI8 - CB open	Level trigger off
58	ARCSARC - ARC flt det	Level trigger off
59	ARCSARC1 - trip	Positive or Rising
60	ARCSARC2- trip	Positive or Rising
61	ARCSARC3- trip	Positive or Rising
62	-	-
63	-	-
64	-	-

3.3.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements.

The analog channels have fixed connections to the different function blocks inside the protection relay's standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder's parameter settings.

The phase currents to the protection relay are fed from a current transformer. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages. The signal VG represents the measured ground voltage.

The protection relay offers six different setting groups which can be set based on individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.3.3.1 Functional diagrams for protection

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

Three non-directional overcurrent stages are offered for detecting phase faults in generators. In addition to the overcurrent stages, one instance of voltage dependent overcurrent protection is also provided and it can be used as a backup protection against phase faults. During certain conditions, the fault current for three phase faults may be less than the full load current of the generator. This may not be noticed by the phase overcurrent protection, but the fault causes the generator terminal voltage to drop. Voltage dependent overcurrent protection can be used to detect and trip such faults.

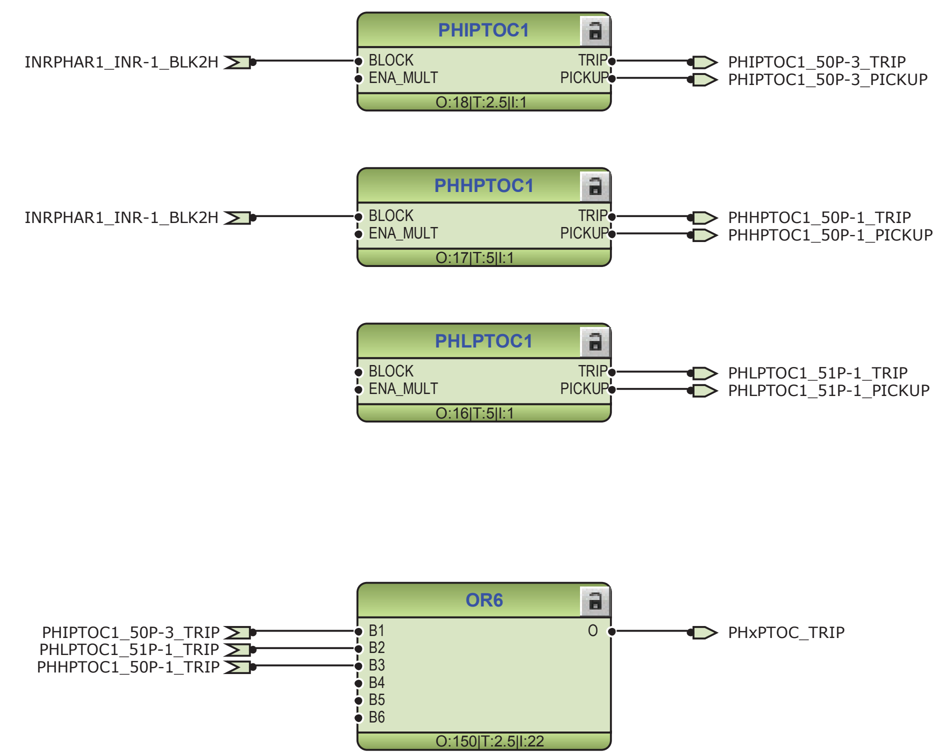


Figure 12: Overcurrent protection function

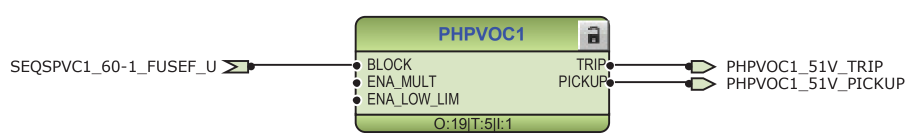


Figure 13: Voltage dependent overcurrent protection function

The output `BLK2H` of three-phase inrush detector INRPHAR1_INR-1 either blocks the function or multiplies the active settings for any of the available overcurrent or ground-fault function blocks. In the configuration, INRPHAR1_INR-1 blocks the high and instantaneous stages of non-directional overcurrent protection.

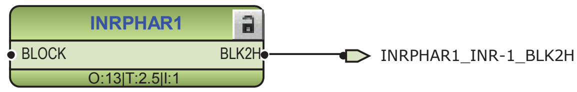


Figure 14: Inrush detector function

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect against unbalance conditions due to unbalance load or unsymmetrical faults.

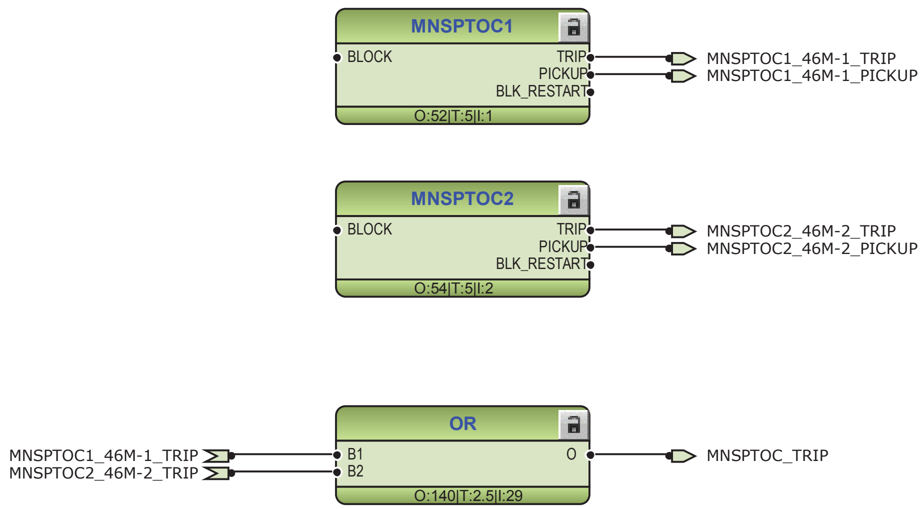


Figure 15: Negative sequence overcurrent protection function

One non-directional ground-fault stage EFHPTOC1_50G-1 and three directional ground-fault stages DEFxPDEF_67/5xN are offered for providing primary and backup protection for generator ground-fault protection.

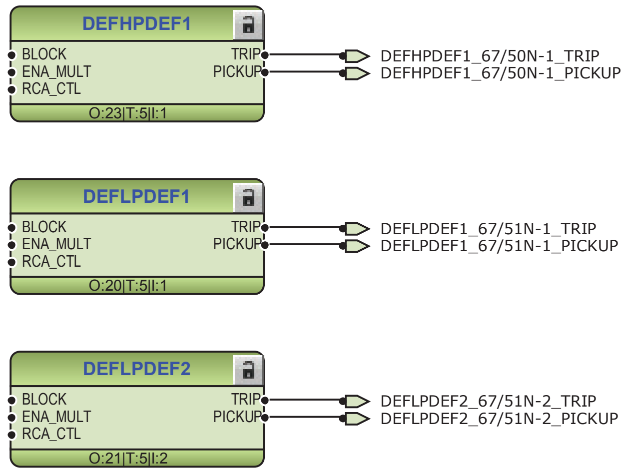


Figure 16: Directional ground-fault protection function

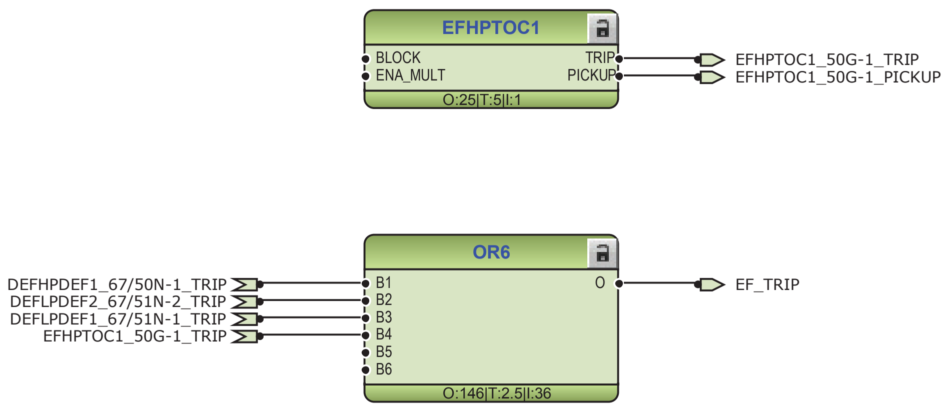


Figure 17: Ground-fault protection function

Third harmonic-based stator ground-fault protection is provided to give 100% stator winding protection. The protection is blocked by the MCB open signal from the neutral side VT.

Figure 18: Third harmonic-based stator ground-fault protection function

Three-phase thermal overload protection, two time constants, T2PTTR1_49T-1 detects continuous overloading conditions preventing excessive insulation damage in the long run.

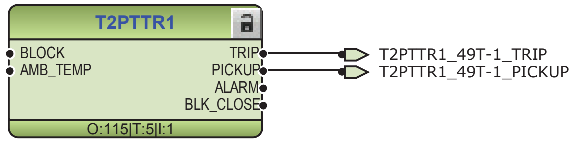


Figure 19: Thermal overload protection function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the PICKUP input by a number of different protection functions available in the relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: TRRET and TRBU. The TRRET operating output is used for retripping its own breaker through TRPPTRC2_68/94-1_TRIP. The TRBU output gives a backup trip to the breaker feeding upstream. For this purpose, the TRBU operating output signal is connected to the binary output X100:PO2. In addition, TRBU operating output is also used to trip field excitation circuit breaker through TRPPTRC6_68/94-6_TRIP_FIELD EXCITATION.

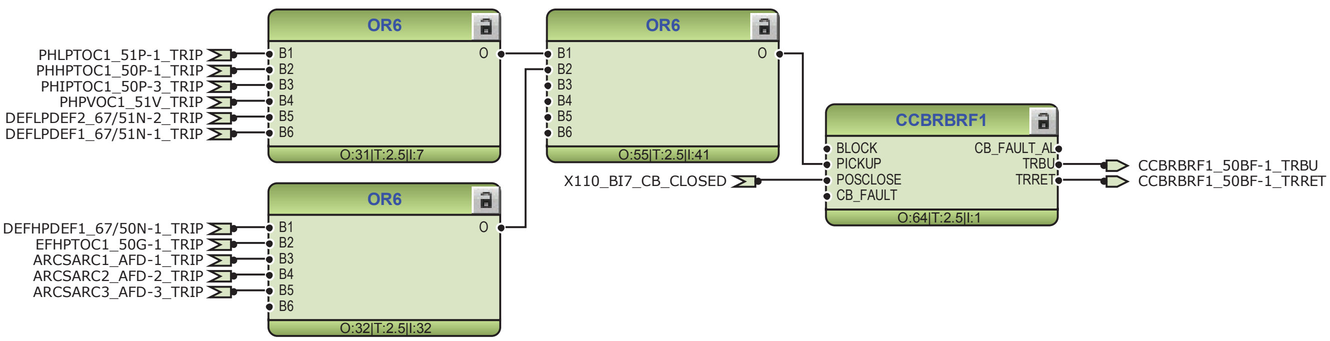


Figure 20: Circuit breaker failure protection function

Three arc protection ARCSARC1...3_AFD-1…3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operating signals from ARCSARC1...3_AFD-1…3 are connected to both generator circuit breaker trip logic TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2 and also to field excitation circuit breaker trip logic TRPPTRC6_68/94-6. If the relay has been ordered with high-speed binary outputs, the individual operating signals from ARCSARC1...3_AFD-1…3 are connected to dedicated trip logic TRPPTRC3...5_68/94-3….5. The output of TRPPTRC3...5_68/94-3….5 is available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

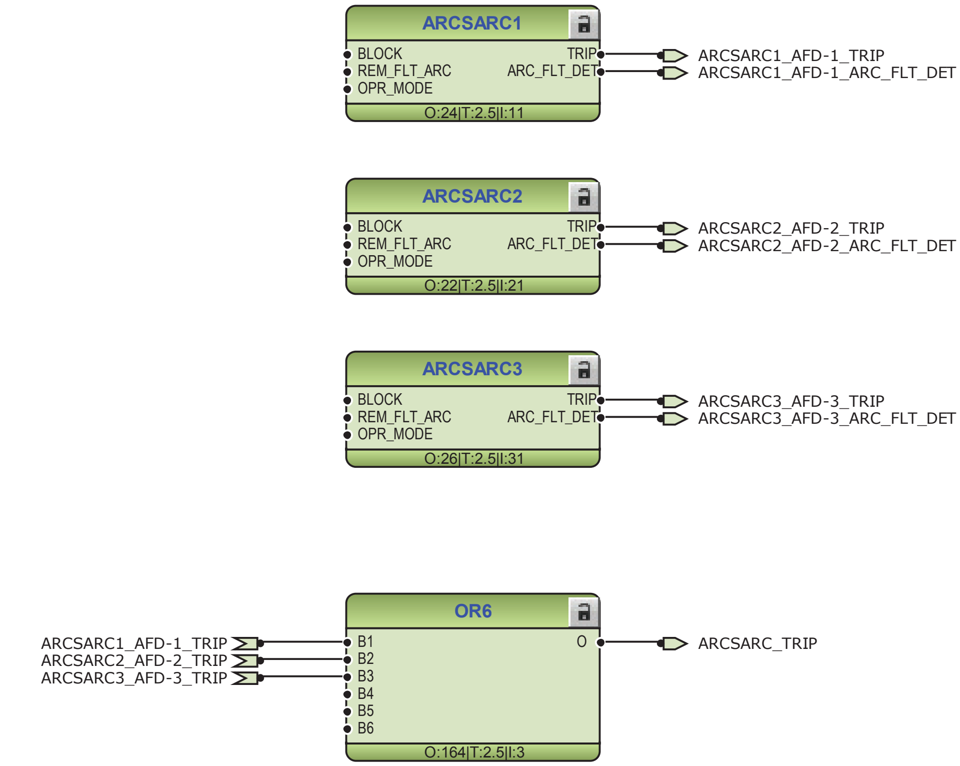


Figure 21: Arc protection function

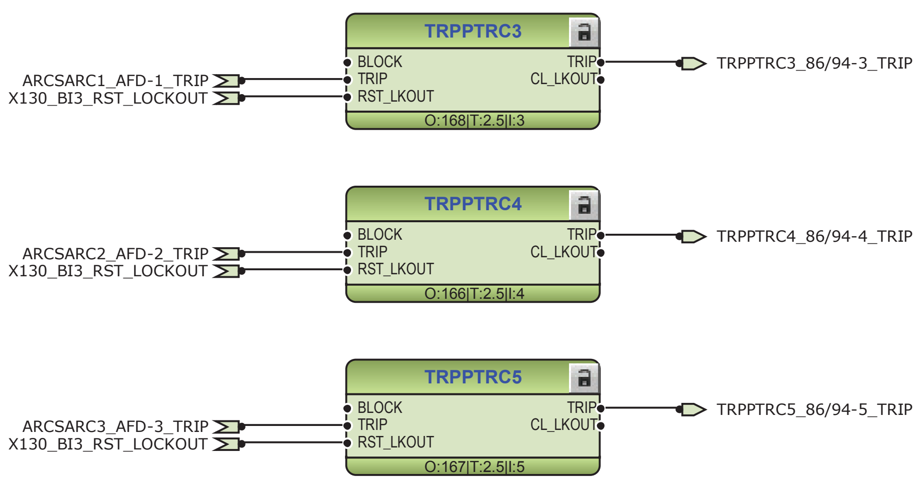


Figure 22: Arc protection with dedicated high-speed output

Two three-phase overvoltage protection stages PHPTOV_59 offer protection against abnormal overvoltage conditions that arise due to load rejection or transient surges in the network or when a generator is running but not connected to a system due to a fault with

AVR. Similarly, two three-phase undervoltage protection stages PHPTUV_27 offer protection against undervoltage conditions or can be used as a backup against underimpedance protection.

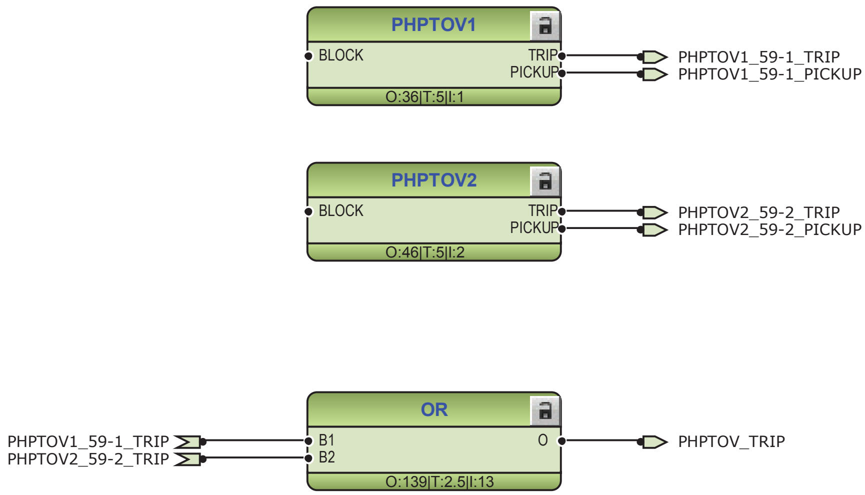


Figure 23: Overvoltage protection function

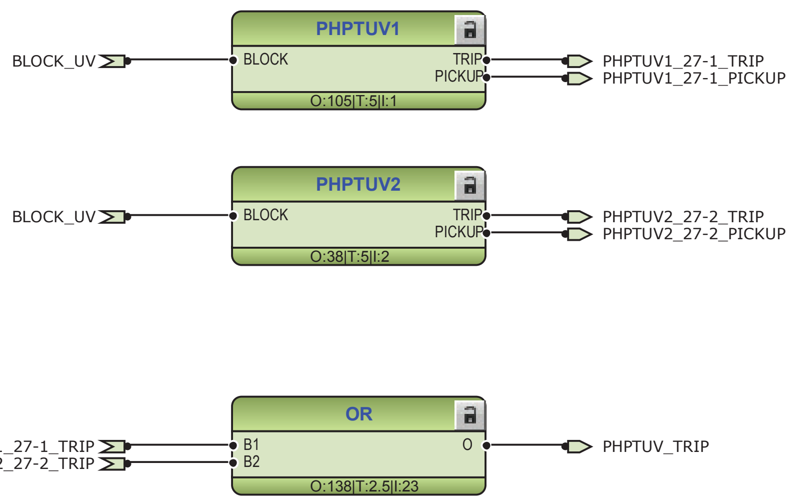


Figure 24: Undervoltage protection function

Two stages of each positive-sequence undervoltage PSPTUV_47U and negative-sequence overvoltage NSPTOV_47 protection functions are also provided. A failure in the voltage measuring circuit is detected by the fuse failure function. The fuse failure activation is connected to block undervoltage protection functions and voltage based unbalance protection functions to avoid faulty tripping. In addition, undervoltage protection is also blocked when a generator circuit breaker is in open position.

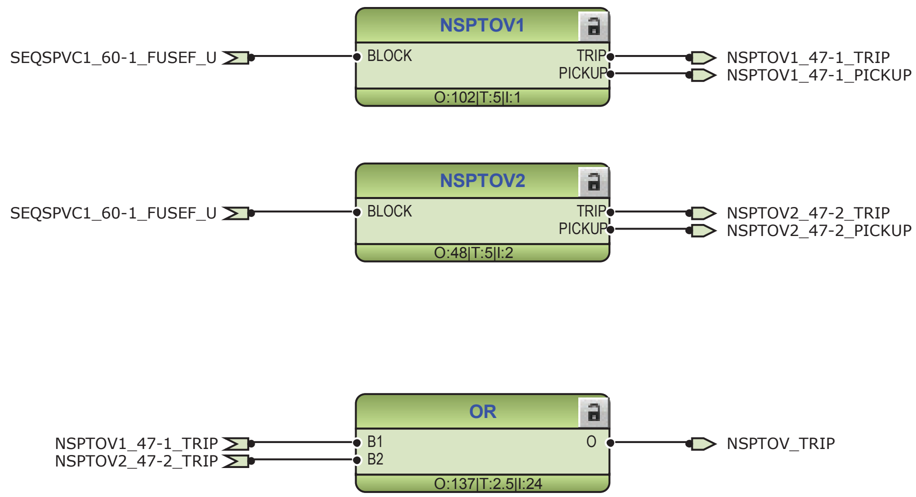


Figure 25: Negative-sequence overvoltage protection function

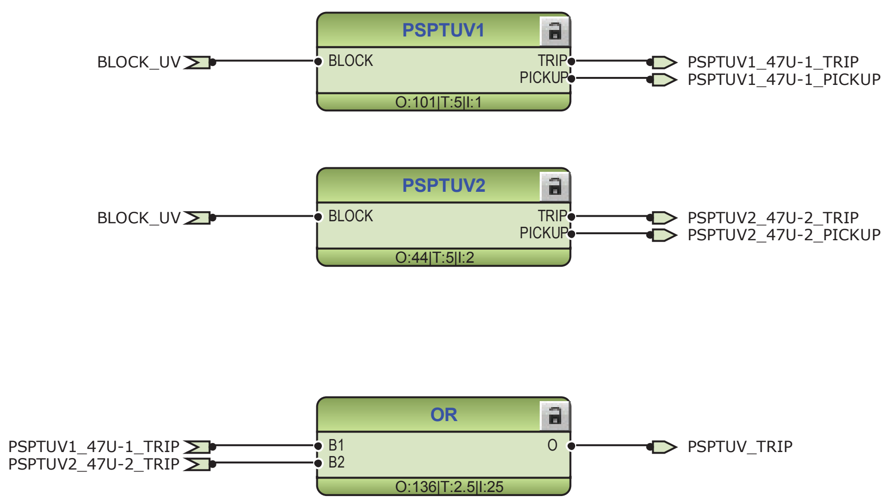


Figure 26: Positive-sequence undervoltage protection function

Residual overvoltage protection ROVPTOV_59G/N provides protection against stator ground faults from 5% to 100% of winding from neutral. Two instances of ROVPTOV_59G/N are provided.

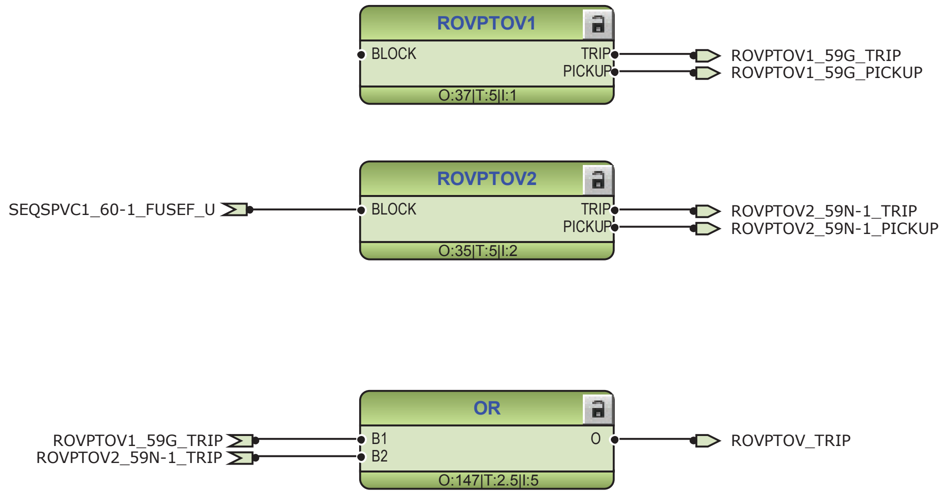


Figure 27: Residual overvoltage protection function

The selectable underfrequency or overfrequency or rate of change of frequency protection FRPFRQ_81 prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. Configuration offers six instances of frequency protection, these instances can be configured to trip as underfrequency or overfrequency or rate of change of frequency according to the system requirement. The frequency protection is blocked when the generator CB is in open position.

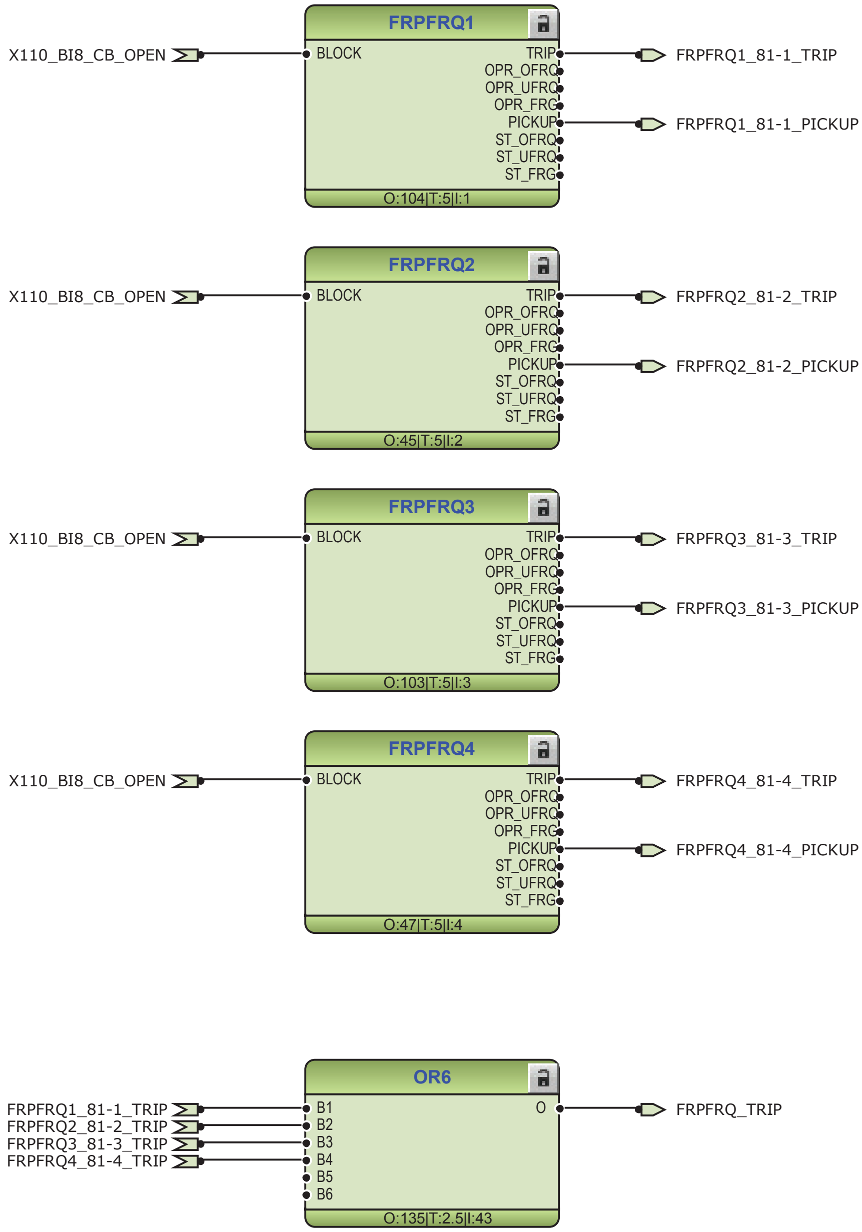


Figure 28: Frequency protection function

Three instances of reverse power/directional overpower protection DOPPDPR_32R-32 are provided to detect either loss of prime mover or detecting motoring action or any abnormal high reactive power being absorbed by the generator.

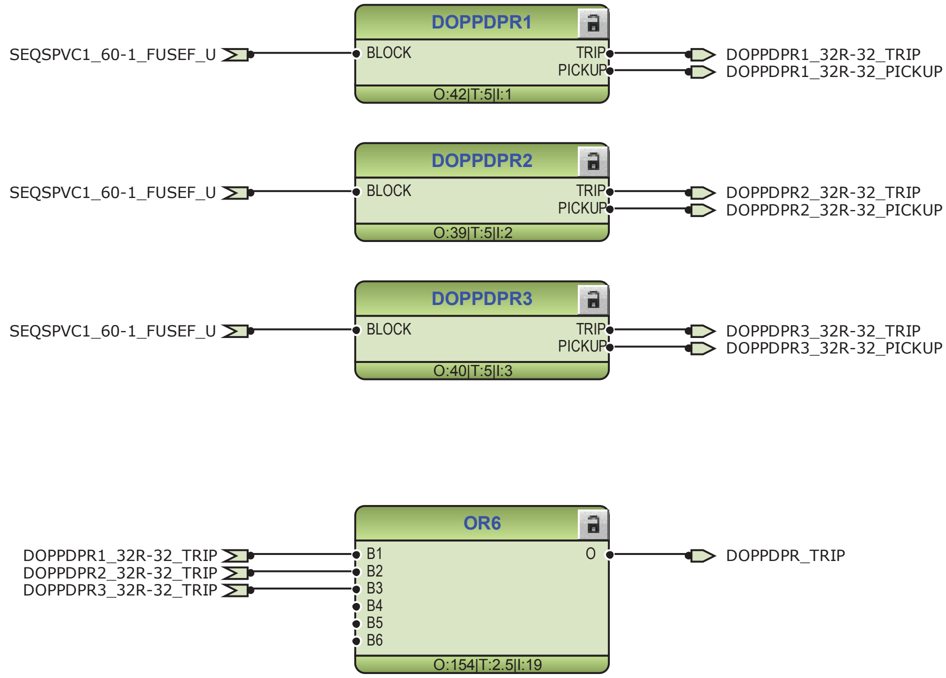


Figure 29: Directional overpower protection function

Two instances of underpower protection DUPPDPR_32U are provided. Normally these are used in coordination with reverse active power protection.

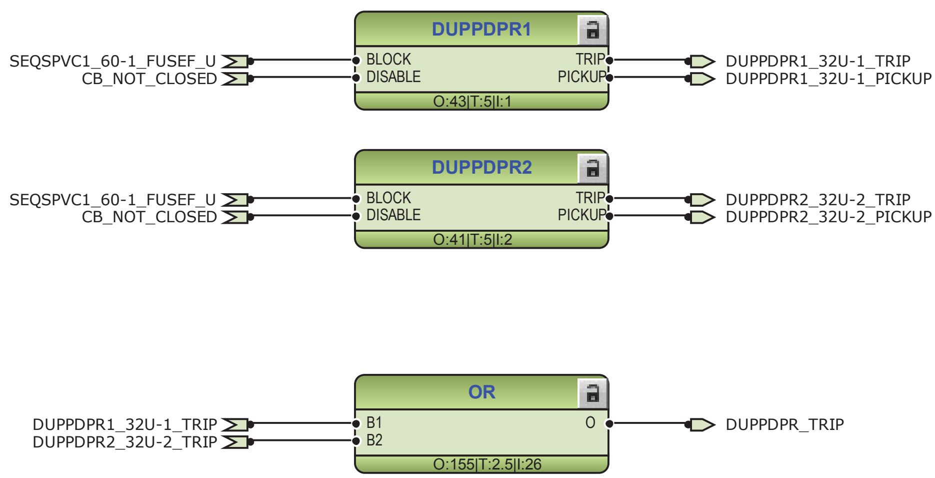


Figure 30: Directional underpower protection function

On losing excitation, the generator may over speed and trip as an induction generator taking reactive power from the system which may reduce system voltages. The three-phase underexcitation protection UEXPDIS1_40-1 is provided to detect such conditions.

Directional underpower protection is disabled when the generator circuit breaker is in open position.

Figure 31: Underexcitation protection function

Three-phase underimpedance protection UZPDIS1_21G-1 can be used as a backup protection against phase faults by calculating impedance at the generator terminals.

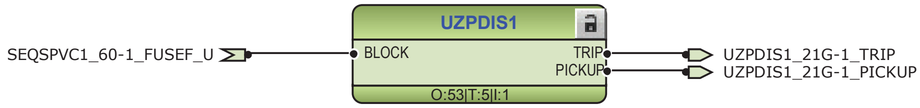


Figure 32: Underimpedance protection function

Overexcitation protection OEPVPH1_24 is provided to protect the generator against overexcitation. Due to overexciation, saturation of the magnetic core of generator and connected transformer may occur, and stray flux may be induced in nonlaminated components that are not designed to carry flux. Excessive flux also causes excessive eddy currents resulting into excessive voltage between laminations causing overheating and damage to insulation.

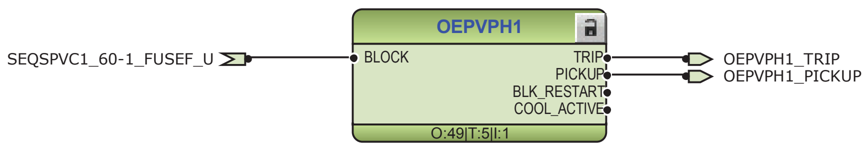


Figure 33: Overexcitation protection function

General pickup and trip signals from all functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary output.

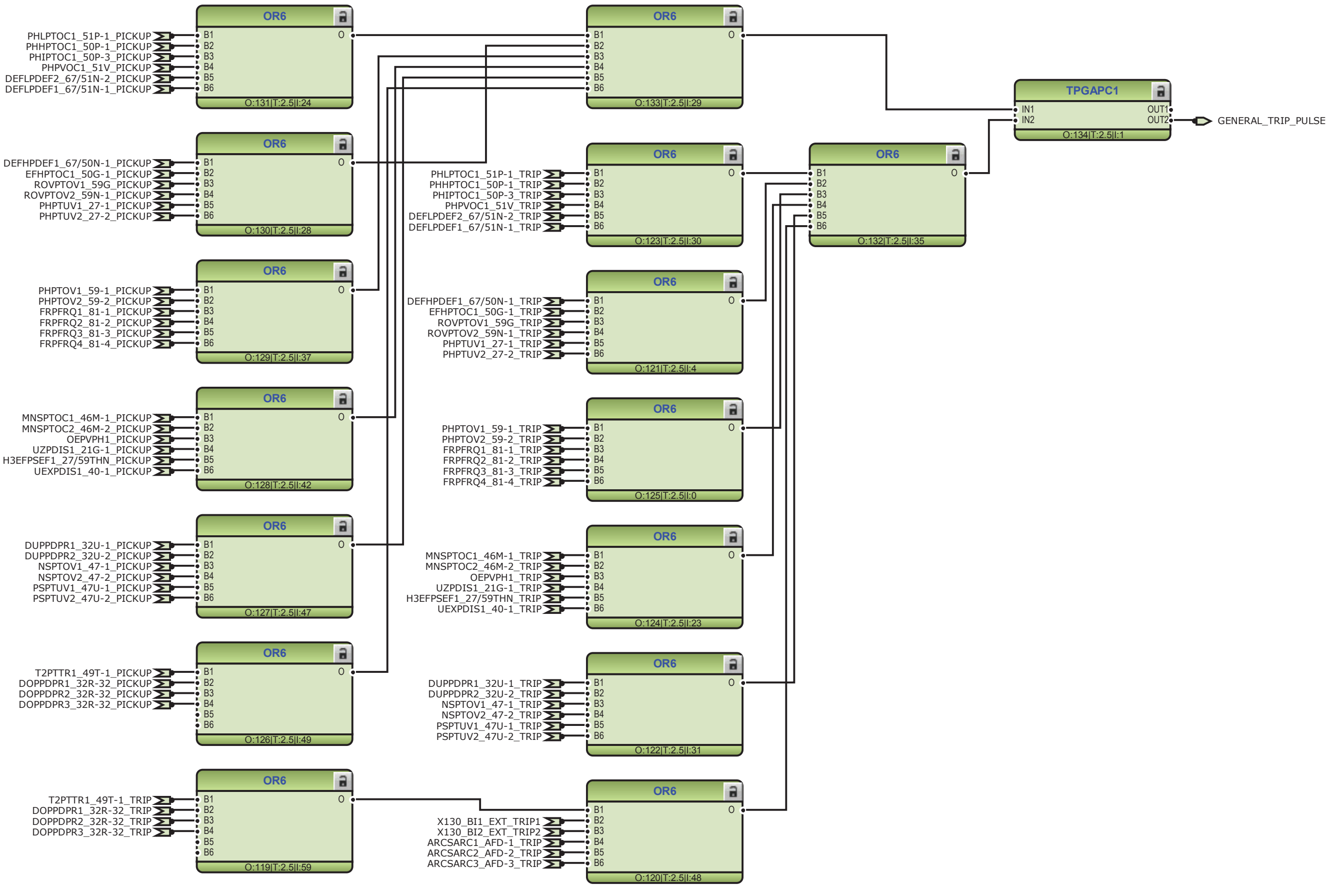


Figure 34: General pickup and trip signal

The operating signals from the protection functions are connected to the two trip logics TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X130:BI3 has been assigned to the `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4_68/94-3….4 are also available if the relay is ordered with high-speed binary output options.

In addition, trip logic TRPPTRC6_68/94-6 is available to trip the circuit breaker of field excitation. The protection function which should trip the field excitations are connected to TRPPTRC6_68/94-6.

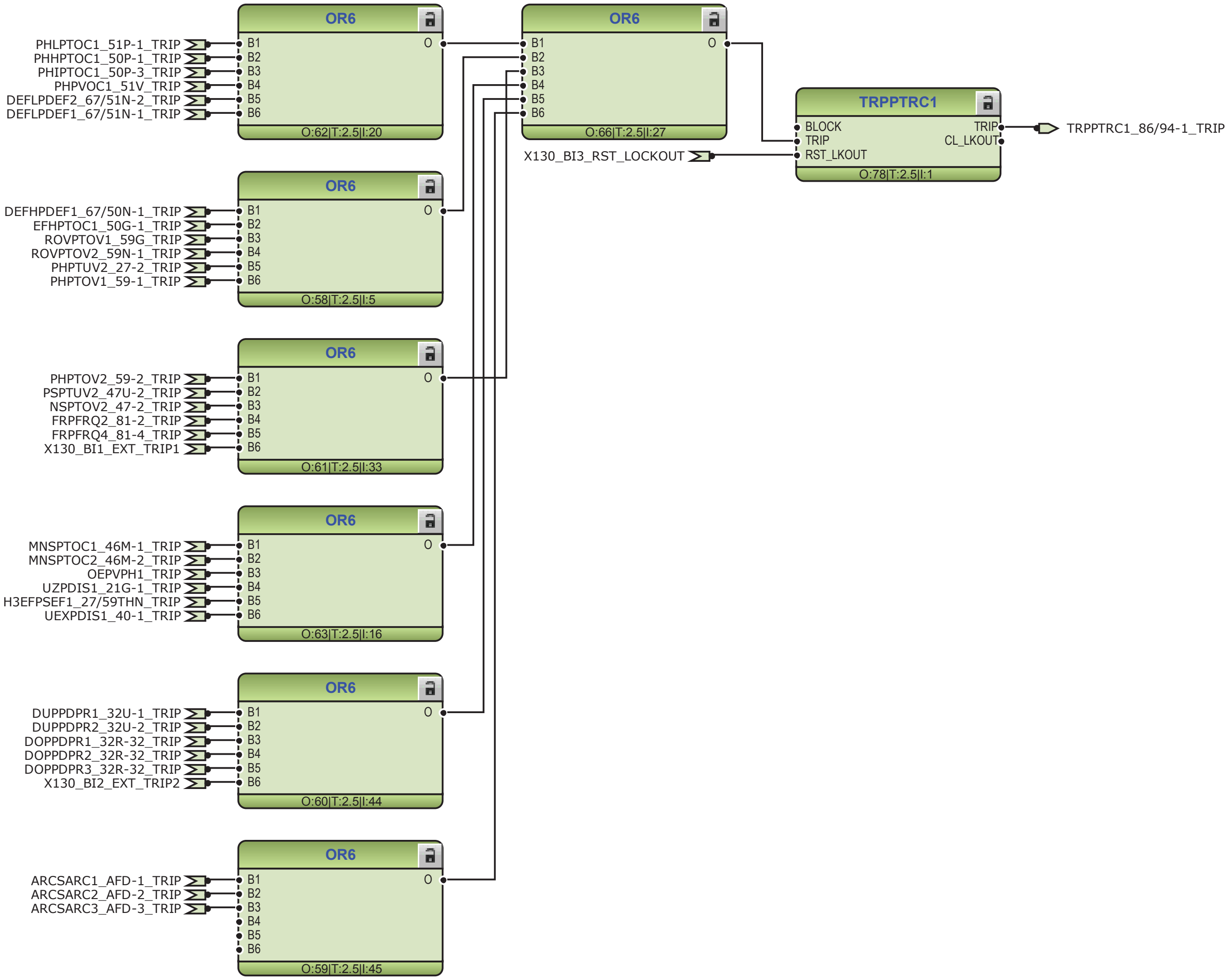


Figure 35: Trip logic TRPPTRC1

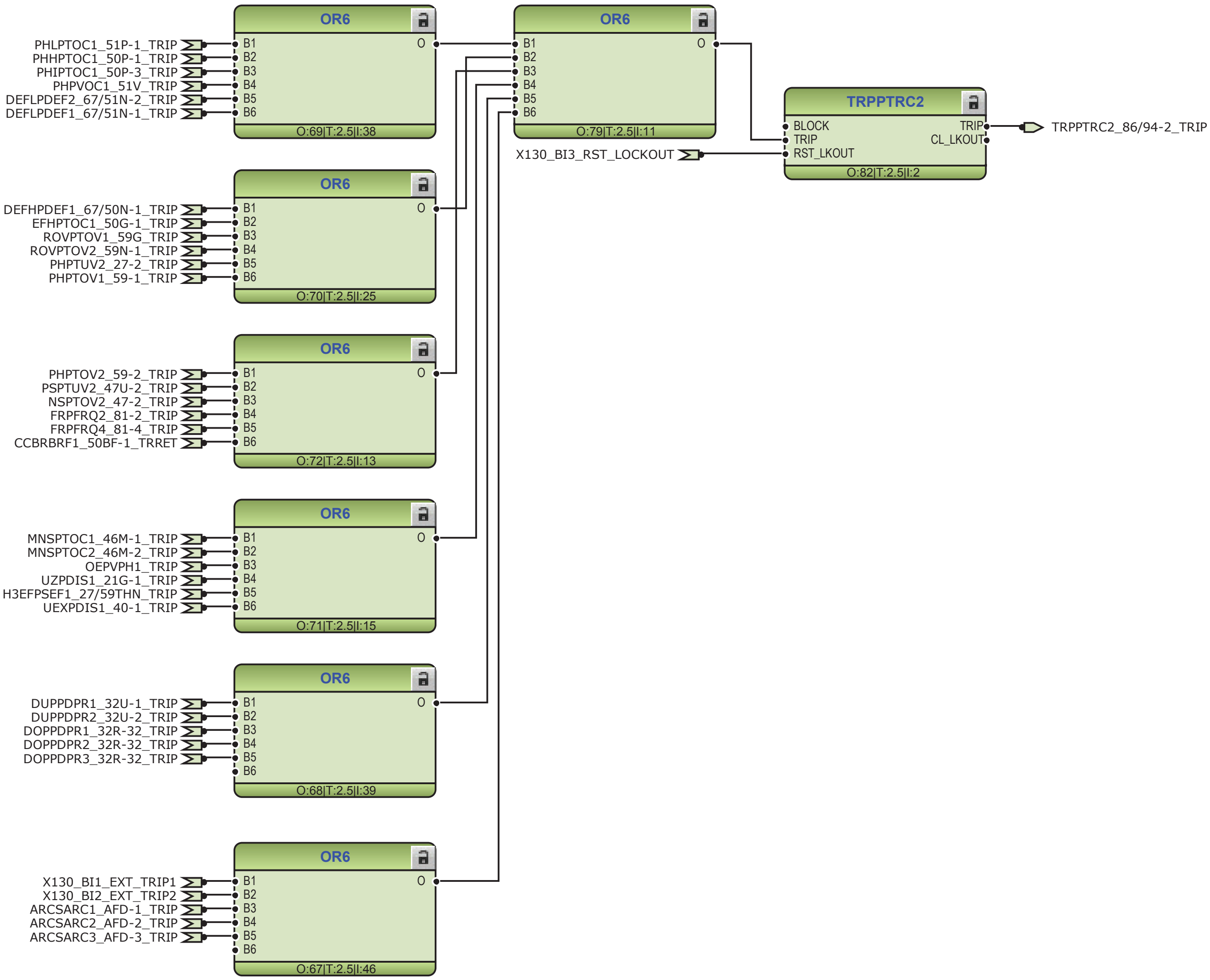


Figure 36: Trip logic TRPPTRC2

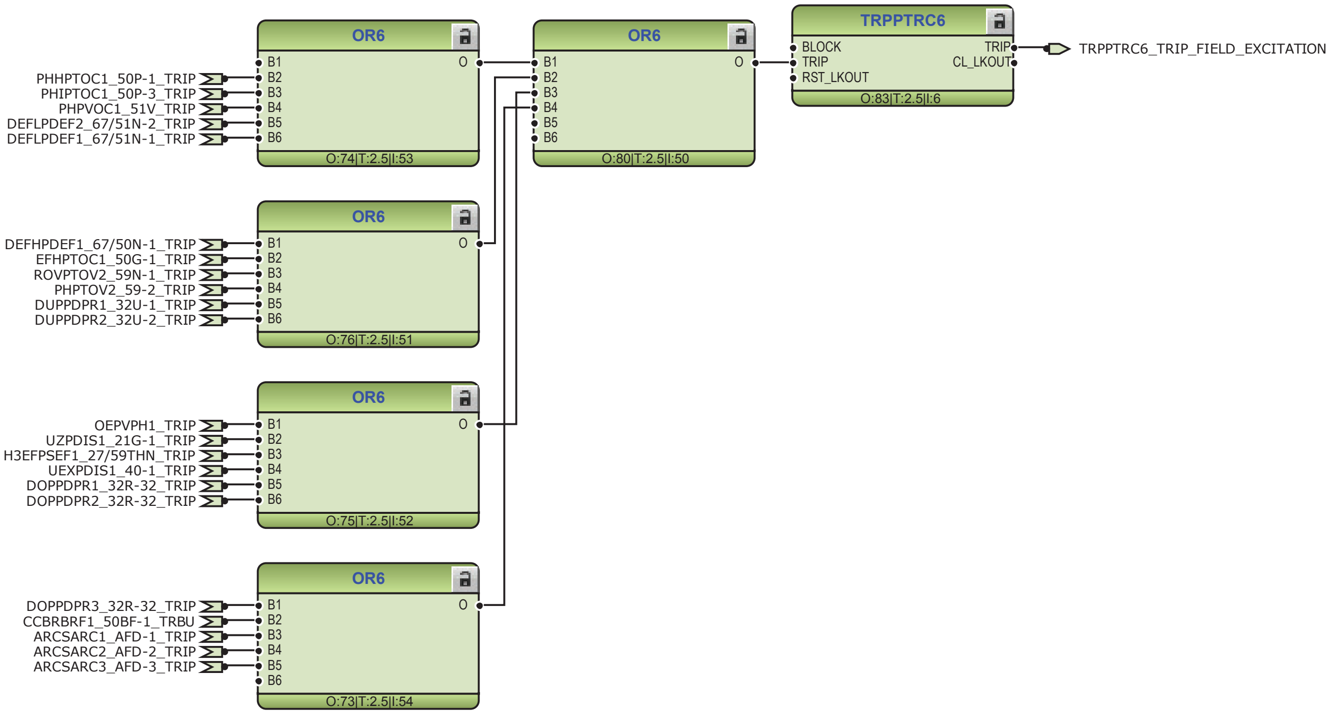


Figure 37: Trip logic TRPPTRC6 (field excitation)

3.3.3.2 Functional diagrams for disturbance recorder

The `PICKUP` and `TRIP` outputs 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 signals from different functions and the few binary inputs are also connected to the disturbance recorder.

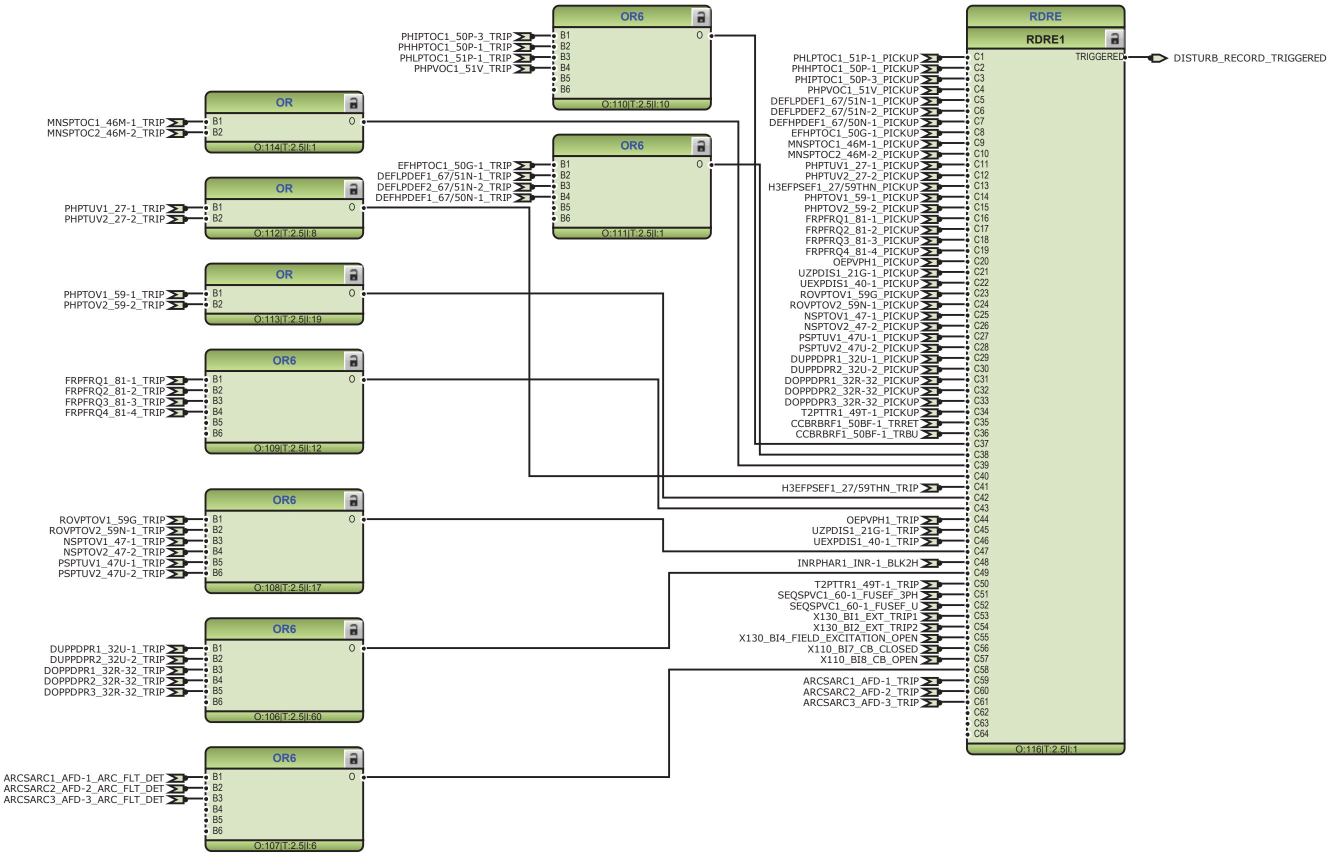


Figure 38: Disturbance recorder

3.3.3.3 Functional diagrams for condition monitoring

The fuse failure supervision SEQSPVC1_60-1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

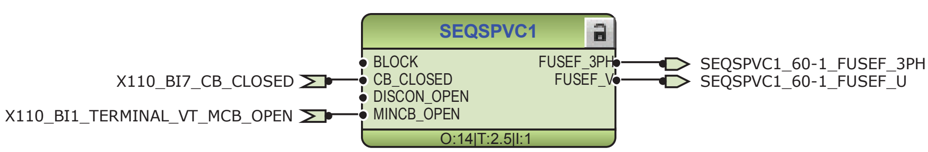


Figure 39: Fuse failure supervision function

Circuit-breaker condition monitoring SSCBR1_52CM-1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM-1 introduces various supervision methods.

Set the parameters for SSCBR1_52CM-1 properly.

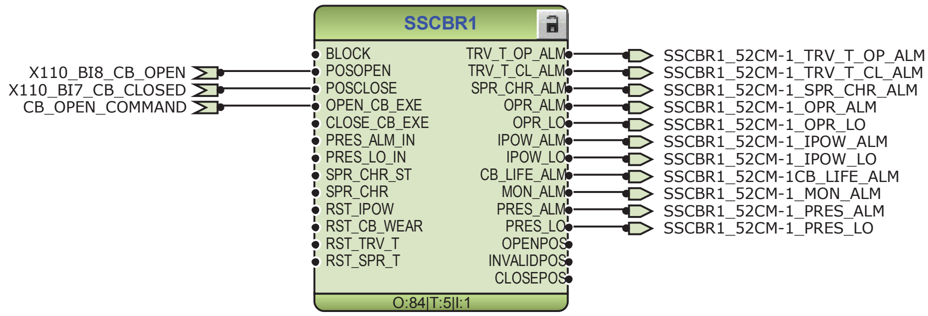


Figure 40: Circuit-breaker condition monitoring function

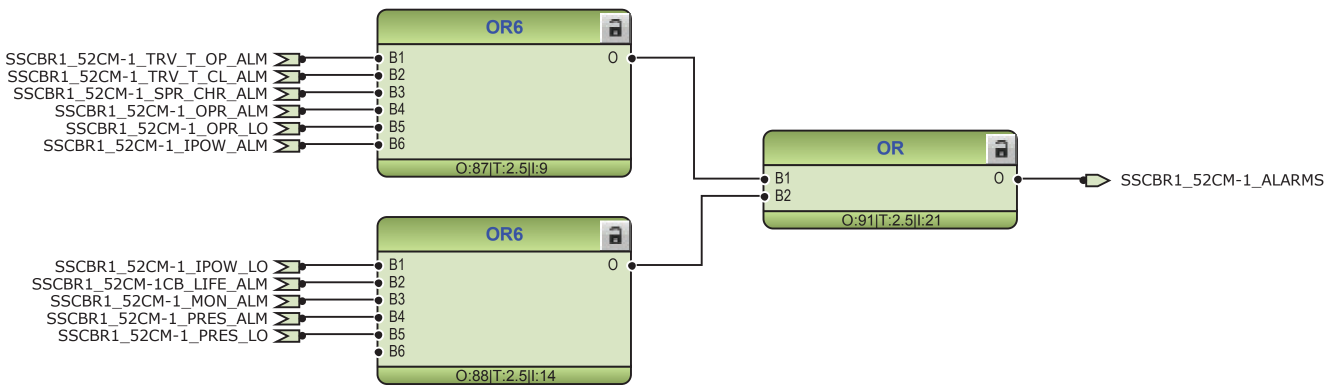


Figure 41: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. The TCSSCBR1_TCM-1 function is blocked by the master trip TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2 and the generator circuit breaker open signal, whereas the TCSSCBR2_TCM-2 function is blocked by the master trip TRPPTRC6_68/94-6 and the field excitation open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR1_TCM-1 properly.

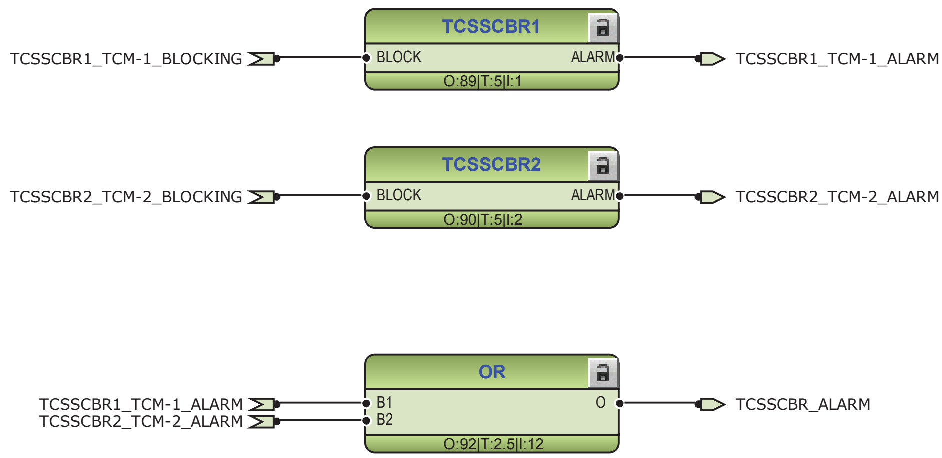


Figure 42: Trip circuit supervision function

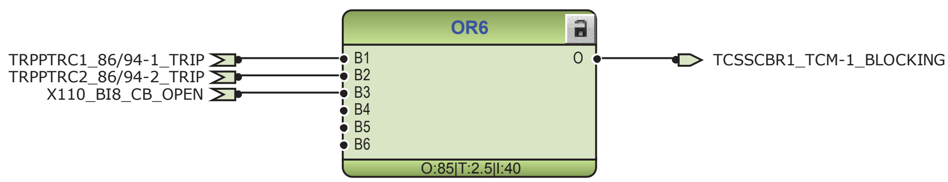


Figure 43: Logic for blocking of trip circuit supervision of generator circuit breaker

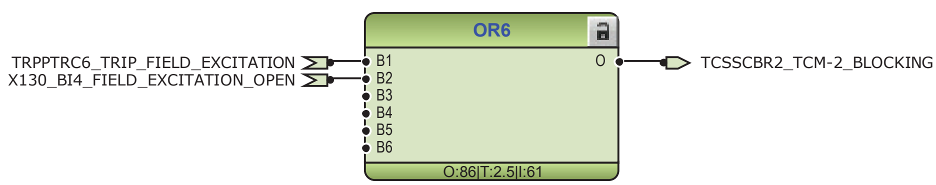


Figure 44: Logic for blocking of trip circuit supervision of field excitation circuit breaker

Runtime counter for machines and devices MDSOPT1_OPTM-1 provides history data since the last commissioning. The counter counts the total number of generator running hours and is incremented when the energizing circuit breaker is closed.

Figure 45: Generator runtime counter

3.3.3.4 Functional diagrams for control and interlocking

The circuit breaker closing is disabled by default, as in case of generator, the closing of the circuit breaker is done by a special synchronizer device.

The OKPOS output from DCSXSWI defines whether the disconnector or breaker truck is open (in test position) or closed (in service position). This output, together with the open ground switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for circuit breaker is always enabled.

Connect the additional signals required for the application for opening of circuit breaker.

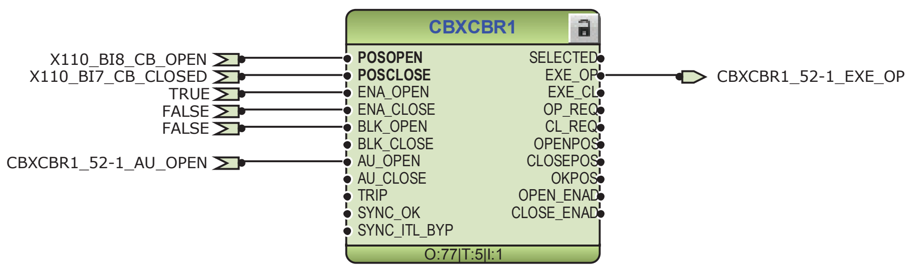


Figure 46: Circuit breaker 1 control logic

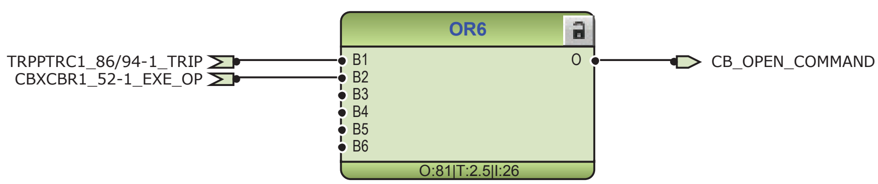


Figure 47: Signal for opening coil of circuit breaker 1

The configuration includes the logic for generating circuit breaker external opening command with the relay in local or remote mode.

Connect additional signals for opening of circuit breaker in local or remote mode, if applicable for the configuration.

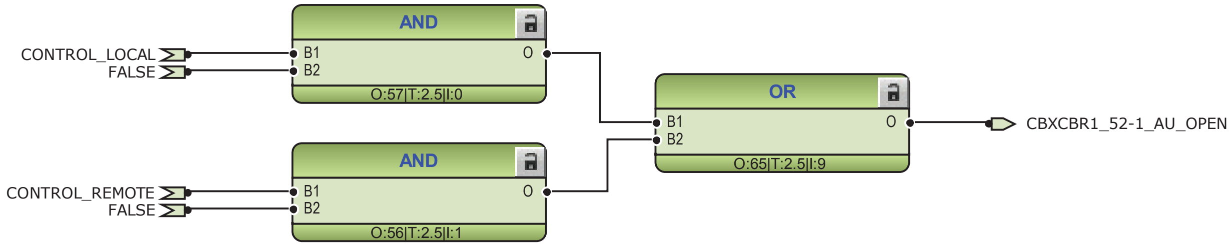


Figure 48: External opening command for circuit breaker 1

3.3.3.5 Functional diagrams for measurement functions

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1. The three-phase current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase terminal side voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1. In addition to phase voltage, terminal side and neutral side residual voltages are measured by residual voltage measurement RESVMMXU1 and RESVMMXU2. The three-phase voltage input as well as residual voltages are connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

The measurements can be seen in the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The frequency measurement FMMXU1 of the power system and three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

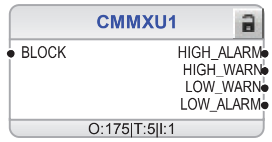


Figure 49: Three-phase current measurement

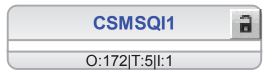


Figure 50: Sequence current measurements

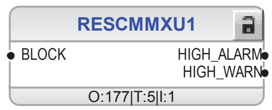


Figure 51: Ground current measurements

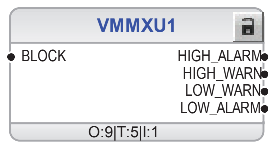


Figure 52: Three-phase voltage measurement

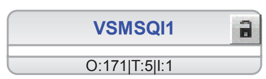


Figure 53: Sequence voltage measurements

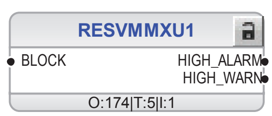


Figure 54: Ground voltage measurements

Figure 55: Residual voltage measurement (Neutral side)

Figure 56: Frequency measurement

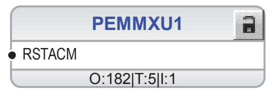
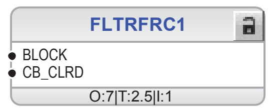


Figure 57: Three-phase power and energy measurement



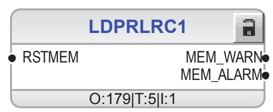


Figure 58: Data monitoring and load profile record

3.3.3.6 Functional diagrams for I/O and alarm LEDs

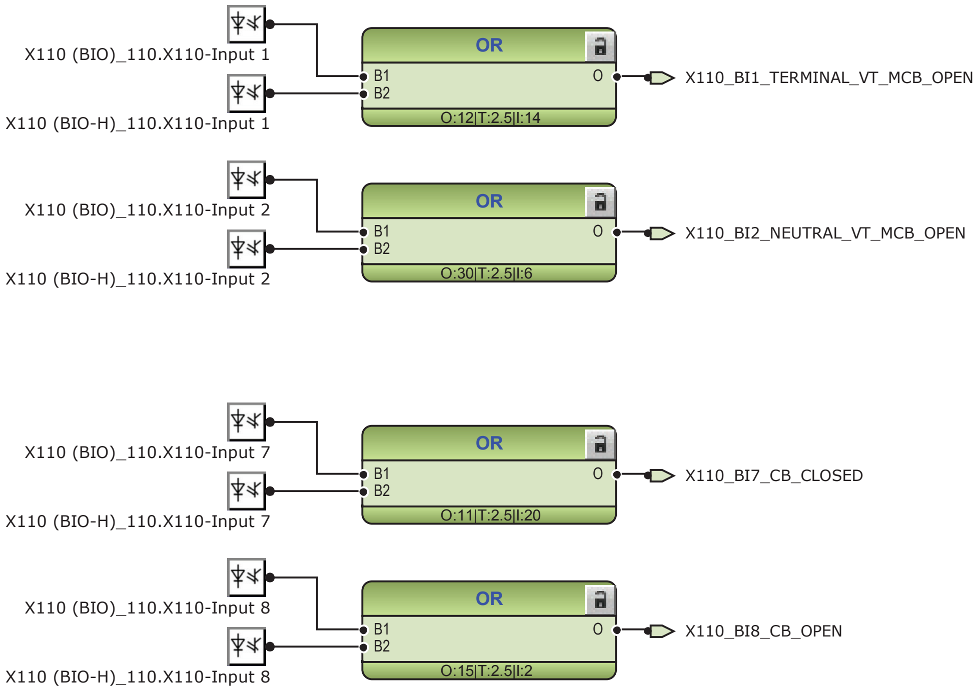


Figure 59: Default binary inputs - X110

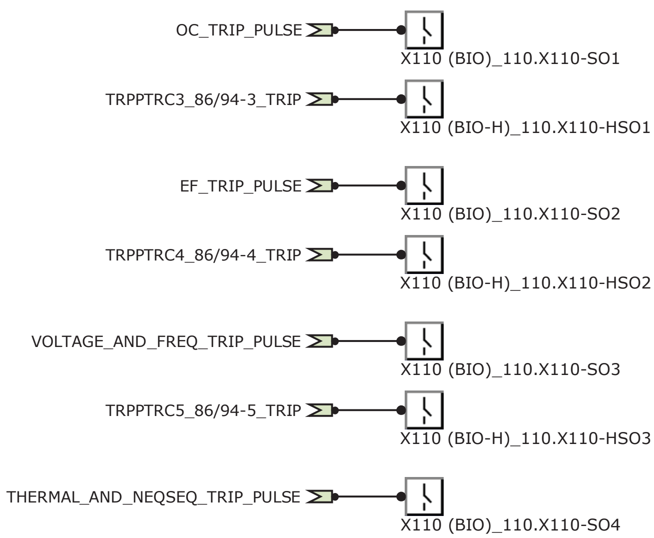


Figure 60: Default binary outputs - X110

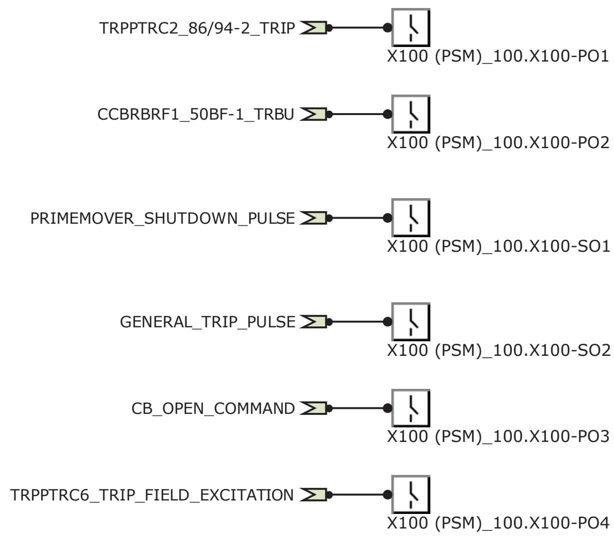


Figure 61: Default binary outputs - X100

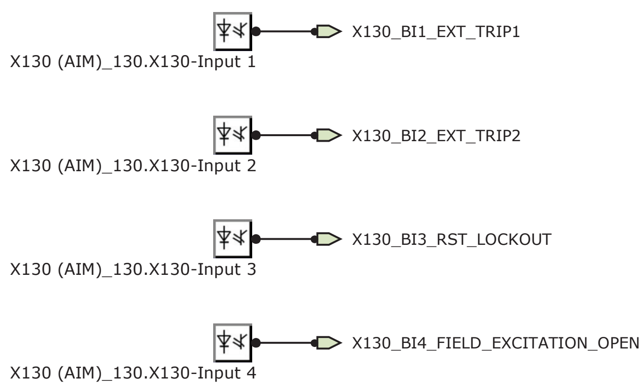


Figure 62: Default binary input - X130

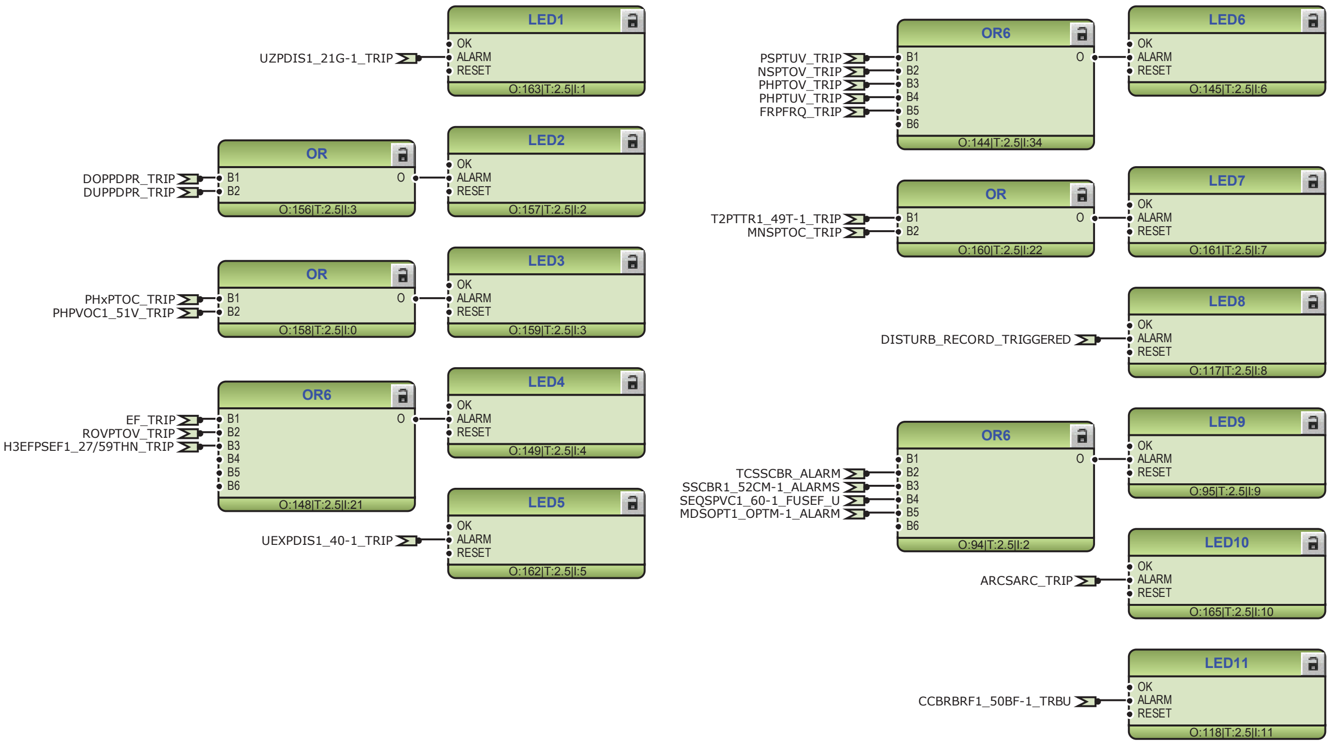


Figure 63: Default LED connection

3.3.3.7 Functional diagrams for other functions

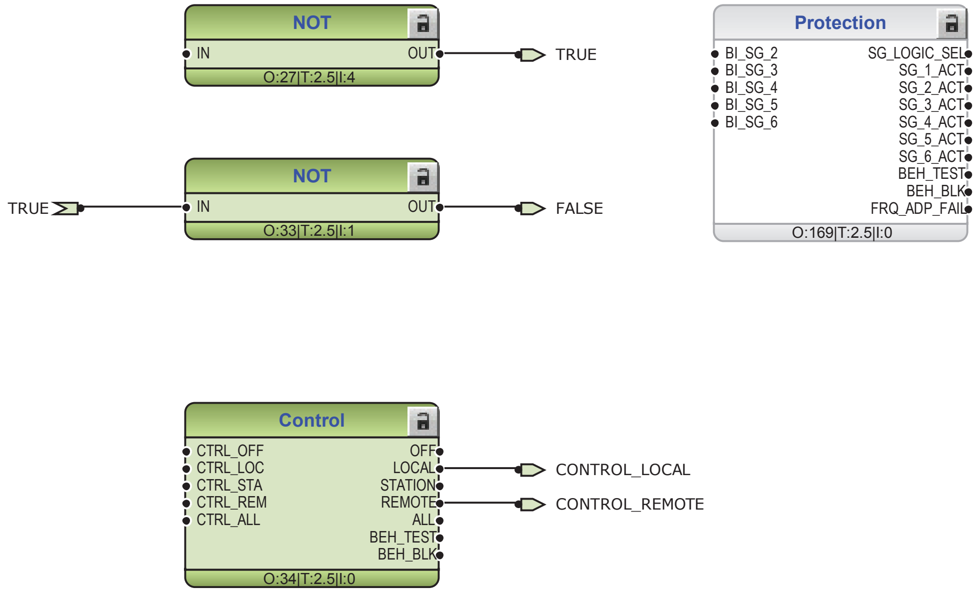


Figure 64: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.3.3.8 Functional diagrams for communication

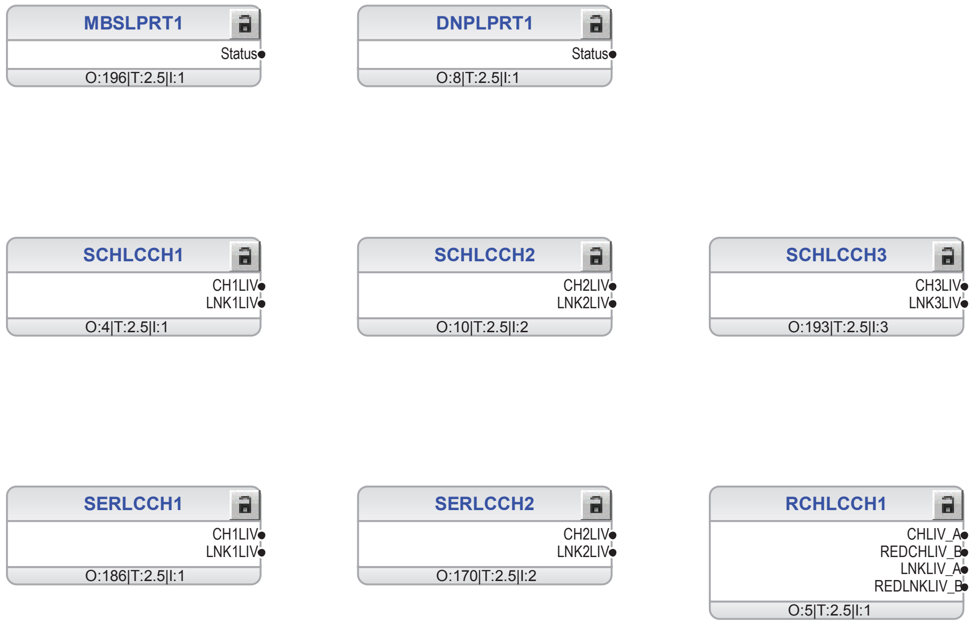


Figure 65: Default communication function connection

3.4 Standard configuration D

3.4.1 Applications

The standard configuration with differential protection for machines, power protection, overcurrent protection, voltage and frequency based protection, underexcitation and out-of-step protection is mainly intended for the main protection for a small size synchronous power generator or as backup protection for a medium size synchronous power generator.

Standard configuration D is not designed for using all the available functionality content in one relay at the same time. Three-phase directional overcurrent protection, three-phase voltage protection, positive-sequence and negative-sequence voltage protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user-specific configuration load is verified with the Application Configuration tool in PCM600.

The protection relay with a standard 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

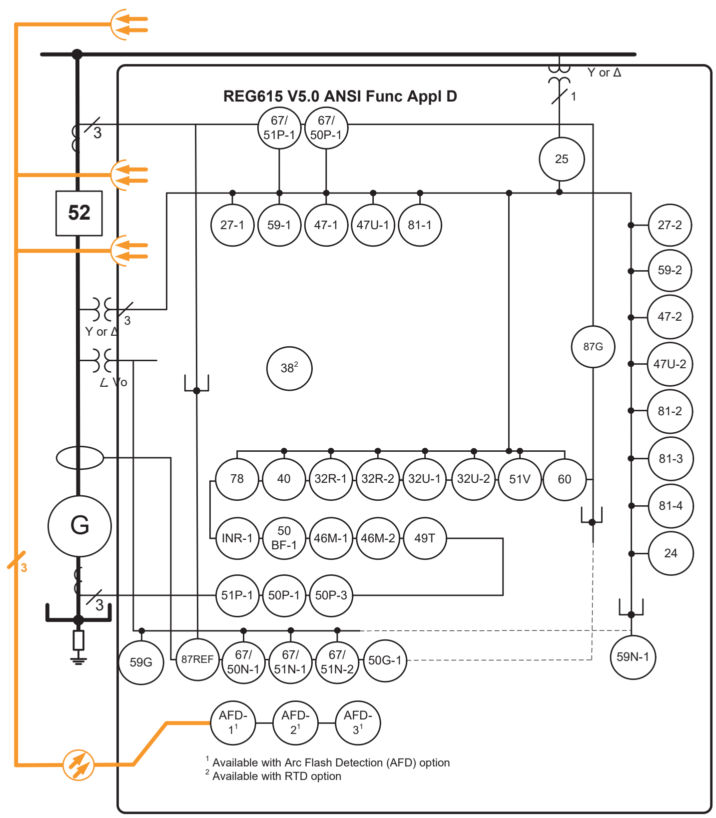


Figure 66: Functionality overview for standard configuration D

3.4.2.1 Default I/O connections

Table 15: Default connections for analog inputs

Analog input	Description	Connector pins
IA_B	Phase A current, neutral side	X120:1-2
IB_B	Phase B current, neutral side	X120:3-4
IC_B	Phase C current, neutral side	X120:5-6
IA	Phase A current, line side	X120:7-8
IB	Phase B current, line side	X120:9-10
IC	Phase C current, line side	X120:11-12
Table continues on next page		

Analog input	Description	Connector pins
IG	Residual current IG	X120:13-14
V12B	Phase-to-phase voltage VAB(2)	X130:9-10
VA	Phase voltage VA	X130:11-12
VB	Phase voltage VB	X130:13-14
VC	Phase voltage VC	X130:15-16
VG	Residual voltage VG	X130:17-18

Table 16: Default connections for binary inputs

Binary input	Description	Connector pins	
		BIO0005	BIO0007
X110-BI1	Terminal VT secondary MCB open	X110:1-2	X110:1,5
X110-BI2	Neutral VT secondary MCB open	X110:3-4	X110:2,5
X110-BI3	-	X110:5-6	X110:3,5
X110-BI4	-	X110:7-6	X110:4-5
X110-BI5	-	X110:8-9	X110:6,10
X110-BI6	-	X110:10-9	X110:7,10
X110-BI7	Circuit breaker closed position indication	X110:11-12	X110:8,10
X110-BI8	Circuit breaker open posotion indication	X110:13-12	X110:9-10
X130-BI1	External trip 1	X130:1-2	
X130-BI2	External trip 2	X130:3-4	
X130-BI3	Lockout reset	X130:5-6	
X130-BI4	Field excitation open indication	X130:7-8	

Table 17: Default connections for binary outputs

Binary output	Description	Connector pins
X100-PO1	Generator circuit breaker trip 2	X100:6-7
X100-PO2	Circuit breaker failure protection trip to upstream breaker	X100:8-9
X100-SO1	Prime mover shutdown	X100:10-11,(12)
X100-SO2	General protection operate indication	X100:13-14
X100-PO3	Generator circuit breaker open command/trip 1	X100:15-19
X100-PO4	Field excitation circuit breaker open command	X100:20-24
X110-SO1	In synchronism for closing	X110:14-16
X110-SO2	Differential protection trip alarm	X110:17-19
X110-SO3	Frequency protection trip alarm	X110:20-22
X110-SO4	Thermal overload and negative phase-sequence trip alarm	X110:23-24

Table continues on next page

Binary output	Description	Connector pins
X110-HSO1	Arc protection instance 1 trip activated	X110:15-16
X110-HSO1	Arc protection instance 2 trip activated	X110:19-20
X110-HSO1	Arc protection instance 3 trip activated	X110:23-24

Table 18: Default connections for LEDs

LED	Default usage	ID	Label description
1	Differential protection trip	LED_Differential	Differential
2	Power protection trip	LED_DirOverpowerProt	Power
3	Overcurrent protection trip	LED_Overcurrent_1	Overcurrent
4	Ground-fault protection trip	LED_EarthFault_1	Ground-fault
5	Synchronism or energization check OK	LED_Synchronism	Synchronism OK
6	Frequency protection trip	LED_FrequencyProt	Frequency
7	Negative sequence overcurrent or thermal overload protection trip	LED_NPSOrThermalOverload_1	Neg. Seq./Thermal Ovld.
8	Disturbance recorder triggered	LED_DisturbRecTriggered_1	Disturb. rec. triggered
9	Supervision alarms	LED_Supervision_1	Supervision
10	Arc flash detection	LED_ArcDetected_1	Arc detected
11	Circuit breaker failure protection trip	LED_BreakerFailure_1	Breaker failure

3.4.2.2 Default disturbance recorder settings

Table 19: Default disturbance recorder analog channels

Channel	Description
1	IL1
2	IL2
3	IL3
4	IL1B
5	IL2B
6	IL3B
7	Io
8	Uo
9	U1
10	U2
11	U3
12	U12B

Table 20: Default disturbance recorder binary channels

Channel	ID text	Level trigger mode
1	PHLPTOC1 - pickup	Positive or Rising
2	PHHPTOC1 - pickup	Positive or Rising
3	PHIPTOC1 - pickup	Positive or Rising
4	PHPVOC1 - pickup	Positive or Rising
5	DEFLPDEF1 - pickup	Positive or Rising
6	DEFLPDEF2 - pickup	Positive or Rising
7	DEFHPDEF1 - pickup	Positive or Rising
8	EFHPTOC1 - pickup	Positive or Rising
9	MNSPTOC1 - pickup	Positive or Rising
10	MNSPTOC2 - pickup	Positive or Rising
11	DOPPDPR1 - pickup	Positive or Rising
12	DOPPDPR2 - pickup	Positive or Rising
13	DUPPDPR1 - pickup	Positive or Rising
14	DUPPDPR2 - pickup	Positive or Rising
15	OEPVPH1 - pickup	Positive or Rising
16	UEXPDIS1 - pickup	Positive or Rising
17	ROVPTOV1 - pickup	Positive or Rising
18	ROVPTOV2 - pickup	Positive or Rising
19	FRPFRQ1 - pickup	Positive or Rising
20	FRPFRQ2 - pickup	Positive or Rising
21	FRPFRQ3 - pickup	Positive or Rising
22	FRPFRQ4 - pickup	Positive or Rising
23	T2PTTR1 - pickup	Positive or Rising
24	PHxPTOC/PHPVOC1 - trip	Level trigger off
25	EFHPTOC1/DEFxPDEF - trip	Level trigger off
26	MNSPTOC - trip	Level trigger off
27	DUPPDPR/DOPPDPR - trip	Level trigger off
28	OEPVPH1 - trip	Level trigger off
29	UEXPDIS1 - trip	Level trigger off
30	ROVPTOV - trip	Level trigger off
31	FRPFRQ - trip	Level trigger off
32	MPDIF1 - opr ls	Positive or Rising
33	MPDIF1 - opr hs	Positive or Rising
34	MPDIF1 - int blkd	Level trigger off
35	T2PTTR1 - trip	Level trigger off

Table continues on next page

Channel	ID text	Level trigger mode
36	CCBRBRF1 - trret	Level trigger off
37	CCBRBRF1 - trbu	Level trigger off
38	INRPHAR1 - blk2h	Level trigger off
39	SEQSPVC1- fusef u	Level trigger off
40	X130BI1 - Ext trip1	Positive or Rising
41	X130BI2 - Ext trip2	Positive or Rising
42	X130BI4 - Field Excitation open	Positive or Rising
43	X110BI7 - CB closed	Level trigger off
44	X110BI8 - CB open	Level trigger off
45	ARCSARC - ARC flt det	Level trigger off
46	ARCSARC1 - trip	Positive or Rising
47	ARCSARC2- trip	Positive or Rising
48	ARCSARC3- trip	Positive or Rising
49	LREFPNDF1 - pickup	Positive or Rising
50	LREFPNDF1 - trip	Level trigger off
51	-	-
52	-	-
53	-	-
54	-	-
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	-
61	-	-
62	-	-
63	-	-
64	-	-

3.4.3 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM600 according to the application requirements.

The analog channels have fixed connections to the different function blocks inside the protection relay's standard configuration. However, the 12 analog channels available for the disturbance recorder function are freely selectable as a part of the disturbance recorder's parameter settings.

The phase currents to the protection relay are fed from a current transformer. The residual current to the protection relay is fed from either residually connected CTs, an external core balance CT, neutral CT or calculated internally.

The signal marked with IA, IB and IC represents the three phase currents. The signal IG represents the measured ground current.

The signal marked with VA, VB and VC represents the three phase voltages. The signal VG represents the measured ground voltage.

The protection relay offers six different setting groups which can be set based on individual needs. Each group can be activated or deactivated using the setting group settings available in the protection relay.

Depending on the communication protocol the required function block needs to be instantiated in the configuration.

3.4.3.1 Functional diagrams for protection

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

Three non-directional overcurrent stages are offered for detecting phase faults in generators. In addition to the overcurrent stages, one instance of voltage dependent overcurrent protection is also provided and it can be used as a backup protection against phase faults. During certain conditions, the fault current for three phase faults may be less than the full load current of the generator. This may not be noticed by the phase overcurrent protection, but the fault causes the generator terminal voltage to drop. Voltage dependent overcurrent protection can be used to detect and trip such faults.

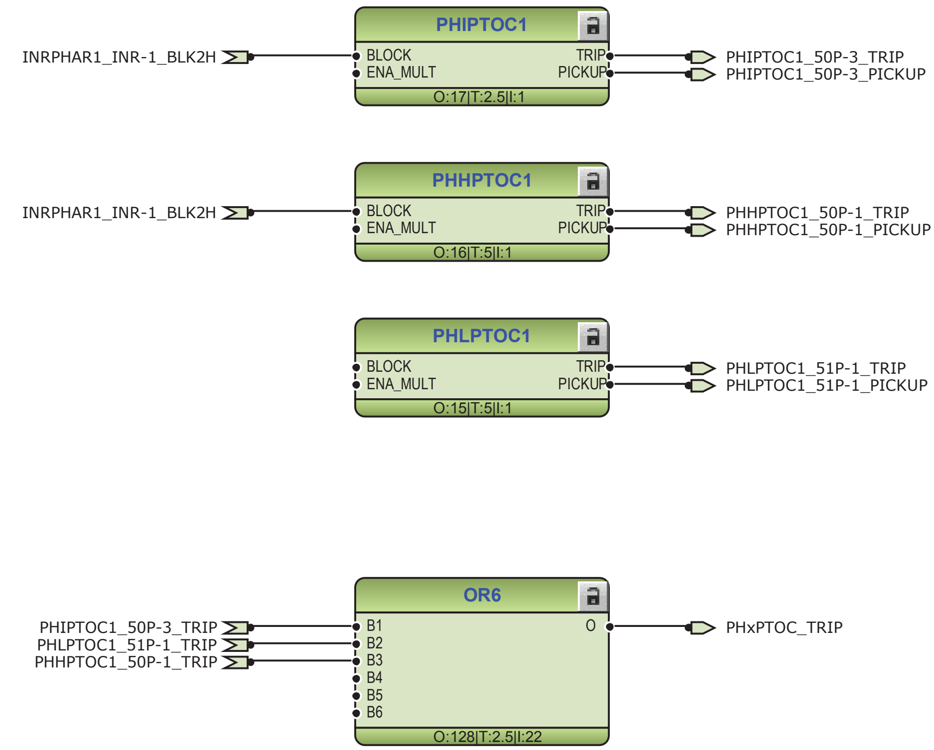


Figure 67: Overcurrent protection function

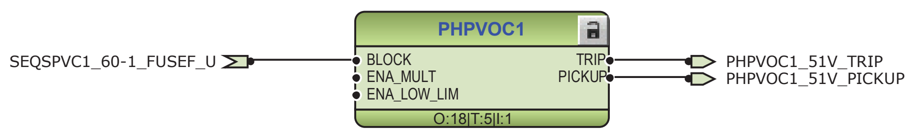


Figure 68: Voltage dependent overcurrent protection function

The output BLK2H of three-phase inrush detector INRPHAR1_INR-1 either blocks the function or multiplies the active settings for any of the available overcurrent or ground-fault function blocks. In the configuration, INRPHAR1_INR-1 blocks the high and instantaneous stages of non-directional overcurrent protection.

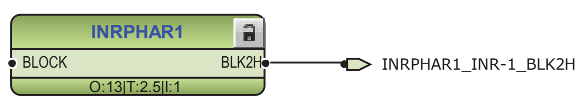


Figure 69: Inrush detector function

Two negative-sequence overcurrent protection stages MNSPTOC1_46M-1 and MNSPTOC2_46M-2 are provided for phase unbalance protection. These functions are used to protect against unbalance conditions due to unbalance load or unsymmetrical faults.

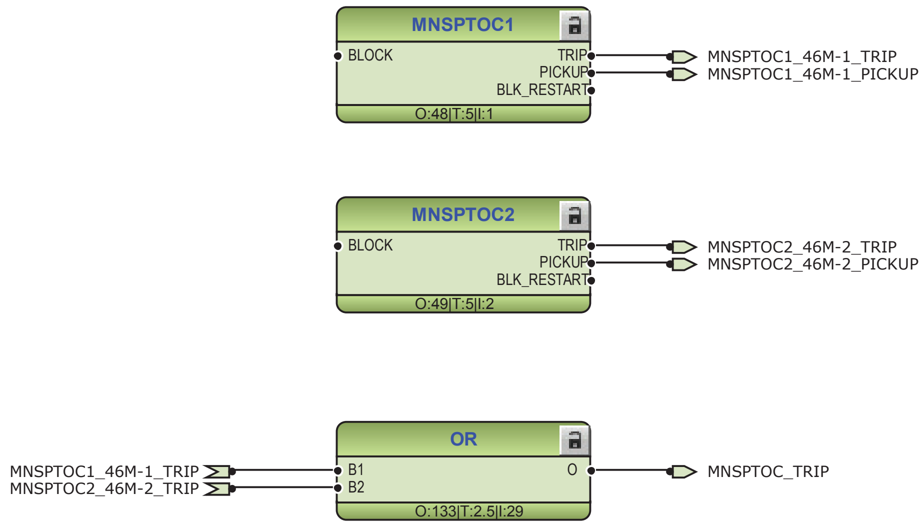


Figure 70: Negative sequence overcurrent protection function

One non-directional sensitive ground-fault stage EFHPTOC1_50G-1 and three directional ground-fault stages DEFxPDEF_67/5xN are offered for providing primary and backup protection for generator ground-fault protection.

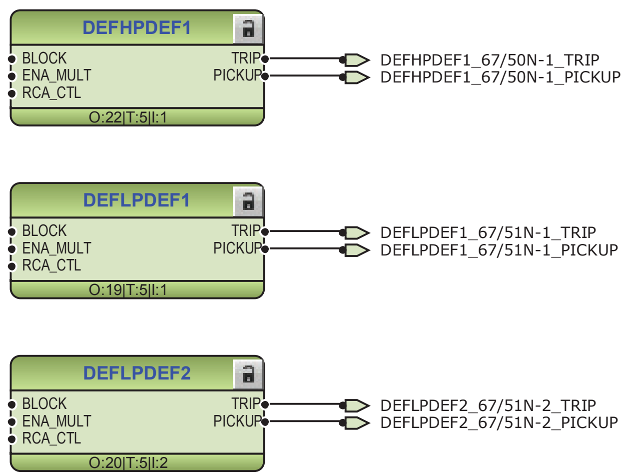


Figure 71: Directional ground-fault protection function

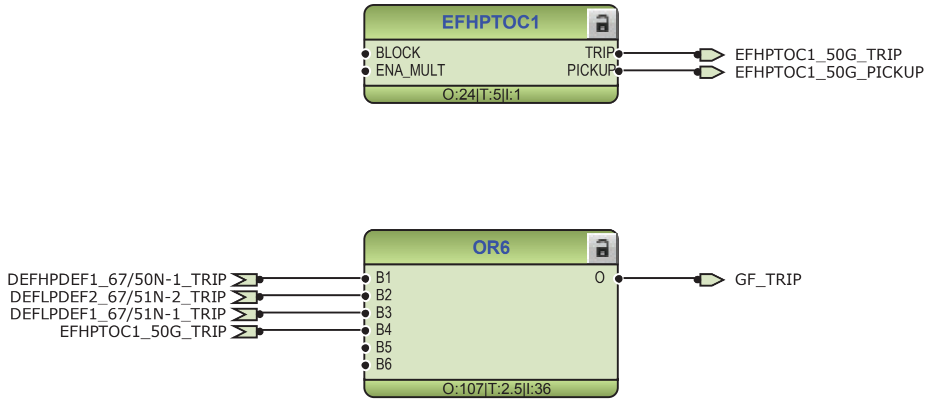


Figure 72: Ground-fault protection function

The configuration includes numerically stabilized low-impedance restricted ground-fault protection LREFPNDF1_87LOZREF. The numerical differential current stage trips exclusively on ground faults occurring in the protected area, that is, in the area between the phase and neutral current transformers. A ground fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and ground.

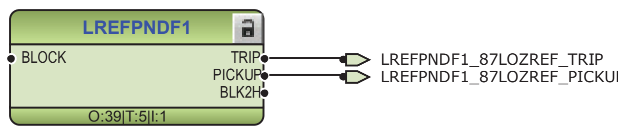


Figure 73: Numerically stabilized low-impedance restricted ground-fault protection function

Third harmonic-based stator ground-fault protection is provided to give 100% stator winding protection. The protection is blocked by the MCB open signal from the neutral side VT.

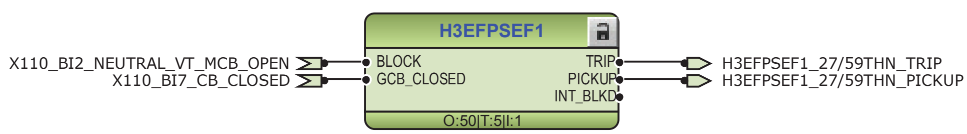


Figure 74: Third harmonic-based stator ground-fault protection function

Three-phase thermal overload protection, two time constants, T2PTTR1_49T-1 detects continuous overloading conditions preventing excessive insulation damage in the long run.

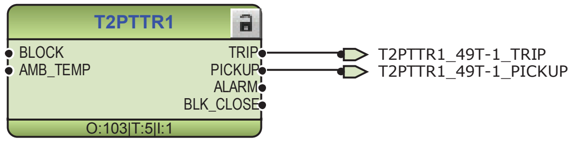


Figure 75: Thermal overload protection function

The stabilized and instantaneous differential protection for machines MPDIF1_87G-1 provides protection against internal failures. The relay compares the phase currents on both sides of the generator to be protected. If the differential current of the phase currents in one of the phases exceeds the setting of the stabilized operation characteristic or the instantaneous protection stage of the function, the function provides an operating signal. The operating signal is connected to the master trip 1 and 2, trip of field excitation and also to the alarm LED 1.

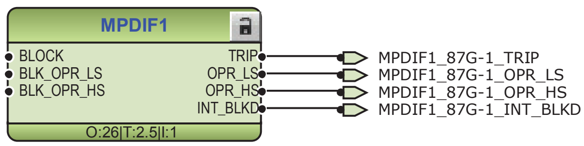


Figure 76: Generator differential protection function

Circuit breaker failure protection CCBRBRF1_50BF-1 is initiated via the `PICKUP` input by a number of different protection functions available in the relay. The breaker failure protection function offers different operating modes associated with the circuit breaker position and the measured phase and residual currents.

The circuit breaker failure protection function has two operating outputs: `TRRET` and `TRBU`. The `TRRET` operating output is used for retripping its own breaker through `TRPPTRC2_68/94-1_TRIP`. The `TRBU` output gives a backup trip to the breaker feeding upstream. For this purpose, the TRBU operating output signal is connected to the binary output X100:PO2. In addition, `TRBU` operating output is also used to trip field excitation circuit breaker through TRPPTRC6_68/94-6_TRIP_FIELD EXCITATION.

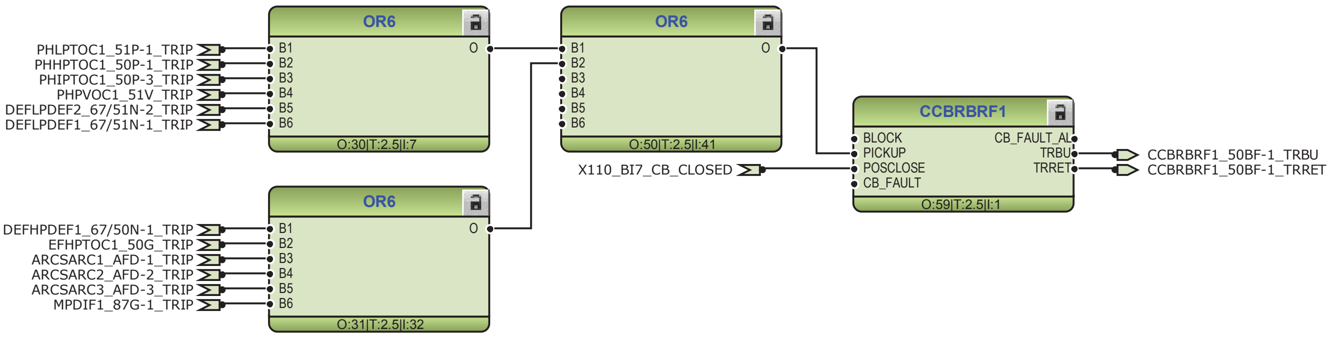


Figure 77: Circuit breaker failure protection function

Three arc protection ARCSARC1...3_AFD-1…3 stages are included as an optional function. The arc protection offers individual function blocks for three arc sensors that can be connected to the relay. Each arc protection function block has two different operation modes, that is, with or without the phase and residual current check.

The operating signals from ARCSARC1...3_AFD-1…3 are connected to both generator circuit breaker trip logic TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2 and also to field excitation circuit breaker trip logic TRPPTRC6_68/94-6. If the relay has been ordered with high-speed binary outputs, the individual operating signals from ARCSARC1...3_AFD-1…3 are connected to dedicated trip logic TRPPTRC3...5_68/94-3….5. The output of TRPPTRC3...5_68/94-3….5 is available at high-speed outputs X110:HSO1, X110:HSO2 and X110:HSO3.

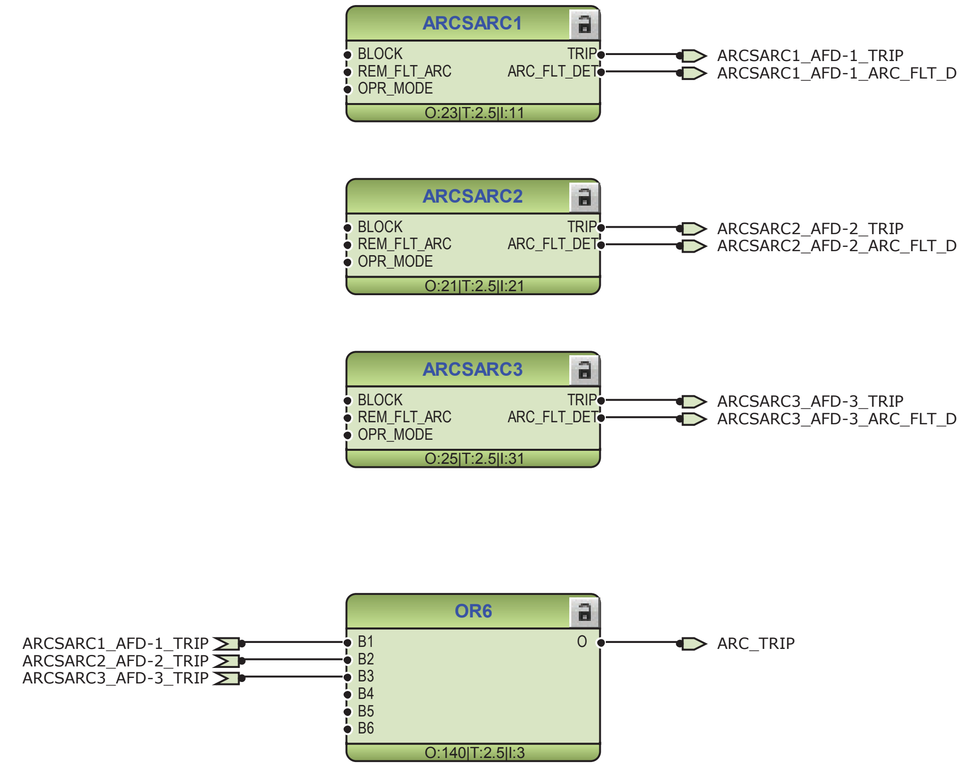


Figure 78: Arc protection function

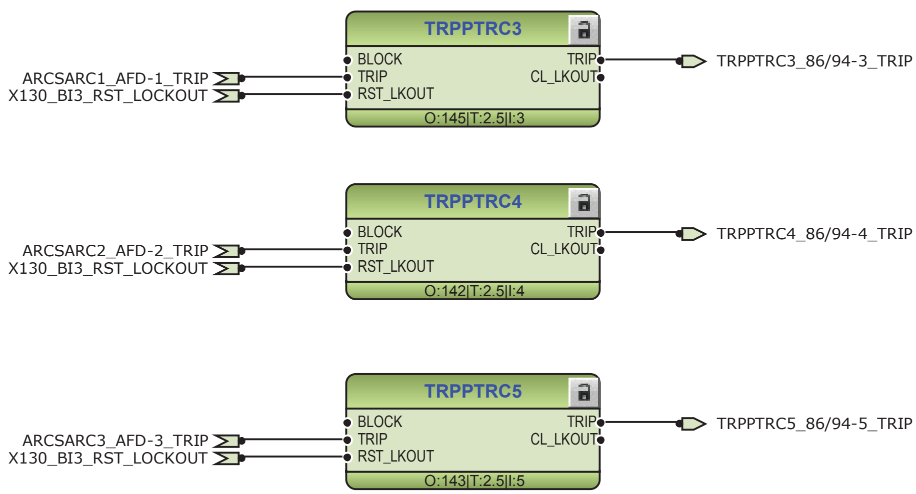


Figure 79: Arc protection with dedicated high-speed output

Residual overvoltage protection ROVPTOV_59G/N provides protection against stator ground faults from 5% to 100% of winding from neutral. Two instances of ROVPTOV_59G/N are provided.

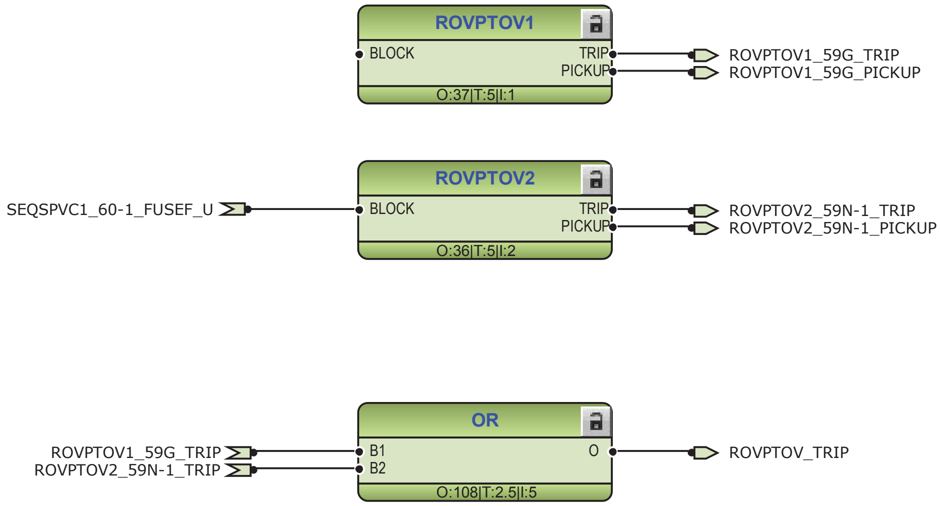


Figure 80: Residual overvoltage protection function

The selectable underfrequency or overfrequency or rate of change of frequency protection FRPFRQ_81 prevents damage to network components under unwanted frequency conditions. The function also contains a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. Configuration offers six instances of frequency protection, these instances can be configured to trip as underfrequency or overfrequency or rate of change of frequency according to the system requirement. The frequency protection is blocked when the generator CB is in open position.

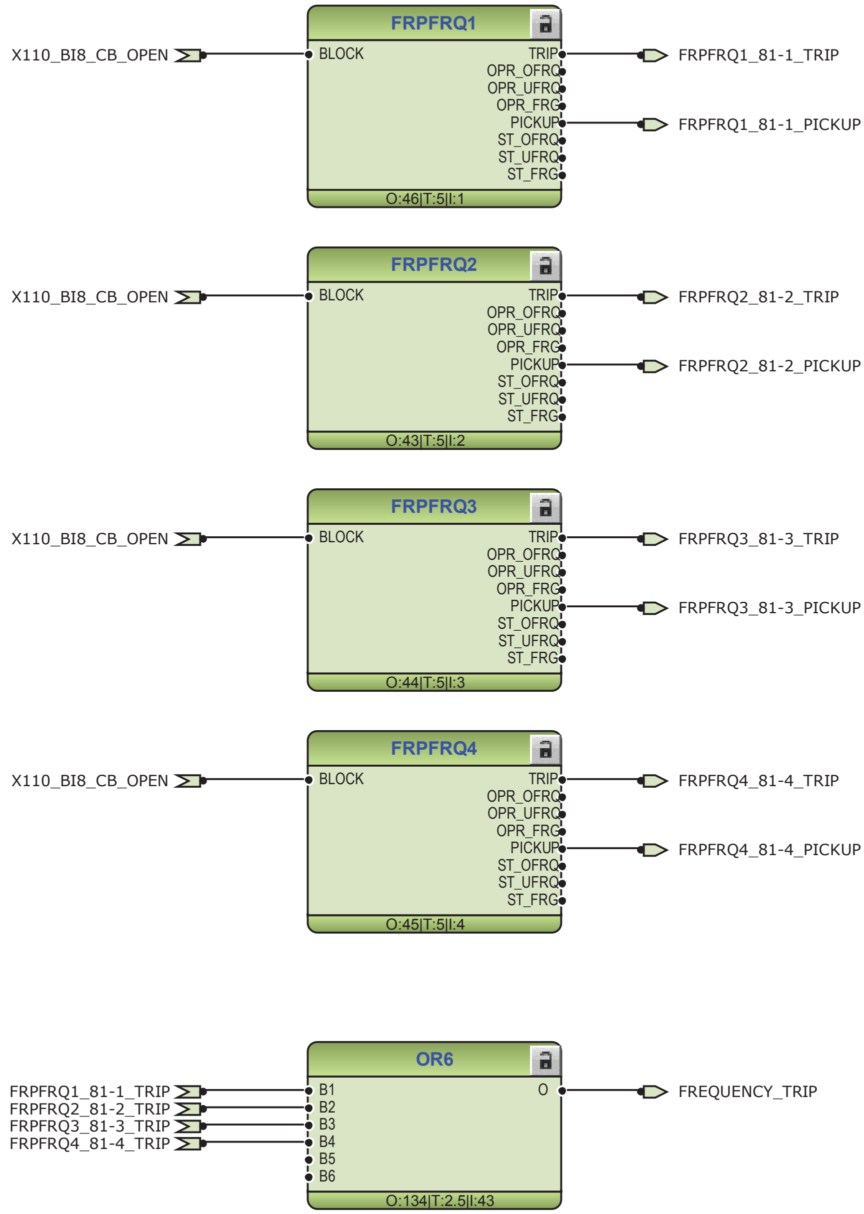


Figure 81: Frequency protection function

Three instances of reverse power/directional overpower protection DOPPDPR_32R-32 are provided to detect either loss of prime mover or detecting motoring action or any abnormal high reactive power being absorbed by the generator.

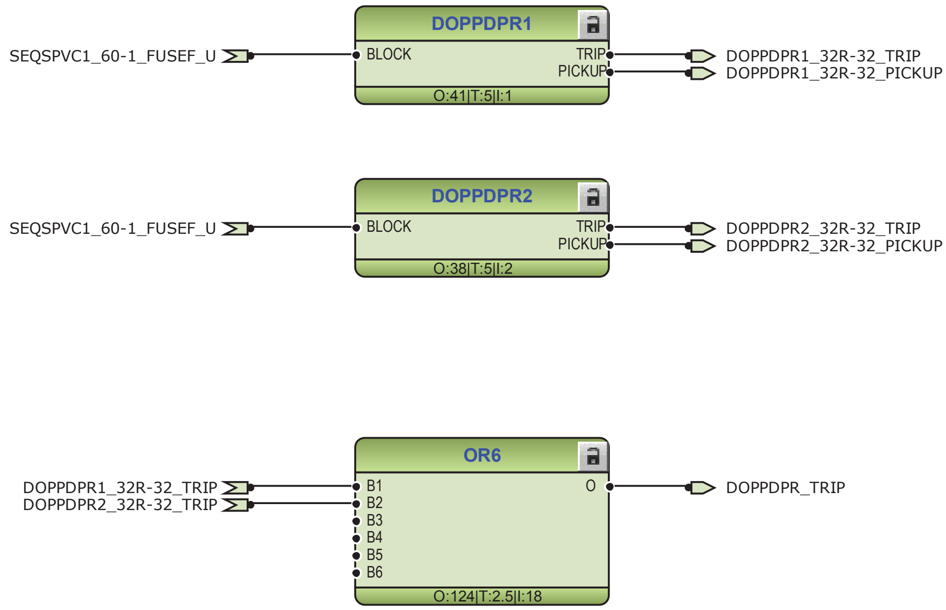


Figure 82: Directional overpower protection function

Two instances of underpower protection DUPPDPR_32U are provided. Normally these are used in coordination with reverse active power protection.

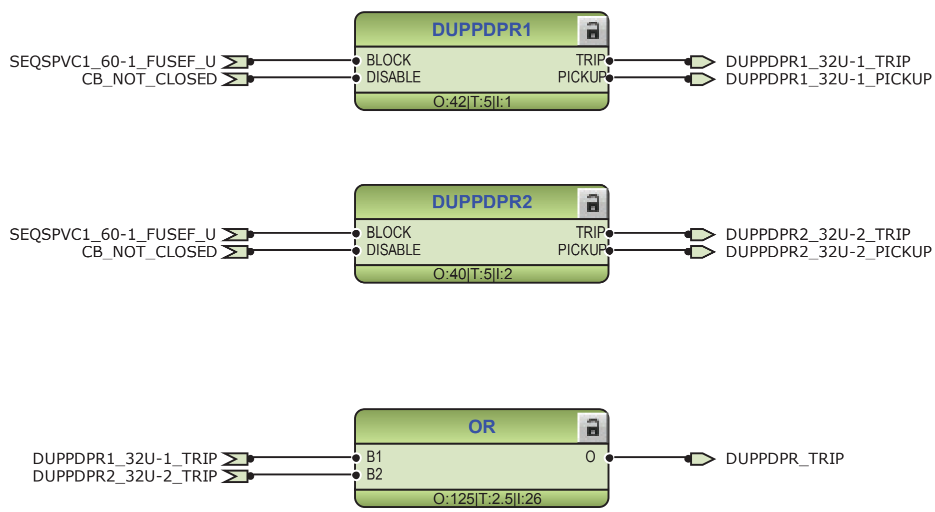


Figure 83: Directional underpower protection function

On losing excitation, the generator may over speed and trip as an induction generator taking reactive power from the system which may reduce system voltages. The three-phase underexcitation protection UEXPDIS1_40-1 is provided to detect such conditions.

Directional underpower protection is disabled when the generator circuit breaker is in open position.

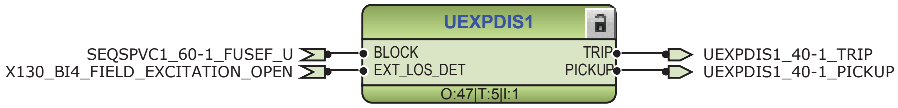


Figure 84: Underexcitation protection function

Overexcitation protection OEPVPH1_24 is provided to protect the generator against overexcitation. Due to overexciation, saturation of the magnetic core of generator and connected transformer may occur, and stray flux may be induced in nonlaminated components that are not designed to carry flux. Excessive flux also causes excessive eddy currents resulting into excessive voltage between laminations causing overheating and damage to insulation.

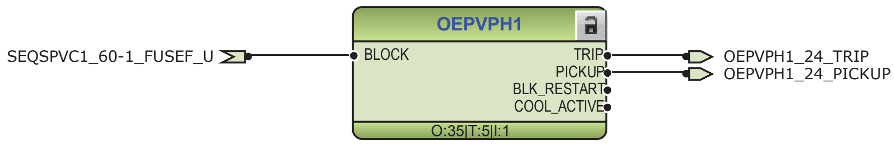


Figure 85: Overexcitation protection function

General pickup and trip signals from all functions are connected to minimum pulse timer TPGAPC1 for setting the minimum pulse length for the outputs. The output from TPGAPC1 is connected to binary output.

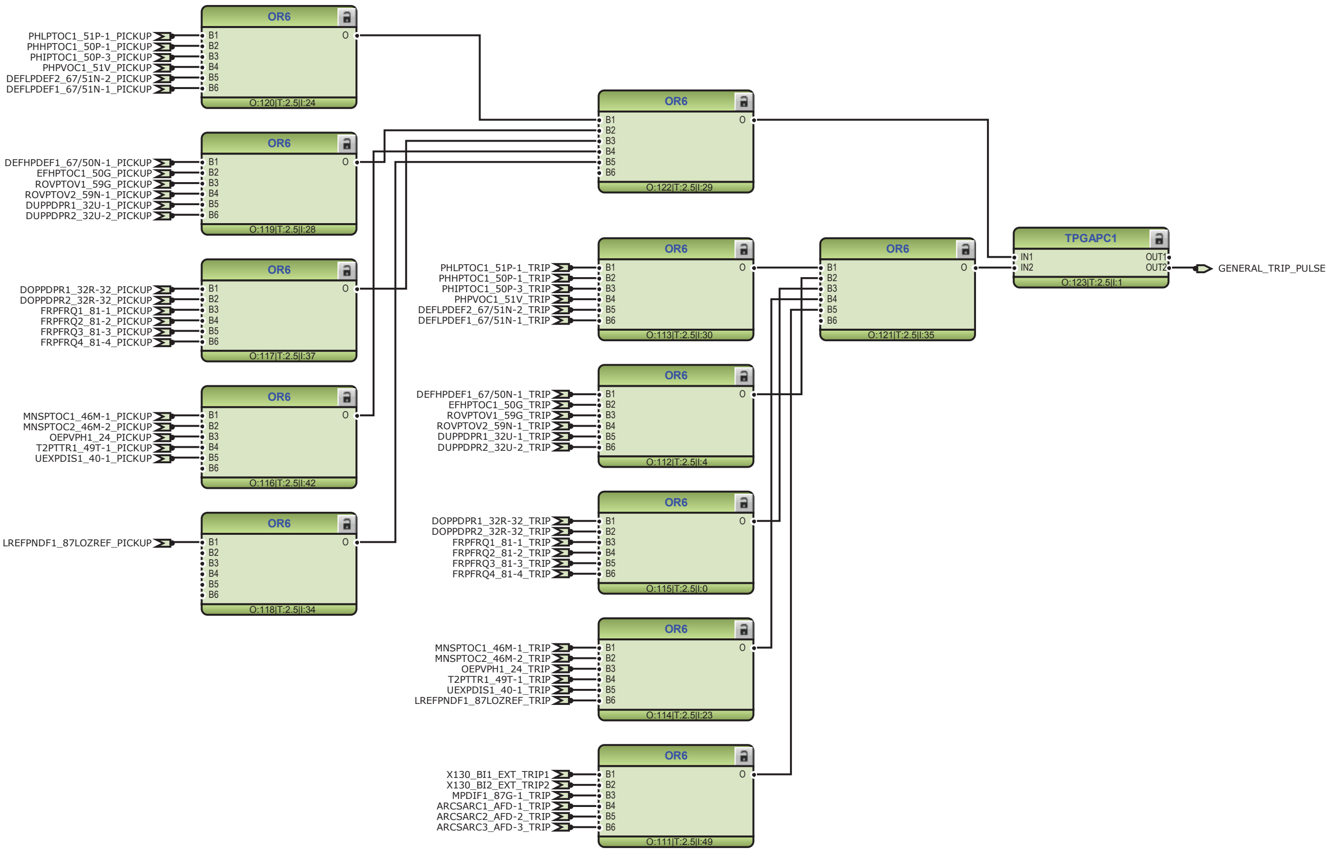


Figure 86: General pickup and trip signal

The operating signals from the protection functions are connected to the two trip logics TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2. The output of these trip logic functions is available at binary outputs X100:PO3 and X100:PO1. The trip logic functions are provided with a lockout and latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, binary input X130:BI3 has been assigned to the `RST_LKOUT` input of both the trip logic to enable external reset with a push button.

Three other trip logics TRPPTRC3...4_68/94-3….4 are also available if the relay is ordered with high-speed binary output options.

In addition, trip logic TRPPTRC6_68/94-6 is available to trip the circuit breaker of field excitation. The protection function which should trip the field excitations are connected to TRPPTRC6_68/94-6.

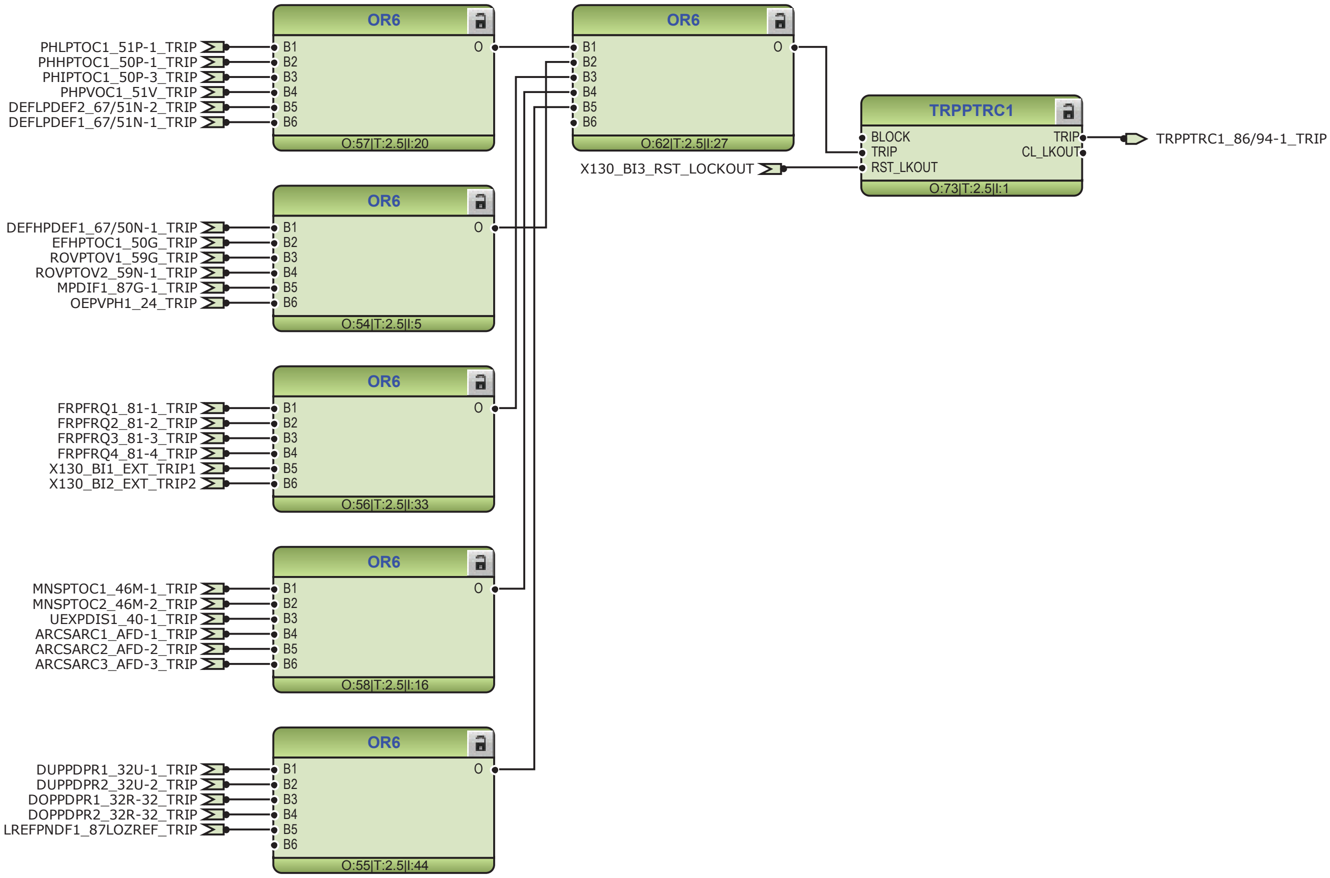


Figure 87: Trip logic TRPPTRC1

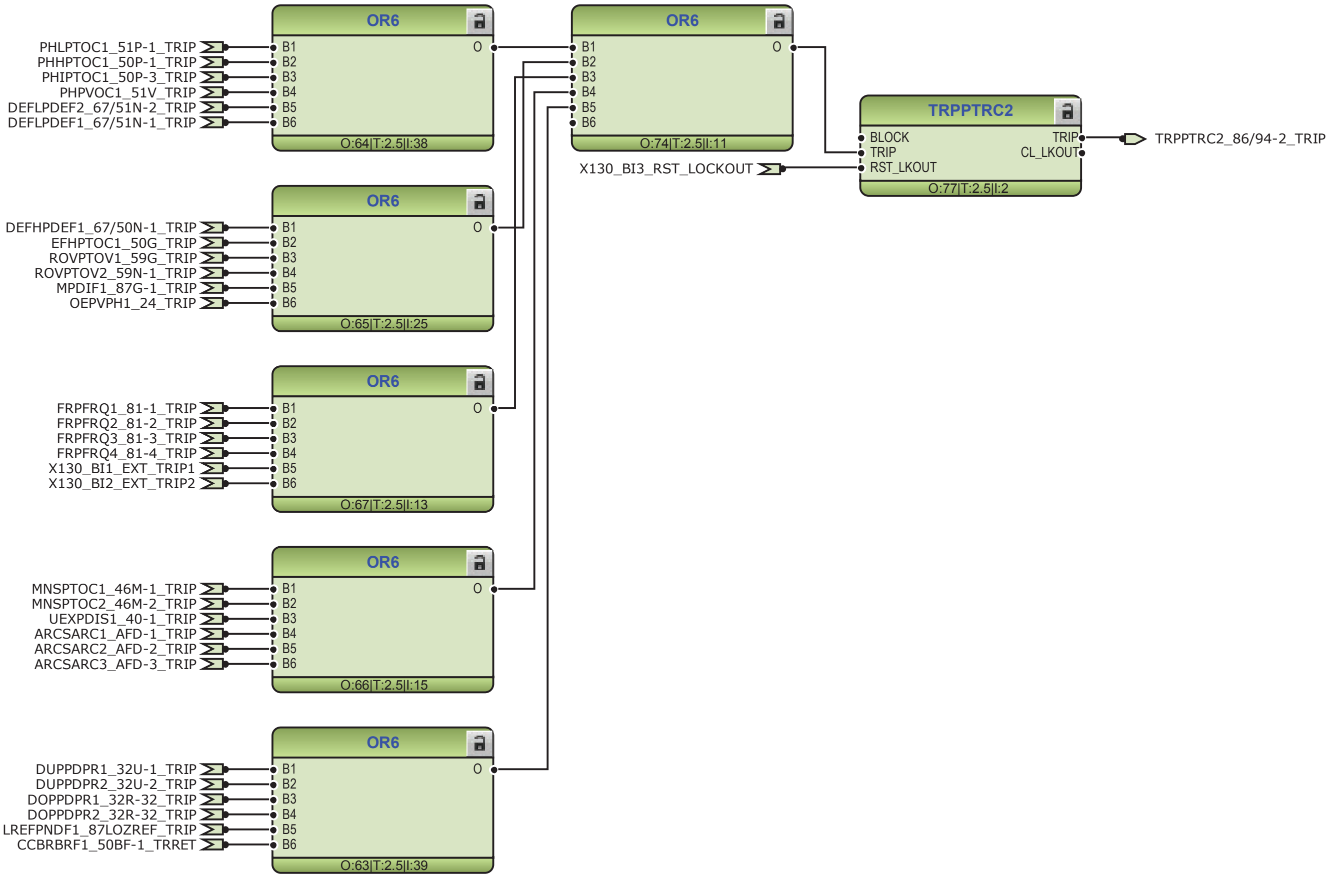


Figure 88: Trip logic TRPPTRC2

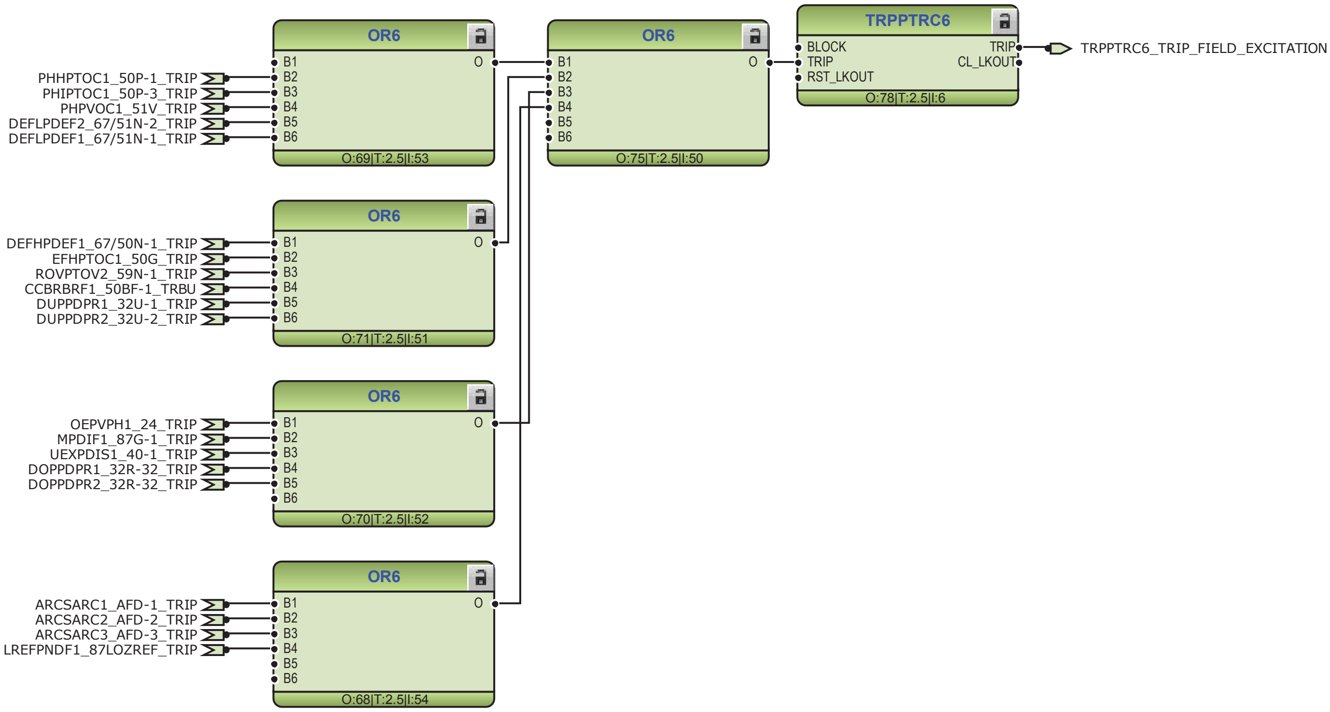


Figure 89: Trip logic TRPPTRC6 (field excitation)

3.4.3.2 Functional diagrams for disturbance recorder

The PICKUP and TRIP outputs 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 signals from different functions and the few binary inputs are also connected to the disturbance recorder.

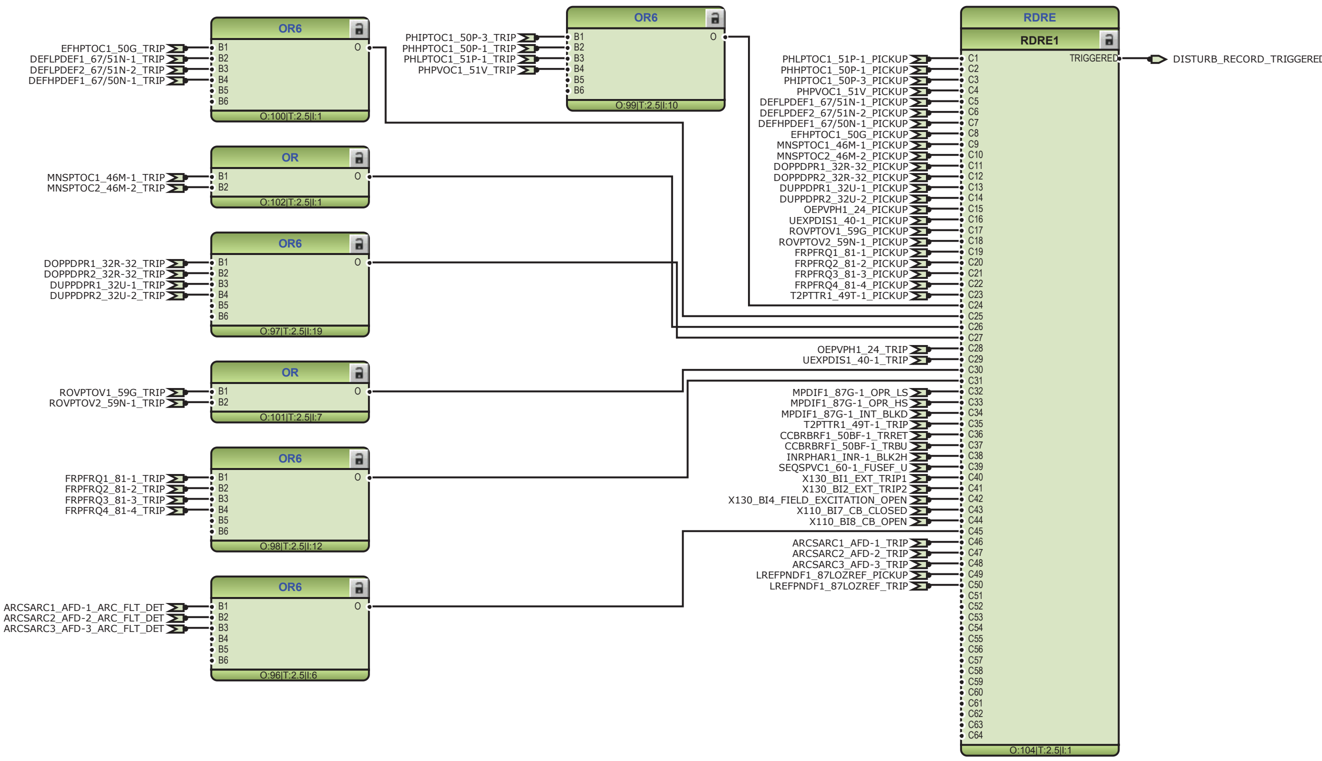


Figure 90: Disturbance recorder

3.4.3.3 Functional diagrams for condition monitoring

The fuse failure supervision SEQSPVC1_60-1 detects failures in the voltage measurement circuits. Failures, such as an open MCB, raise an alarm.

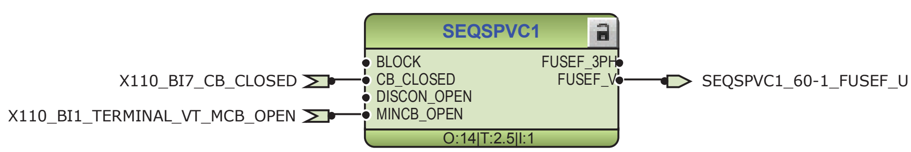


Figure 91: Fuse failure supervision function

Circuit-breaker condition monitoring SSCBR1_52CM-1 supervises the switch status based on the connected binary input information and the measured current levels. SSCBR1_52CM-1 introduces various supervision methods.

Set the parameters for SSCBR1_52CM-1 properly.

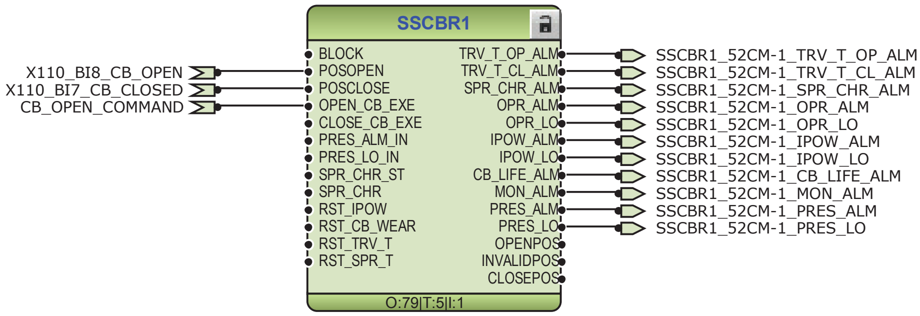


Figure 92: Circuit-breaker condition monitoring function

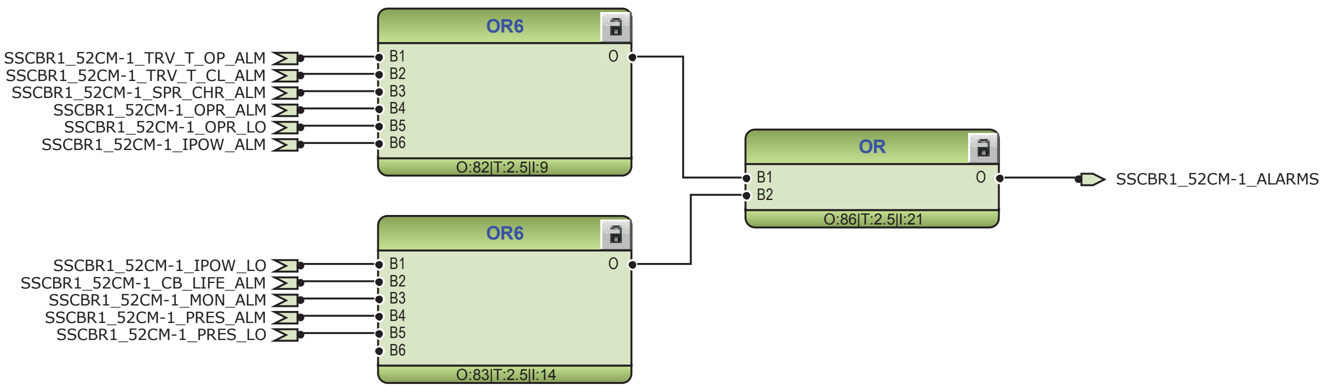


Figure 93: Logic for circuit breaker monitoring alarm

Two separate trip circuit supervision functions are included: TCSSCBR1_TCM-1 for power output X100:PO3 and TCSSCBR2_TCM-2 for power output X100:PO4. The TCSSCBR1_TCM-1 function is blocked by the master trip TRPPTRC1_68/94-1 and TRPPTRC2_68/94-2 and the generator circuit breaker open signal, whereas the TCSSCBR2_TCM-2 function is blocked by the master trip TRPPTRC6_68/94-6 and the field excitation open signal.

It is assumed that there is no external resistor in the circuit breaker tripping coil circuit connected in parallel with the circuit breaker normally open auxiliary contact.

Set the parameters for TCSSCBR1_TCM-1 properly.

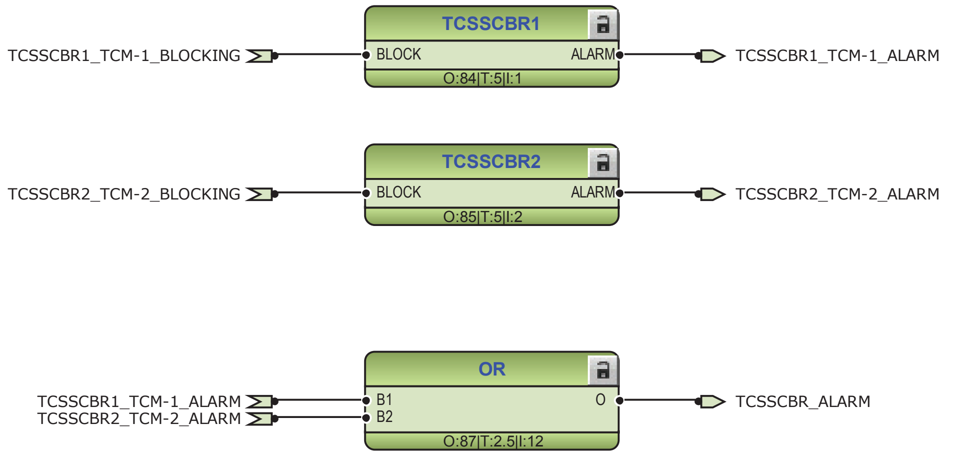


Figure 94: Trip circuit supervision function

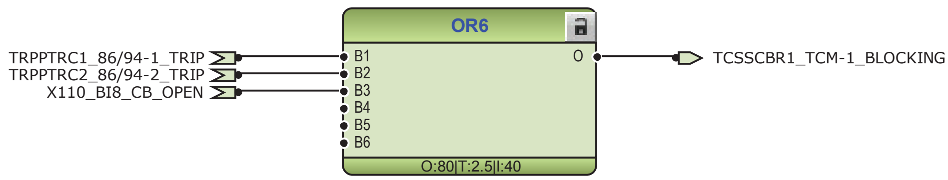


Figure 95: Logic for blocking of trip circuit supervision of generator circuit breaker

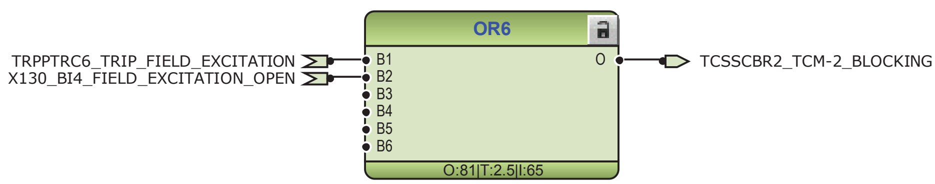


Figure 96: Logic for blocking of trip circuit supervision of field excitation circuit breaker

Runtime counter for machines and devices MDSOPT1_OPTM-1 provides history data since the last commissioning. The counter counts the total number of generator running hours and is incremented when the energizing circuit breaker is closed.

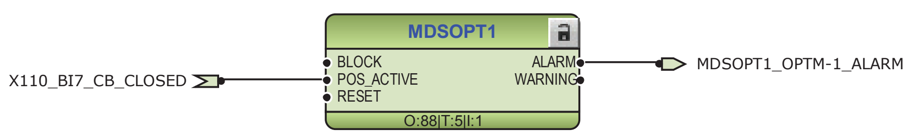


Figure 97: Generator runtime counter

3.4.3.4 Functional diagrams for control and interlocking

The main purpose of the synchronism and energizing check SECRSYN_25 is to provide control over the closing of the circuit breakers in power networks to prevent the closing if conditions for synchronism are not detected. The energizing function allows closing, for example, when one side of the breaker is dead.

SECRSYN_25 measures the bus and line voltages and compares them to set conditions. When all the measured quantities are within the set limits, the output `SYNC_OK` is activated for closing the circuit breaker or allowing the closing. The `SECRSYN1_25_SYNC_OK` output signal of SECRSYN is connected to `SYNC_OK` input of CBXCBR1_52-1 through control logic. The function is blocked in case of terminal side or bus side MCB is open.

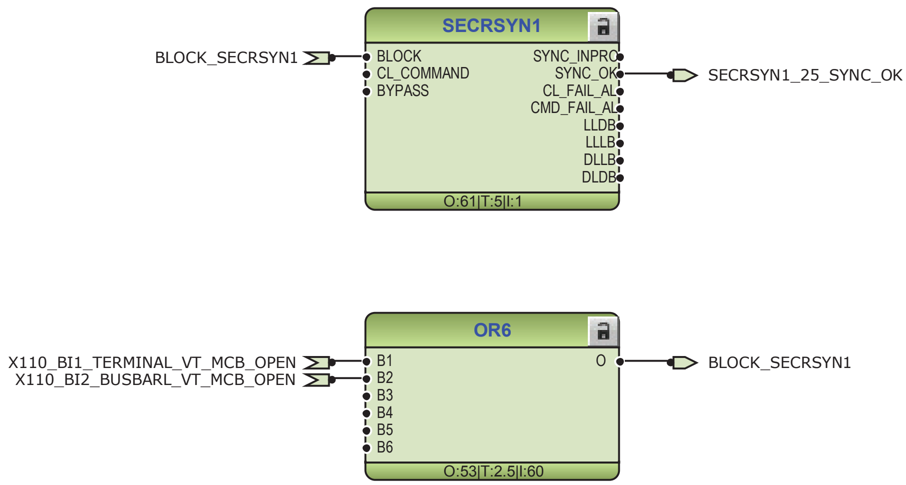


Figure 98: Synchrocheck function

The circuit breaker closing is disabled by default, as in case of generator, the closing of the circuit breaker is done by a special synchronizer device.

The `OKPOS` output from DCSXSWI defines whether the disconnector or breaker truck is open (in test position) or closed (in service position). This output, together with the open ground switch and non-active trip signals, activates the close-enable signal to the circuit breaker control function block. The open operation for circuit breaker is always enabled.

Connect the additional signals required for the application for opening of circuit breaker.

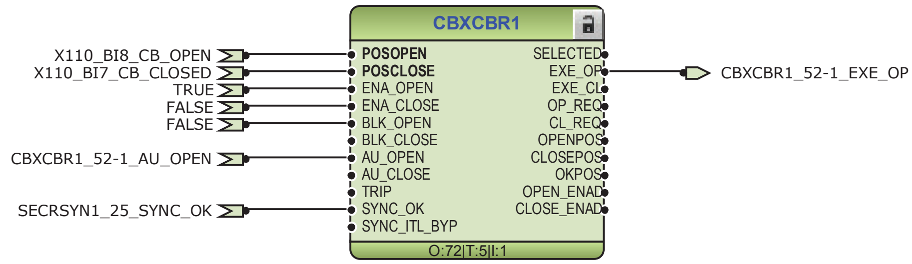


Figure 99: Circuit breaker 1 control logic

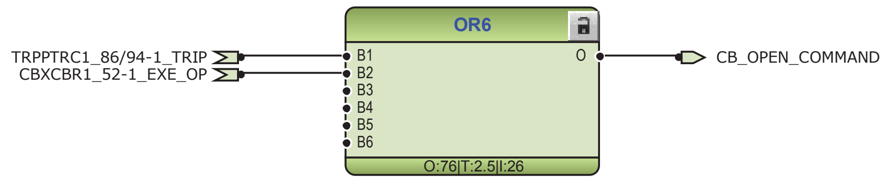


Figure 100: Signal for opening coil of circuit breaker 1

The configuration includes the logic for generating circuit breaker external opening command with the relay in local or remote mode.

Connect additional signals for opening of circuit breaker in local or remote mode, if applicable for the configuration.

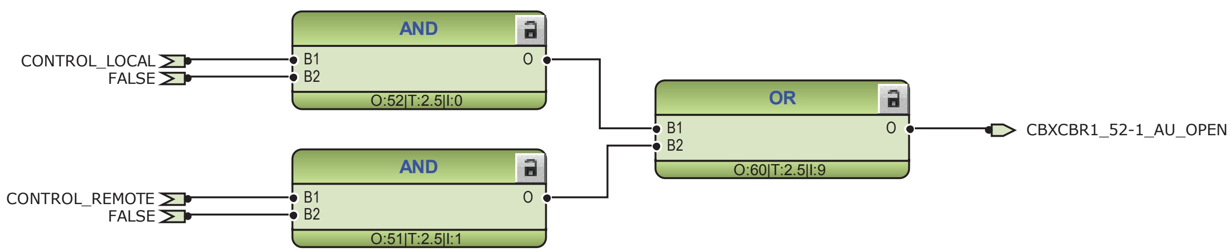


Figure 101: External opening command for circuit breaker 1

3.4.3.5 Functional diagrams for measurement functions

The phase current inputs to the relay are measured by the three-phase current measurement function CMMXU1. The phase current terminal side current inputs to the relay are measured by the three-phase current measurement function CMMXU2. The three-phase current input is connected to the X120 card in the back panel. The sequence current measurement CSMSQI1 measures the sequence current and the residual current measurement RESCMMXU1 measures the residual current.

The three-phase terminal side voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU1. The synchronism voltage inputs to the relay are measured by the three-phase voltage measurement function VMMXU2.In addition to phase voltage, residual voltage are measured by residual voltage measurement RESVMMXU1. The three-phase voltage input as well as residual voltages are connected to the X130 card in the back panel. The sequence voltage measurement VSMSQI1 measures the sequence voltage.

The measurements can be seen in the LHMI and they are available under the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm or warning and high alarm or warning signals for the measured current values.

The frequency measurement FMMXU1 of the power system and three-phase power and energy measurement PEMMXU1 are available. Load profile record LDPRLRC1 is included in the measurements sheet. LDPRLRC1 offers the ability to observe the loading history of the corresponding feeder.

Figure 102: Three-phase current measurement

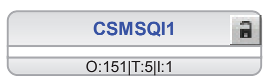


Figure 103: Sequence current measurements

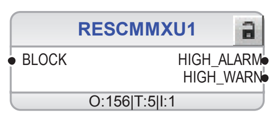


Figure 104: Ground current measurements

Figure 105: Three-phase voltage measurement

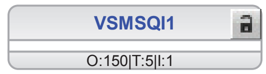


Figure 106: Sequence voltage measurements

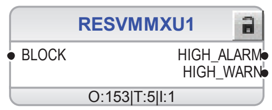


Figure 107: Ground voltage measurements

Figure 108: Frequency measurement

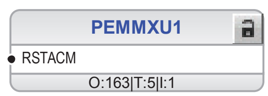


Figure 109: Three-phase power and energy measurement

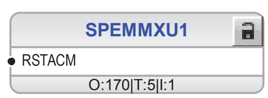


Figure 110: Single phase power and energy measurement

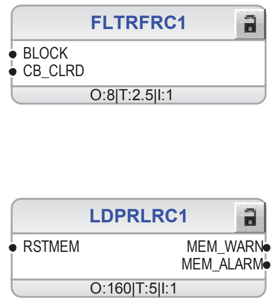


Figure 111: Data monitoring and load profile record

3.4.3.6 Functional diagrams for I/O and alarm LEDs

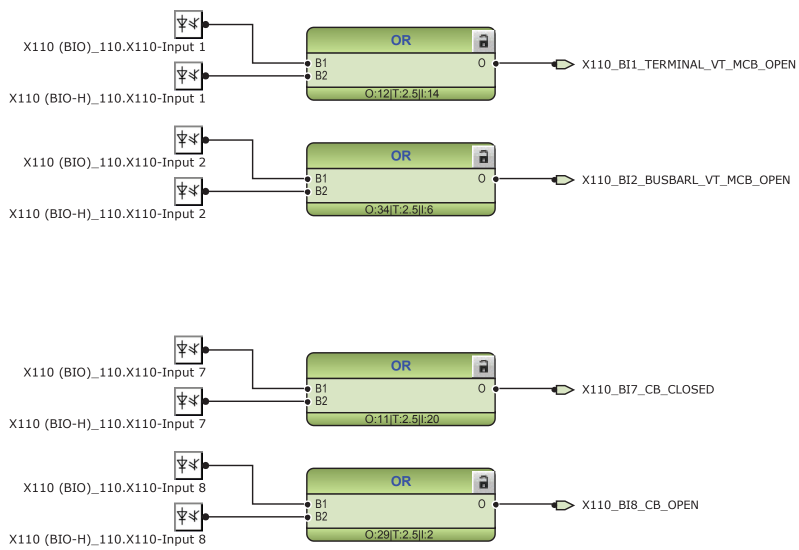


Figure 112: Default binary inputs - X110

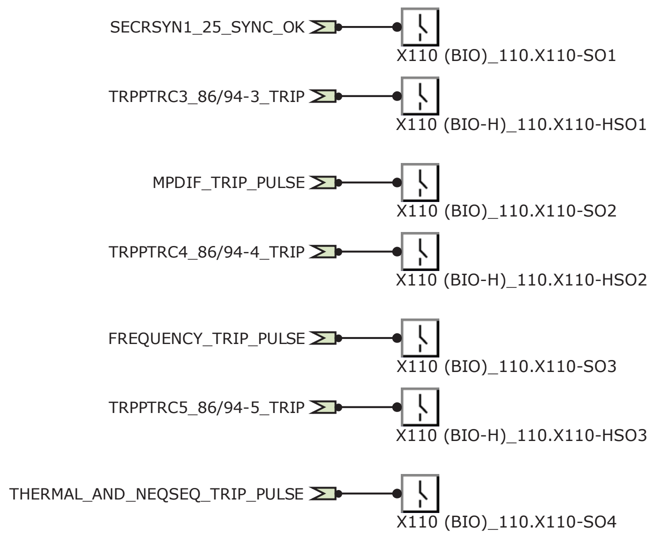


Figure 113: Default binary outputs - X110

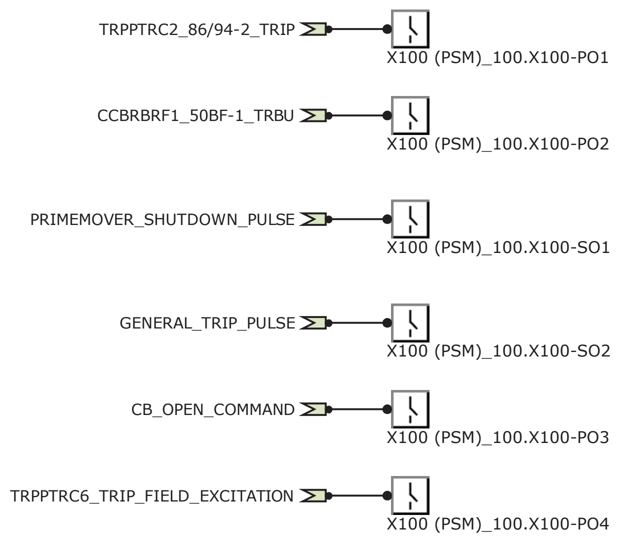


Figure 114: Default binary outputs - X100

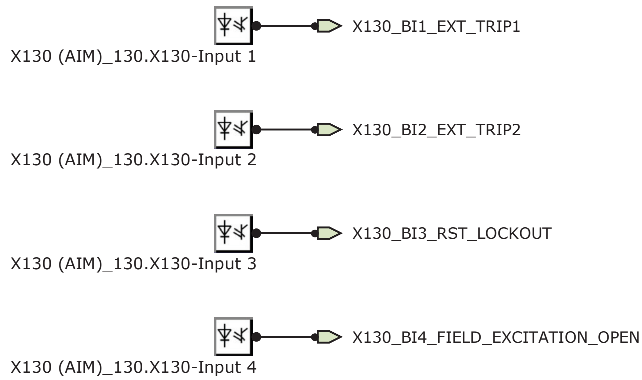


Figure 115: Default binary input - X130

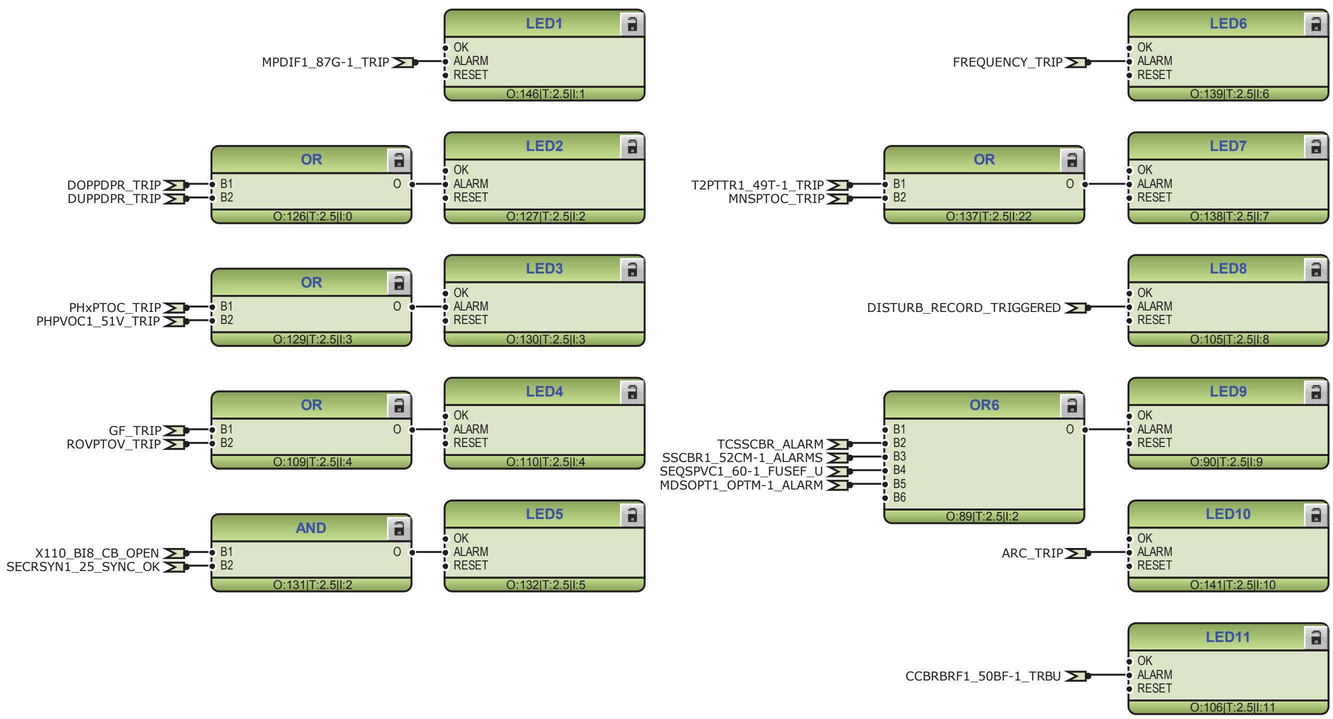


Figure 116: Default LED connection

3.4.3.7 Functional diagrams for other functions

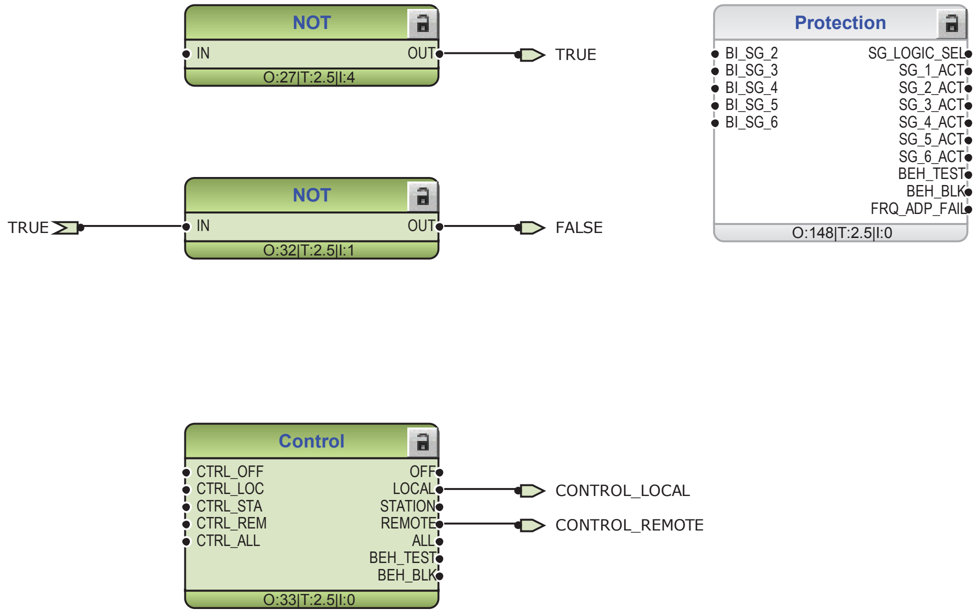


Figure 117: Functions for general logic states TRUE and FALSE, protection setting group selection and local and remote control

Other functions include generic function blocks which are related to the relay only, for example, local/remote switch, some generic functions related to logic TRUE or FALSE, push button logic (valid for certain relay types) and so on.

3.4.3.8 Functional diagrams for communication

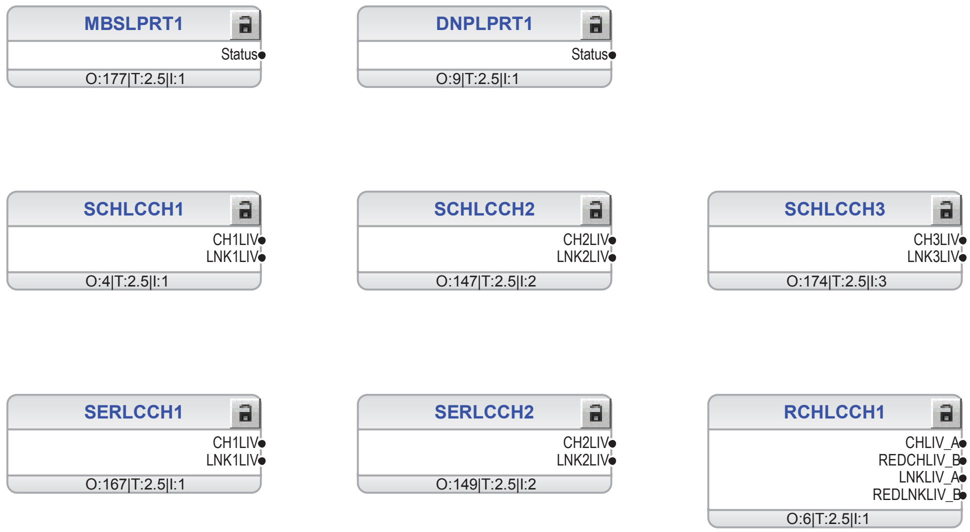


Figure 118: Default communication function connection

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. The protection settings of the protection relay should be defined in accordance with the CT performance as well as other factors.

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 21: 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. This should be noted also if there are accuracy requirements for the metering functions (current metering, power metering, and so on) of the protection relay.

The CT accuracy primary limit current describes the highest fault current magnitude at which the CT fulfils the specified accuracy. Beyond this level, the secondary current of the CT is distorted and it might have severe effects on the performance of the protection relay.

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 pickup current settings

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

Current pickup 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 trip 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 pickup 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 trip 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 pickup current. This depends on the accuracy limit factor of the CT, on the remanence flux of the core of the CT, and on the trip 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.

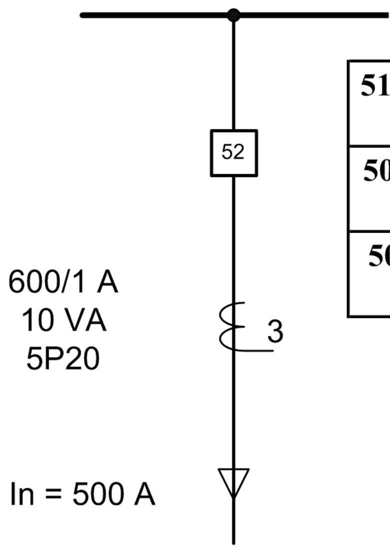
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the pickup current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

The *Current pickup value* is the primary pickup 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.



51P	**1200 A** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
50P-1/2	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
50P-3	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 119: 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 pickup current setting for low-set stage (51P) is selected to be about twice the nominal current of the cable. The trip time is selected so that it is selective with the next protection relay (not visible in Figure 119). 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 pickup current settings have to be defined so that the protection relay operates with the minimum fault current and it does not trip with the maximum load current. The settings for all three stages are as in Figure 119.

For the application point of view, the suitable setting for instantaneous stage (50P-3) 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 22: Phase current inputs included in configuration C

Terminal	Description
X120:7-8	IA
X120:9-10	IB
X120:11-12	IC

Table 23: Phase current inputs included in configuration D

Terminal	Description
X120:1-2	IA(2)
X120:3-4	IB(2)
X120:5-6	IC(2)
X120:7-8	IA(1)
X120:9-10	IB(1)
X120:11-12	IC(1)

5.1.1.2 Ground current

Table 24: Ground current input included in configurations C and D

Terminal	Description
X120:13-14	IG

5.1.1.3 Phase voltages

Table 25: Phase voltage inputs included in configurations C and D

Terminal	Description
X130:11-12	VA
X130:13-14	VB
X130:15-16	VC

Table 26: Reference voltage input for SECRSYN1 included in configuration D

Terminal	Description
X130:9-10	V12B

5.1.1.4 Ground voltage

Table 27: Additional residual voltage inputs included in configurations C and D

Terminal	Description
X130:9-10	V0B 1)
X130:17-18	V0

1) Used only for H3EFPSEF1 in configuration C

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 is marked on the LHMI of the protection relay on the top of the HMI of the plug-in unit.

Table 28: 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 digital fault recorder or for remote control of protection relay's settings.

Binary inputs of slot X110 are available with configurations C and D.

Table 29: Binary input terminals X110:1-13 with BIO0005 module

Terminal	Description
X110:1 X110:2	BI1, + BI1, -
X110:3 X110:4	BI2, + BI2, -
X110:5 X110:6	BI3, + BI3, -
X110:6 X110:7	BI4, - BI4, +
X110:8 X110:9	BI5, + BI5, -
X110:9 X110:10	BI6, - BI6, +
X110:11 X110:12	BI7, + BI7, -
X110:12 X110:13	BI8, - BI8, +

Table 30: Binary input terminals X110:1-10 with BIO0007 module

Terminal	Description
X110:1 X110:5	BI1, + BI1, -
X110:2 X110:5	BI2, + BI2, -
X110:3 X110:5	BI3, + BI3, -
X110:4 X110:5	BI4, + BI4, -
X110:6 X110:10	BI5, + BI5, -
X110:7 X110:10	BI6, + BI6, -
X110:8 X110:10	BI7, + BI7, -
X110:9 X110:10	BI8, + BI8, -

Binary inputs of slot X120 are available with configuration C and D.

Table 31: 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 C and D.

Table 32: Binary input terminals X130:1-8 with AIM0006 module

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

5.1.4 Optional light sensor inputs

If the protection relay is provided with the optional communication module with light sensor inputs, the pre-manufactured lens-sensor fibers are connected to inputs X13, X14 and X15. See the connection diagrams.For further information, see arc flash detector.

The protection relay is provided with connection sockets X13, X14 and X15 only if the optional communication module with light sensor inputs has been installed. If the arc flash detector option is selected when ordering a protection relay, the light sensor inputs are included in the communication module.

Table 33: Light sensor input connectors

Terminal	Description
X13	Input Light sensor 1
X14	Input Light sensor 2
X15	Input Light sensor 3

5.1.5 RTD/mA inputs

It is possible to connect mA and RTD based measurement sensors to the protection relay if the protection relay is provided with the AIM0003 module in standard configurations C and D.

Table 34: Optional RTD/mA inputs with AIM0003 module

Terminal	Description
X130:1	mA 1 (AI1), +
X130:2	mA 1 (AI1), -
X130:3	RTD1 (AI2), +
X130:4	RTD1 (AI2), -
X130:5	RTD1 (AI2), ground
X130:6	RTD2 (AI3), +
X130:7	RTD2 (AI3), -
X130:8	RTD2 (AI3), ground

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 35: Output contacts

Terminal	Description
X100:6	PO1, NO
X100:7	PO1, NO
X100:8	PO2, NO
X100:9	PO2, NO
X100:15	PO3, NO (TCM resistor)

Table continues on next page

Terminal	Description
X100:16	PO3, NO
X100:17	PO3, NO
X100:18	PO3 (TCM1 input), NO
X100:19	PO3 (TCM1 input), NO
X100:20	PO4, NO (TCM resistor)
X100:21	PO4, NO
X100:22	PO4, NO
X100:23	PO4 (TCM2 input), NO
X100:24	PO4 (TCM2 input), NO

5.2.2 Outputs for signalling

SO output contacts can be used for signalling on pickup and tripping of the protection relay. On delivery from the factory, the pickup and alarm signals from all the protection stages are routed to signalling outputs.

Table 36: 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 X110 are available with configurations C and D.

Output contacts of slot X110 are optional.

Table 37: Output contacts X110:14-24 with BIO0005

Terminal	Description
X110:14	SO1, common
X110:15	SO1, NO
X110:16	SO1, NC
X110:17	SO2, common
X110:18	SO2, NO
X110:19	SO2, NC
X110:20	SO3, common
X110:21	SO3, NO

Table continues on next page

Terminal	Description
X110:22	SO3, NC
X110:23 X110:24	SO4, common SO4, NO

Table 38: Optional high-speed output contacts X110:15-24 with BIO0007

Terminal	Description
X110:15 X110:16	HSO1, NO HSO1, NO
X110:19 X110:20	HSO2, NO HSO2, NO
X110:23 X110:24	HSO3, NO HSO3, NO

5.2.3 IRF

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

Table 39: IRF contact

Terminal	Description
X100:3	IRF, common
X100:4	Closed; IRF, or V_{aux} disconnected
X100:5	Closed; no IRF, and V_{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
615 series	Series of numerical protection and control relays for protection and supervision applications of utility substations, and industrial switchgear and equipment
AI	Analog input
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
AVR	Automatic voltage regulator
BI	Binary input
BIO	Binary input and output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
DAN	Doubly attached node
DC	1. Direct current 2. Disconnector 3. Double command
DFR	Digital fault recorder
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
FTP	File transfer protocol

FTPS	FTP Secure
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HSO	High-speed output
HSR	High-availability seamless redundancy
HTTPS	Hypertext Transfer Protocol Secure
I/O	Input/output
IEC 61850	International standard for substation communication and modeling
IEC 61850-9-2 LE	Lite Edition of IEC 61850-9-2 offering process bus interface
IP	Internet protocol
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.
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
MAC	Media access control
MCB	Miniature circuit breaker
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
NC	Normally closed
NO	Normally open
PCM600	Protection and Control IED Manager
PO	Power output
PRP	Parallel redundancy protocol
RIO600	Remote I/O unit
RJ-45	Galvanic connector type
RSTP	Rapid spanning tree protocol

RTD	Resistance temperature detector
RTU	Remote terminal unit
SAN	Single attached node
Single-line diagram	Simplified notation for representing a three-phase power system. Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.
SLD	Single-line diagram
SNTP	Simple Network Time Protocol
SO	Signal output
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
UDP	User datagram protocol
UL	Underwriters Laboratories
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

—
ABB Distribution Solutions
Distribution Automation
P.O. Box 699
FI-65101 VAASA, Finland
Phone +358 10 22 11

ABB Inc.
655 Century Point
Lake Mary, FL 32746, USA
Phone +1-800-222 1946

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