RELION® 630 SERIES

Generator Protection and Control REG630

Application Manual

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Table of contents

Section 1 Introduction

1.1 This manual

The application manual contains descriptions of preconfigurations. The manual can be used as a reference for configuring control, protection, measurement, recording and LED functions. The manual can also be used when creating configurations according to specific application requirements.

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

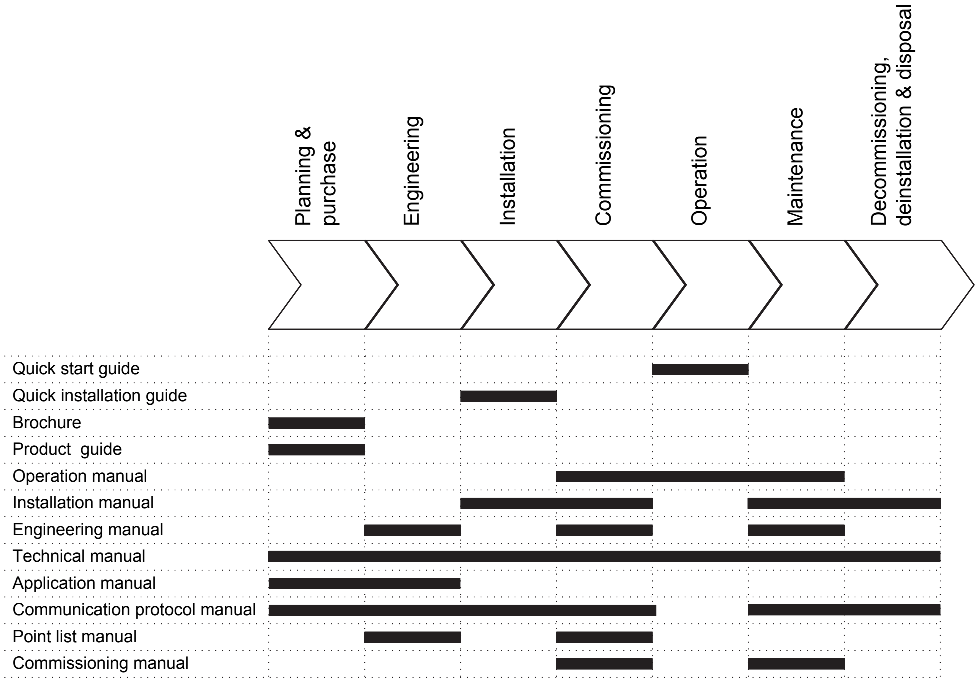


Figure 1: The intended use of documents during the product life cycle

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/2012-08-29	1.2	First release
B/2014-11-28	1.3	Content updated to correspond to the product version
C/2019-02-25	1.3	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
DNP3 Communication Protocol Manual	1MRS756789
IEC 61850 Communication Protocol Manual	1MRS756793
IEC 60870-5-103 Communication Protocol Manual	1MRS757203
Installation Manual	1MRS755958
Operation Manual	1MRS756509
Technical Manual	1MRS756508
Engineering Manual	1MRS756800
Commissioning Manual	1MRS756801

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**.
- WHMI menu names are presented in bold.
  Click **Information** in the WHMI menu structure.
- 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.
- The ^ character in front of an input or output signal name in the function block symbol given for a function, indicates that the user can set an own signal name in PCM600.
- The * character after an input or output signal name in the function block symbol given for a function, indicates that the signal must be connected to another function block in the application configuration to achieve a valid application configuration.

1.4.3 Functions, codes and symbols

Table 1: Functions included in the relay

Description	IEC 61850	IEC 60617	ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	3I>	51P-1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	3I>>	51P-2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	3I>>>	50P/51P
Voltage dependent overcurrent protection	PHPVOC	I(U)>	51V
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67-2
Non-directional earth-fault protection, low stage	EFLPTOC	I0>	51N-1
Non-directional earth-fault protection, high stage	EFHPTOC	I0>>	51N-2
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	I0>>>	50N/51N

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Directional earth-fault protection, low stage	DEFLPDEF	I0> ->	67N-1
Directional earth-fault protection, high stage	DEFHPDEF	I0>> ->	67N-2
Third harmonic based stator earth-fault protection	H3EFPSEF	dUo(3H)>/ Uo(3H)<	27/59THD
High-impedance based restricted earth-fault protection	HREFPDIF	dI0Hi>	87NH
Rotor earth-fault protection	MREFPTOC	Io>R	64R
Negative-sequence overcurrent protection for machines	MNSPTOC	I2>G/M	46G/46M
Three-phase thermal overload protection, two time constants	T2PTTR	3Ith>T/G	49T/G
Three-phase current inrush detection	INRPHAR	3I2f>	68
Transformer differential protection for two-winding transformers	TR2PTDF	3dI>T	87T
High-impedance or flux-balance based differential protection for machines	MHZPDIF	3dIHi>G/M	87GH/87MH
Stabilized differential protection for machines	MPDIF	3dI>G/M	87G/87M
Three-phase overvoltage protection	PHPTOV	3U>	59
Three-phase undervoltage protection	PHPTUV	3U<	27
Positive-sequence overvoltage protection	PSPTOV	U1>	47O+
Positive-sequence undervoltage protection	PSPTUV	U1<	47U+
Negative-sequence overvoltage protection	NSPTOV	U2>	47O-
Residual overvoltage protection	ROVPTOV	U0>	59G
Directional reactive power undervoltage protection	DQPTUV	Q>-->,3U<	32Q,27
Reverse power/directional overpower protection	DOPPDPR	P>	32R/32O
Underpower protection	DUPPDPR	P<	32U
Frequency gradient protection	DAPFRC	df/dt>	81R
Overfrequency protection	DAPTOF	f>	81O
Underfrequency protection	DAPTUF	f<	81U
Low voltage ride through protection function	LVRTPTUV	U<RT	27RT
Overexcitation protection	OEPVPH	U/f>	24
Voltage vector shift protection	VVSPPAM	VS	78V
Three-phase underexcitation protection	UEXPDIS	X<	40
Three-phase underimpedance protection	UZPDIS	Z< GT	21GT
Circuit breaker failure protection	CCBRBRF	3I>/I0>BF	51BF/51NBF
Tripping logic	TRPPTRC	I -> O	94
Multipurpose analog protection	MAPGAPC	MAP	MAP
Control			
Bay control	QCCBAY	CBAY	CBAY
Interlocking interface	SCILO	3	3
Table continues on next page			

Description	IEC 61850	IEC 60617	ANSI
Circuit breaker/disconnector control	GNRLCSWI	I <-> O CB/DC	I <-> O CB/DC
Circuit breaker	DAXCBR	I <-> O CB	I <-> O CB
Disconnector	DAXSWI	I <-> O DC	I <-> O DC
Local/remote switch interface	LOCREM	R/L	R/L
Synchrocheck	SYNCRSYN	SYNC	25
Generic process I/O			
Single point control (8 signals)	SPC8GGIO	-	-
Double point indication	DPGGIO	-	-
Single point indication	SPGGIO	-	-
Generic measured value	MVGGIO	-	-
Logic Rotating Switch for function selection and LHMI presentation	SLGGIO	-	-
Selector mini switch	VSGGIO	-	-
Pulse counter for energy metering	PCGGIO	-	-
Event counter	CNTGGIO	-	-
Supervision and monitoring			
Runtime counter for machines and devices	MDSOPT	OPTS	OPTM
Circuit breaker condition monitoring	SSCBR	CBCM	CBCM
Fuse failure supervision	SEQRFUF	FUSEF	60
Current circuit supervision	CCRDIF	MCS 3I	MCS 3I
Trip-circuit supervision	TCSSCBR	TCS	TCM
Station battery supervision	SPVNZBAT	U<>	U<>
Energy monitoring	EPDMMTR	E	E
Measured value limit supervision	MVEXP	-	-
Measurement			
Three-phase current measurement	CMMXU	3I	3I
Three-phase voltage measurement (phase-to-earth)	VPHMMXU	3Upe	3Upe
Three-phase voltage measurement (phase-to-phase)	VPPMMXU	3Upp	3Upp
Residual current measurement	RESCMMXU	I0	I0
Residual voltage measurement	RESVMMXU	U0	U0
Power monitoring with P, Q, S, power factor, frequency	PWRMMXU	PQf	PQf
Sequence current measurement	CSMSQI	I1, I2	I1, I2
Sequence voltage measurement	VSMSQI	U1, U2	V1, V2
Analog channels 1-10 (samples)	A1RADR	ACH1	ACH1
Analog channels 11-20 (samples)	A2RADR	ACH2	ACH2
Analog channels 21-30 (calc. val.)	A3RADR	ACH3	ACH3
Analog channels 31-40 (calc. val.)	A4RADR	ACH4	ACH4
Table continues on next page			

Description	IEC 61850	IEC 60617	ANSI
Binary channels 1-16	B1RBDR	BCH1	BCH1
Binary channels 17 -32	B2RBDR	BCH2	BCH2
Binary channels 33 -48	B3RBDR	BCH3	BCH3
Binary channels 49 -64	B4RBDR	BCH4	BCH4
Station communication (GOOSE)			
Binary receive	GOOSEBINRCV	-	-
Double point receive	GOOSEDPRCV	-	-
Interlock receive	GOOSEINTLKRCV	-	-
Integer receive	GOOSEINTRCV	-	-
Measured value receive	GOOSEMVRCV	-	-
Single point receive	GOOSESPRCV	-	-

Section 2 REG630 overview

2.1 Overview

REG630 is a comprehensive generator management relay for protection, control, measuring and supervision of small and medium size generators. REG630 is a member of ABB's Relion® product family and a part of its 630 series characterized by functional scalability and flexible configurability.

The supported communication protocols including IEC 61850 offer seamless connectivity to industrial automation systems.

2.1.1 Product version history

Product version	Product history
1.2	First release

1.3	• Reactive power undervoltage protection
	• Vector surge
	• Low voltage ride through protection
	• Operation time counter
	• Comparison functions
	    • equality (EQ)
	    • greater than or equal (GE)
	    • greater than (GT)
	    • less than or equal (LE)
	    • less than (LT)
	    • not equal (NE)
	• AND and OR gates with 20 inputs

2.1.2 PCM600 and IED connectivity package version

- Protection and Control IED Manager PCM600 Ver. 2.5 or later
- ABB REG630 Connectivity Package Ver. 1.3 or later
  - Application Configuration
  - Parameter Setting
  - Signal Matrix
  - Signal Monitoring
  - Disturbance Handling
  - Event Viewer
  - Graphical Display Editor
  - Hardware Configuration
  - IED Users

- IED Compare
- Communication Management
- 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 Product variants

The IED capabilities can be adjusted by selecting a product variant. The IED capabilities can be extended by adding HW and/or SW options to the basic variant. For example, the physical communication connector can be either an electrical or optical Ethernet connector.

The number of binary inputs and outputs depends on the amount of the optional BIO modules selected. For a 4U IED, it is possible to take 2 additional BIO modules at the maximum, and for a 6U IED, it is possible to take 4 additional BIO modules at the maximum.

- Basic variant: 14 binary inputs and 9 binary outputs
- With one optional BIO module: 23 binary inputs and 18 binary outputs
- With two optional BIO modules: 32 binary inputs and 27 binary outputs
- With three optional BIO modules: 41 binary inputs and 36 binary outputs
- With four optional BIO modules: 50 binary inputs and 45 binary outputs

2.2.2 Optional functions

Some of the available functions are optional, that is, they are included in the delivered product only when defined by the order code.

- Transformer differential protection for two-winding transformers
- Third-harmonic based stator earth-fault protection

2.3 Physical hardware

The mechanical design of the IED is based on a robust mechanical rack. The HW design is based on the possibility to adapt the HW module configuration to different customer applications.

Table 2: IED contents

Content options	
LHMI	
Communication and CPU module	1 electrical Ethernet connector for the detached LHMI module (the connector must not be used for any other purpose) 1 Ethernet connector for communication (selectable electrical or optical connector) IRIG-B (external time synchronization) connector 1 fibre-optic connector pair for serial communication (selectable plastic or glass fibre) 14 binary control inputs
Auxiliary power/binary output module	48-125 V DC or 100-240 V AC/110-250 V DC Input contacts for the supervision of the auxiliary supply battery level 3 normally open power output contacts with TCS 3 normally open power output contacts 1 change-over signalling contact 3 additional signalling contacts 1 dedicated internal fault output contact
Analog input module	4, 7 or 8 current inputs (1/5 A) 4, 3 or 2 voltage inputs (100/110/115/120 V) With 4 current inputs (1/5 A) also max. 1 accurate current input for sensitive earth fault protection (0.1/0.5 A)
Binary input and output module	3 normally open power output contacts 1 change-over signalling contact 5 additional signalling contacts 9 binary control inputs
RTD input and mA output module	8 RTD-inputs (sensor/R/V/mA) 4 outputs (mA)

All external wiring, that is CT and VT connectors, BI/O connectors, power supply connector and communication connections, can be disconnected from the IED modules with wiring, for example, in service situations. The CT connectors have a build-in mechanism which automatically short-circuits CT secondaries when the connector is disconnected from the IED.

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.

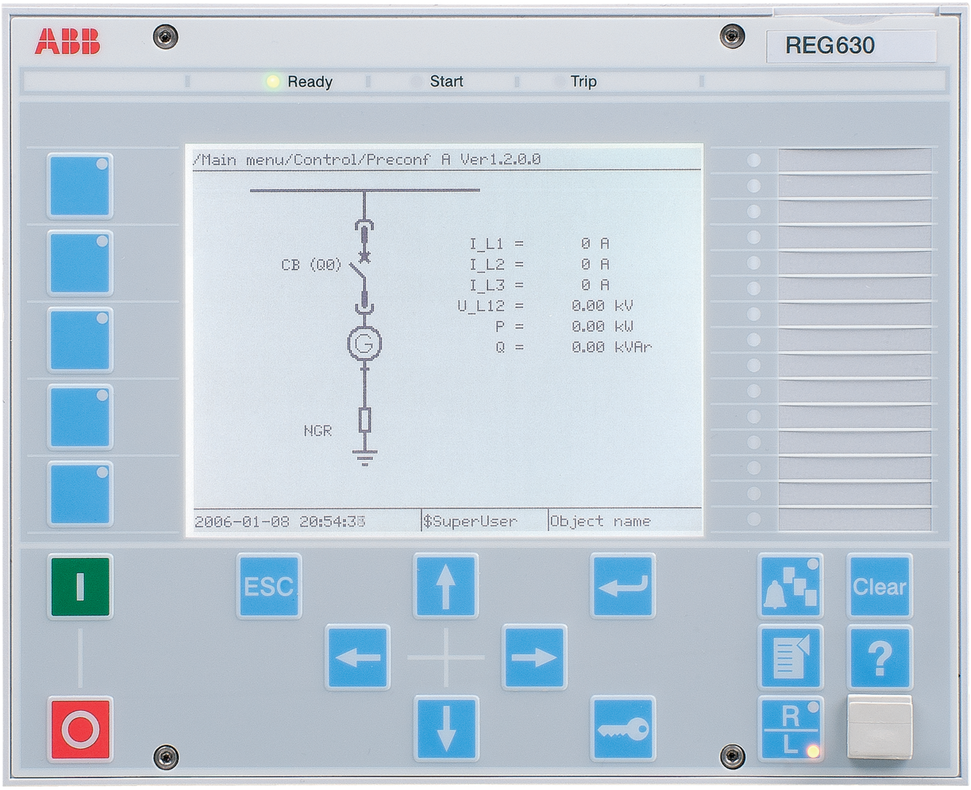


Figure 2: LHMI

2.4.1 Display

The LHMI includes a graphical monochrome display with a resolution of 320 x 240 pixels. The character size can vary. The amount of characters and rows fitting the view depends on the character size and the view that is shown.

The display view is divided into four basic areas.

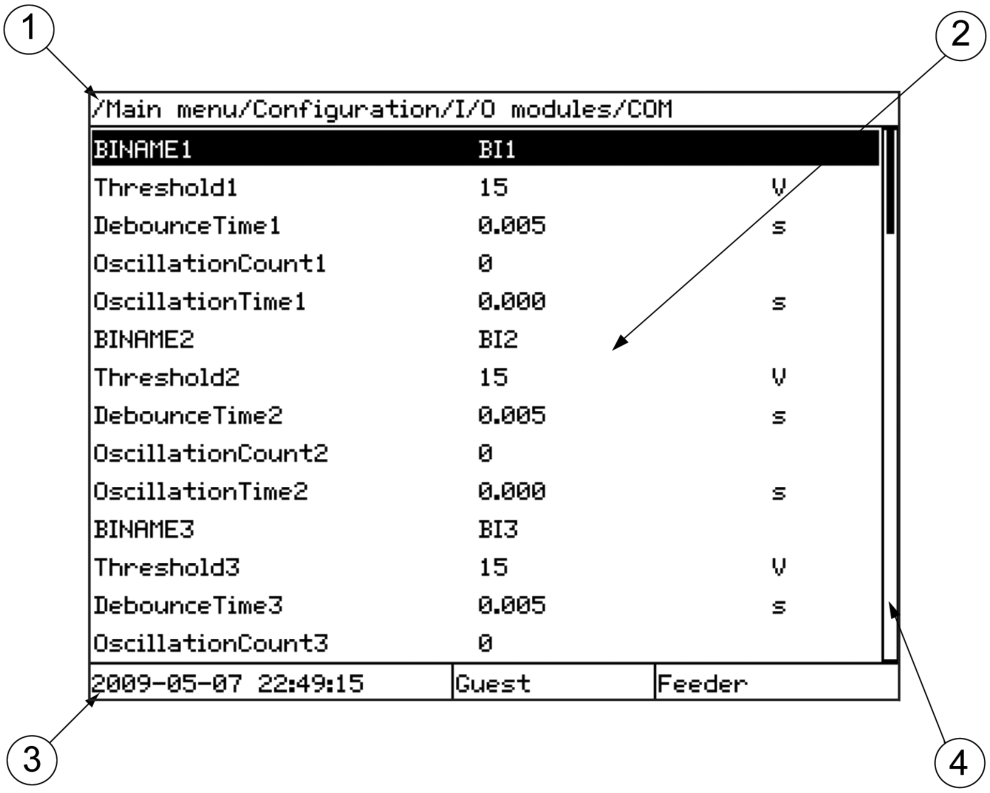


Figure 3: Display layout

1 Path

2 Content

3 Status

4 Scroll bar (appears when needed)

The function button panel shows on request what actions are possible with the function buttons. Each function button has a LED indication that can be used as a feedback signal for the function button control action. The LED is connected to the required signal with PCM600.

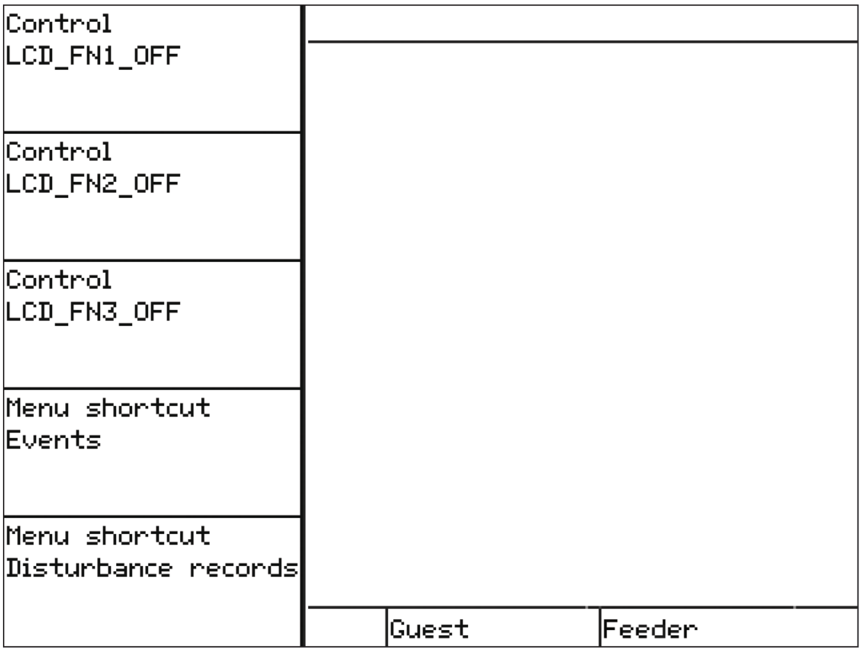


Figure 4: Function button panel

The alarm LED panel shows on request the alarm text labels for the alarm LEDs.

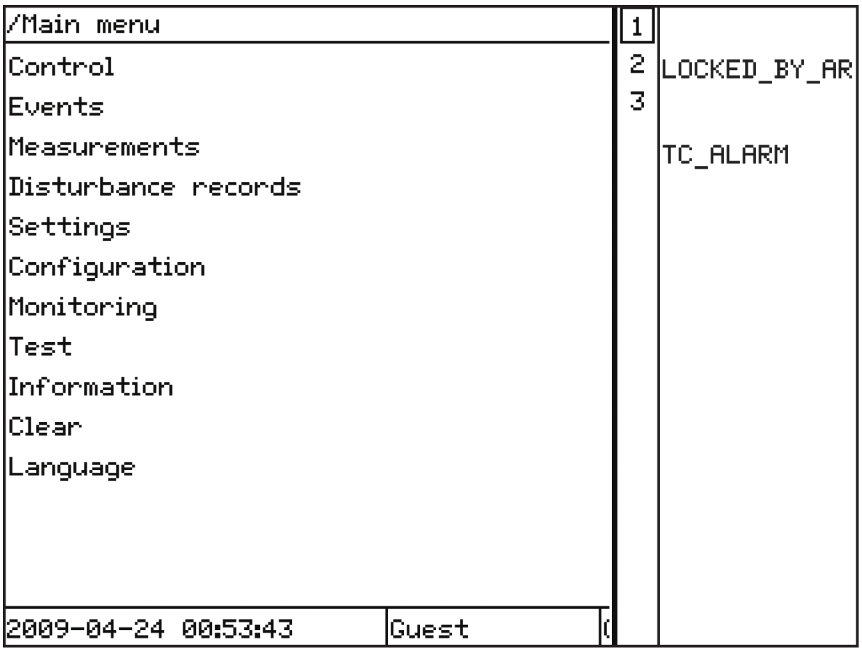


Figure 5: Alarm LED panel

The function button and alarm LED panels are not visible at the same time. Each panel is shown by pressing one of the function buttons or the Multipage button. Pressing the ESC button clears the panel from the display. Both the panels have dynamic width that depends on the label string length that the panel contains.

2.4.2 LEDs

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

There are 15 programmable alarm LEDs on the front of the LHMI. Each LED can indicate three states with the colors: green, yellow and red. The alarm texts related to each three-color LED are divided into three pages. Altogether, the 15 physical three-color LEDs can indicate 45 different alarms. The LEDs can be configured with PCM600 and the operation mode can be selected with the LHMI, WHMI or PCM600.

2.4.3 Keypad

The LHMI keypad contains push-buttons which are used to navigate in different views or menus. With the push-buttons you can control objects in the single-line diagram, for example, circuit breakers or disconnectors The push-buttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

The keypad also contains programmable push-buttons that can be configured either as menu shortcut or control buttons.

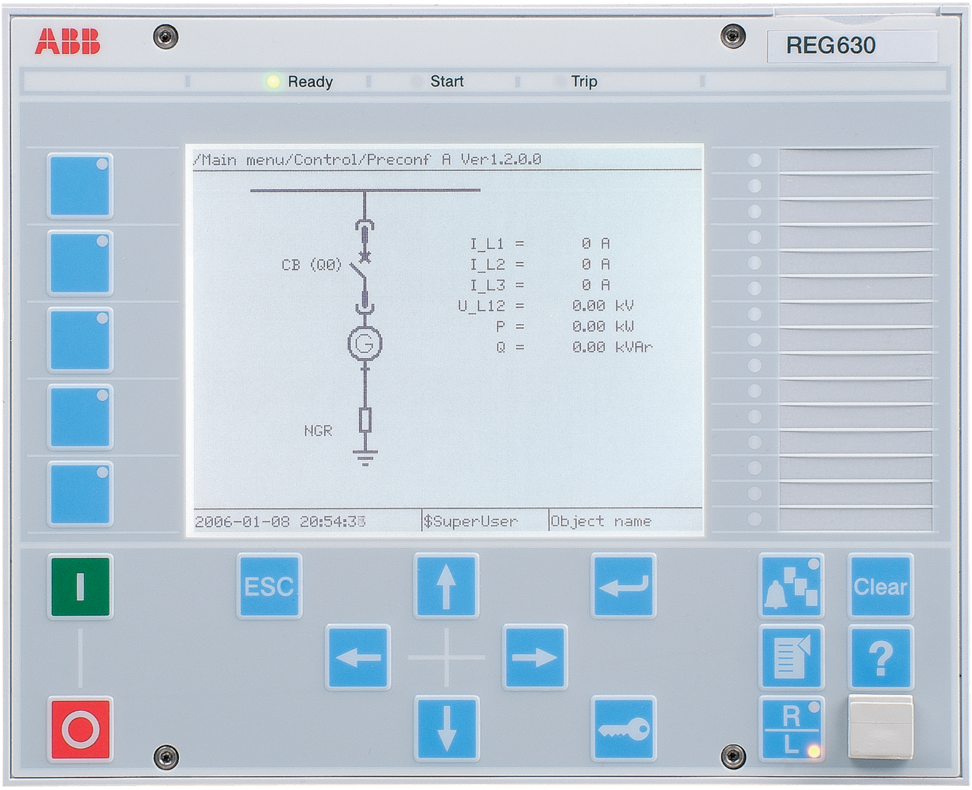


Figure 6: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

2.5 Web HMI

The WHMI enables the user to access the IED via a web browser. The supported Web browser versions are Internet Explorer 8.0, 9.0 and 10.0.

WHMI is disabled by default. To enable the WHMI, select **Main menu/Configuration/HMI/Web HMI/Operation** via the LHMI.

WHMI offers several functions.

- Alarm indications and event lists
- System supervision
- Parameter settings
- Measurement display
- Disturbance records
- Phasor diagram

Viewing phasor diagram with WHMI requires downloading a SVG Viewer plugin.

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

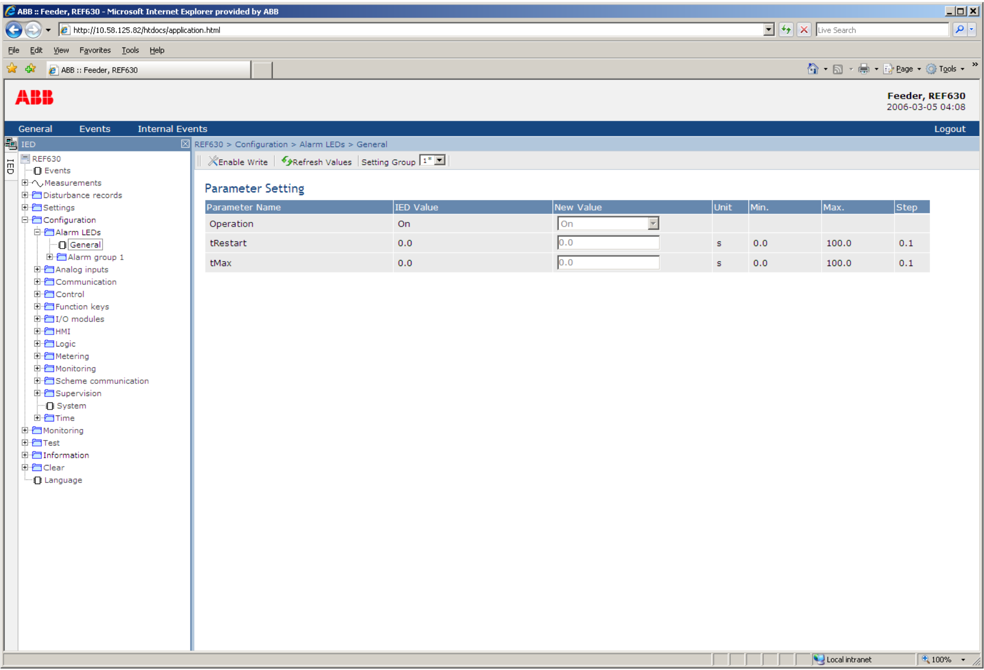


Figure 7: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting the user's computer to the IED via the front communication port.
- Remotely over LAN/WAN.

2.6 Authorization

At delivery, logging on to the IED is not required to be able to use the LHMI. The IED user has full access to the IED as a SuperUser until users and passwords are created with PCM600 and written into the IED.

The available user categories are predefined for LHMI and WHMI, each with different rights.

Table 3: Available user categories

User category	User rights
SystemOperator	Control from LHMI, no bypass
ProtectionEngineer	All settings
DesignEngineer	Application configuration
UserAdministrator	User and password administration

All changes in user management settings cause the IED to reboot.

2.7 Communication

The protection relay supports communication protocols IEC 61850-8-1, IEC 60870-5-103 and DNP3 over TCP/IP.

All operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication (GOOSE) between the protection relays, is only enabled by the IEC 61850-8-1 communication protocol.

Disturbance files are accessed using the IEC 61850 or IEC 60870-5-103 protocols. Disturbance files are also available to any Ethernet based application in the standard COMTRADE format. The protection relay can send binary signals to other protection relays (so called horizontal communication) using the IEC 61850-8-1 GOOSE

(Generic Object Oriented Substation Event) profile. Binary GOOSE messaging can, for example, be employed for protection and interlocking-based protection schemes. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard. Further, the protection relay supports the sending and receiving of analog values using GOOSE messaging. Analog GOOSE messaging enables fast transfer of analog measurement values over the station bus, thus facilitating for example sharing of RTD input values, such as surrounding temperature values, to other relay applications. The protection relay interoperates with other IEC 61850 compliant devices, tools and systems and simultaneously reports events to five different clients on the IEC 61850 station bus. For a system using DNP3 over TCP/IP, events can be sent to four different masters. For systems using IEC 60870-5-103, the protection relay can be connected to one master in a station bus with star-topology.

All communication connectors, except for the front port connector, are placed on integrated communication modules. The protection relay is connected to Ethernet-based communication systems via the RJ-45 connector (10/100BASE-TX) or the fibre-optic multimode LC connector (100BASE-FX).

IEC 60870-5-103 is available from optical serial port where it is possible to use serial glass fibre (ST connector) or serial plastic fibre (snap-in connector).

The protection relay supports the following time synchronization methods with a timestamping resolution of 1 ms.

Ethernet communication based

- SNTP (simple network time protocol)
- DNP3

With special time synchronization wiring

- IRIG-B

IEC 60870-5-103 serial communication has a time-stamping resolution of 10 ms.

Section 3 REG630 variants

3.1 Presentation of preconfigurations

The 630 series protection relays are offered with optional factory-made preconfigurations for various applications. The preconfigurations contribute to faster commissioning and less engineering of the protection relay. The preconfigurations include default functionality typically needed for a specific application. Each preconfiguration is adaptable using the Protection and Control IED Manager PCM600. By adapting the preconfiguration the protection relay can be configured to suit the particular application.

The adaptation of the preconfiguration may include adding or removing of protection, control and other functions according to the specific application, changing of the default parameter settings, configuration of the default alarms and event recorder settings including the texts shown in the HMI, configuration of the LEDs and function buttons, and adaptation of the default single-line diagram.

In addition, the adaptation of the preconfiguration always includes communication engineering to configure the communication according to the functionality of the protection relay. The communication engineering is done using the communication configuration function of PCM600.

If none of the offered preconfigurations fulfill the needs of the intended area of application, 630 series protection relays can also be ordered without any preconfiguration. In this case the protection relay needs to be configured from the ground up.

The functional diagrams are divided into sections which each constitute one functional entity. The external connections are also divided into sections. Only the relevant connections for a particular functional entity are presented in each section.

Protection function blocks are part of the functional diagram. They are identified based on their IEC 61850 name but the IEC based symbol and the ANSI function number are also included. Some function blocks, such as PHHPTOC, are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name, IEC symbol and ANSI function number are appended with a running number, an instance number, from one onwards.

3.1.1 Preconfigurations

Table 4: REG630 preconfiguration ordering options

Description	Preconfiguration	
Preconfiguration A for generator	A	
Number of instances available		n

Table 5: Functions used in preconfigurations

Description	A	n
Protection		
Three-phase non-directional overcurrent protection, low stage	1	1
Three-phase non-directional overcurrent protection, high stage	1	2
Three-phase non-directional overcurrent protection, instantaneous stage	-	1
Voltage dependent overcurrent protection	2	2
Three-phase directional overcurrent protection, low stage	-	2
Three-phase directional overcurrent protection, high stage	-	1
Non-directional earth-fault protection, low stage	-	1
Non-directional earth-fault protection, high stage	-	1
Non-directional earth-fault protection, instantaneous stage	-	1
Directional earth-fault protection, low stage	1	2
Directional earth-fault protection, high stage	1	1
Third harmonic based stator earth-fault protection	-	1
High-impedance based restricted earth-fault protection	-	1
Rotor earth-fault protection	-	1
Negative-sequence overcurrent protection for machines	2	2
Three-phase thermal overload protection, two time constants	1	1
Three-phase current inrush detection	-	1
Transformer differential protection for two-winding transformers	-	1
High-impedance or flux-balance based differential protection for machines	-	1
Stabilized differential protection for machines	1	1
Three-phase overvoltage protection	2	2
Three-phase undervoltage protection	2	2
Positive-sequence overvoltage protection	-	2
Positive-sequence undervoltage protection	-	2
Negative-sequence overvoltage protection	-	2
Residual overvoltage protection	2	3
Directional reactive power undervoltage protection	-	2
Reverse power/directional overpower protection	2	3
Underpower protection	2	3
Frequency gradient protection	2	4
Table continues on next page		

Description	A	n
Overfrequency protection	2	4
Underfrequency protection	2	4
Low voltage ride through protection function	-	3
Overexcitation protection	-	2
Voltage vector shift protection	-	1
Three-phase underexcitation protection	2	2
Three-phase underimpedance protection	-	2
Circuit breaker failure protection	1	2
Tripping logic	1	2
Multipurpose analog protection	-	16
Control		
Bay control	1	1
Interlocking interface	3	10
Circuit breaker/disconnector control	3	10
Circuit breaker	1	2
Disconnector	2	8
Local/remote switch interface	-	1
Synchrocheck	-	1
Generic process I/O		
Single point control (8 signals)	-	5
Double point indication	-	15
Single point indication	-	64
Generic measured value	-	15
Logic Rotating Switch for function selection and LHMI presentation	-	10
Selector mini switch	-	10
Pulse counter for energy metering	-	4
Event counter	-	1
Supervision and monitoring		
Runtime counter for machines and devices	-	1
Circuit breaker condition monitoring	1	2
Fuse failure supervision	1	1
Current circuit supervision	-	2
Trip-circuit supervision	2	3
Station battery supervision	-	1
Energy monitoring	1	1
Measured value limit supervision	-	40
Measurement		
Three-phase current measurement	1	2
Three-phase voltage measurement (phase-to-earth)	-	2
Table continues on next page		

Description	A	n
Three-phase voltage measurement (phase-to-phase)	1	2
Residual current measurement	1	1
Residual voltage measurement	1	1
Power monitoring with P, Q, S, power factor, frequency	1	1
Sequence current measurement	1	1
Sequence voltage measurement	1	1
Disturbance recorder function		
Analog channels 1-10 (samples)	1	1
Analog channels 11-20 (samples)	-	1
Analog channels 21-30 (calc. val.)	-	1
Analog channels 31-40 (calc. val.)	-	1
Binary channels 1-16	1	1
Binary channels 17-32	1	1
Binary channels 33-48	1	1
Binary channels 49-64	1	1
Station communication (GOOSE)		
Binary receive	-	10
Double point receive	-	32
Interlock receive	-	59
Integer receive	-	32
Measured value receive	-	60
Single point receive	-	64
n = total number of available function instances regardless of the preconfiguration selected 1, 2, ... = number of included instances		

3.2 Preconfiguration A for generator

3.2.1 Application

The preconfiguration A is designed to be used for protecting generator units which are grounded through NGR. Typically, it protects a diesel generator set or an embedded power generation plant. The generator is connected to a busbar system with a truck circuit breaker.

The IED controls the circuit breaker apparatus. The switching of a NGR is not governed by the IED. Similarly, the earth switch is considered to be operated manually. The open, close and undefined status of the circuit breaker, NGR and earth switch are indicated on the LHMI.

The preconfiguration includes:

- Control functions
- Stabilized differential protection
- Current protection functions
- Voltage protection functions
- Frequency protection functions
- Supervision functions
- Disturbance recorders
- LED configurations
- Measurement functions

3.2.2 Functions

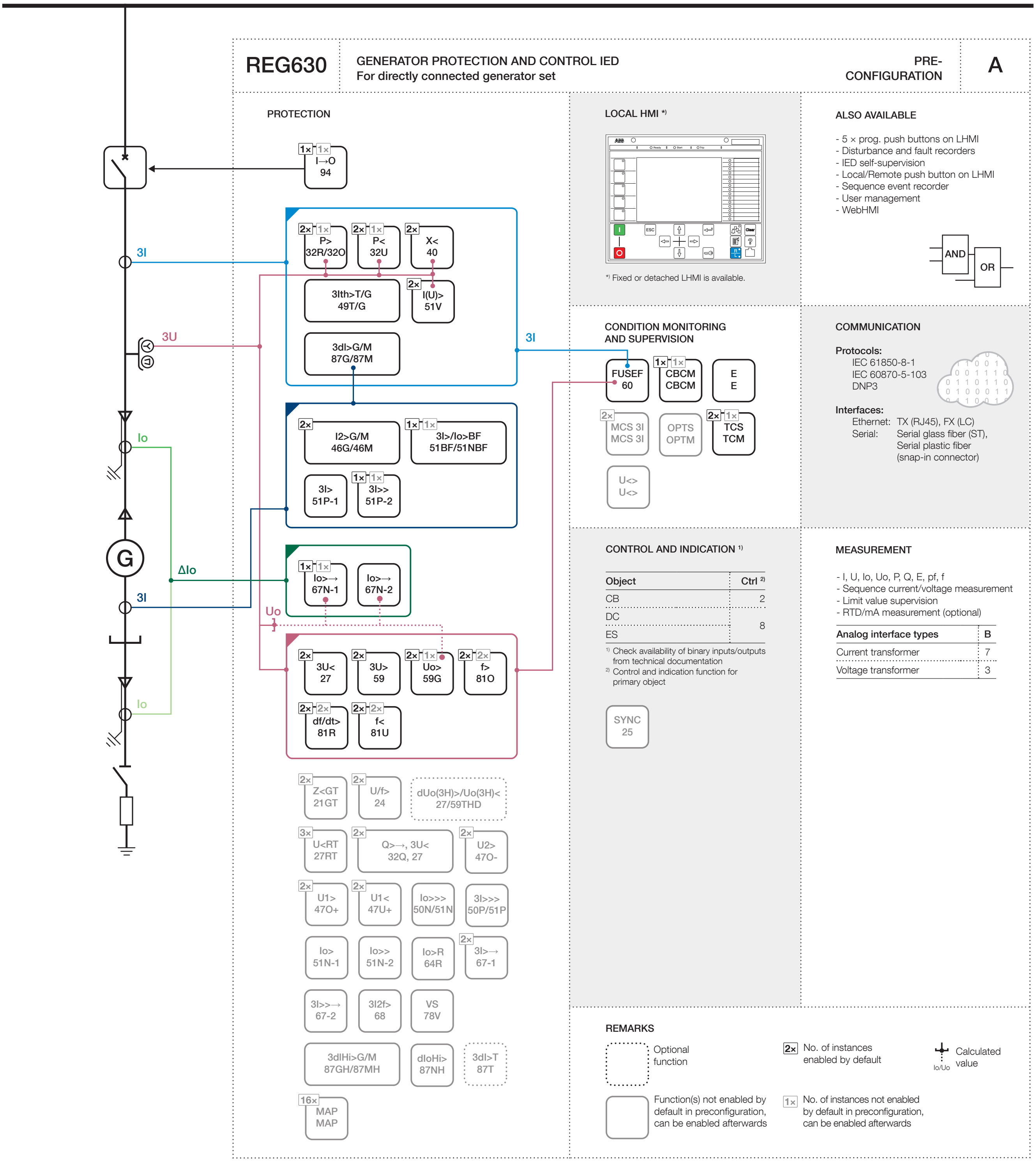


Figure 8: Functionality overview for preconfiguration A

3.2.3 Input/output signal interface

Table 6: Binary input interface

Hardware module instance	Hardware channel	Usage
COM	BI1	Generator circuit breaker close
COM	BI2	Generator circuit breaker open
COM	BI3	Generator circuit breaker truck close
COM	BI4	Generator circuit breaker truck open
COM	BI5	Earthing switch close
COM	BI6	Earthing switch open
COM	BI7	NGR switch close
COM	BI8	NGR switch open
COM	BI9	Operate signal from AVR
COM	BI10	Operate signal from turbine
COM	BI11	Lockout reset
COM	BI12	Generator circuit breaker gas pressure (lockout)
COM	BI13	Generator circuit breaker spring charged
COM	BI14	Voltage transformer MCB open

The IED outputs are categorized as power outputs (POx) and signal outputs (SOx). The power outputs can be used for starting and stopping the motor. The signal outputs are not heavy-duty outputs. They are used for alarm or signalling purposes.

Table 7: Binary output interface

Hardware module instance	Hardware channel	Usage
PSM	PO1	Master Trip 1 (generator circuit breaker open)
PSM	PO2	Generator circuit breaker close enable signal
PSM	PO3	Master Trip 2 (generator circuit breaker open)
PSM	PO4	Operate from directional over power protection
PSM	PO5	Operate from differential protection
PSM	PO6	Operate from frequency protection
PSM	SO1	Common generator circuit breaker operate signal
PSM	SO2	Common generator circuit breaker start signal
PSM	SO3	Generator circuit breaker trip circuit and monitoring alarm

The IED measures the analog signals needed for protection and measuring functions via galvanically-isolated matching transformers. The matching transformer input channels 1…7 are intended for current measuring, and the channels 8...10 for voltage measuring.

Table 8: Analog input interface

Hardware module instance	Hardware channel	Usage
AIM_2	CH1	Line-side current, IL1
AIM_2	CH2	Line-side current, IL2
AIM_2	CH3	Line-side current, IL3
AIM_2	CH4	Differential neutral current, I0
AIM_2	CH5	Neutral-side current, IL1_N
AIM_2	CH6	Neutral-side current, IL2_N
AIM_2	CH7	Neutral-side current, IL3_N
AIM_2	CH8	Line-side voltage, U1
AIM_2	CH9	Line-side voltage, U2
AIM_2	CH10	Line-side voltage, U3

3.2.4 Preprocessing blocks and fixed signals

The analog current and voltage signals coming to the IED are processed by preprocessing blocks. A preprocessing block with two different task times is available. All the function blocks functioning at 3 ms task time must be connected with a preprocessor operating at 3 ms. Similarly, all the function blocks functioning at 10 ms task time must be connected with a preprocessor operating at 10 ms.

The preprocessor calculates various quantities based on an adaptive DFT. The adaptive DFT requires a reference frequency for performing calculations. In this configuration, the voltage signals are taken as reference for calculating various phase-side and neutral-side current quantities.

See the technical manual for details on frequency adaptive.

A fixed signal block providing logical `TRUE` and `FALSE` output is used, and connected internally to other functional blocks as needed.

3.2.5 Control functions

3.2.5.1 Generator bay control QCCBAY

Bay control is used for handling the selection of the operator place per bay. It provides blocking functions that can be distributed to different apparatus within a bay. Bay control sends information about the PSTO and blocking conditions to other functions within the bay, such as to switch control functions.

3.2.5.2 Apparatus control SCILO, GNRLCSWI, DAXCBR and DAXSWI

Apparatus control initializes and supervises the proper selection and switches on primary apparatus. Each apparatus requires an interlocking function, switch control function and apparatus functions.

3.2.5.3 Circuit-breaker control function

The circuit breaker is controlled by a combination of switch interlocking function SCILO, switch controller function GNRLCSWI and circuit breaker controller function DAXCBR.

The position information of the circuit breaker and the truck is connected to DAXCBR. The interlocking logics for the circuit breaker is programmed to open at any time. The configuration is designed so that the direct closing of the breaker is prevented from the IED (as this is done after synchronisation in most of the cases). However, the configuration provides a circuit breaker closing enable signal at the binary output PO2 after evaluating certain conditions, that is, ensuring that the gas pressure inside the circuit breaker is sufficient, the spring charge time is below the set limit, and the earthing switch is in open position when the truck is in close position. This enables using the binary output PO2 externally along with the synchronizer for closing circuit breaker.

The SCILO function checks for the interlocking conditions and provides closing and opening enable signals. The enable signal is used by the GNRLCSWI function block which checks for operator place selector before providing the final open or close signal to the DAXCBR function.

The open, closed and undefined states of the circuit breaker are indicated on the LHMI.

3.2.5.4 Earthing switch control function

The earthing switch control function is used for earthing switch position indication. The IED is not used to control the switching of the earthing switch in this configuration.

The earthing switch position information is connected to respective DAXSWI via binary inputs.

3.2.5.5 Neutral grounding resistor switch control function

The earth-switch control function is used for position indication of the NGR switch. However, the IED is not used to control the switching of the NGR in this configuration.

The position information of the NGR switch is connected to the respective DAXSWI via binary inputs.

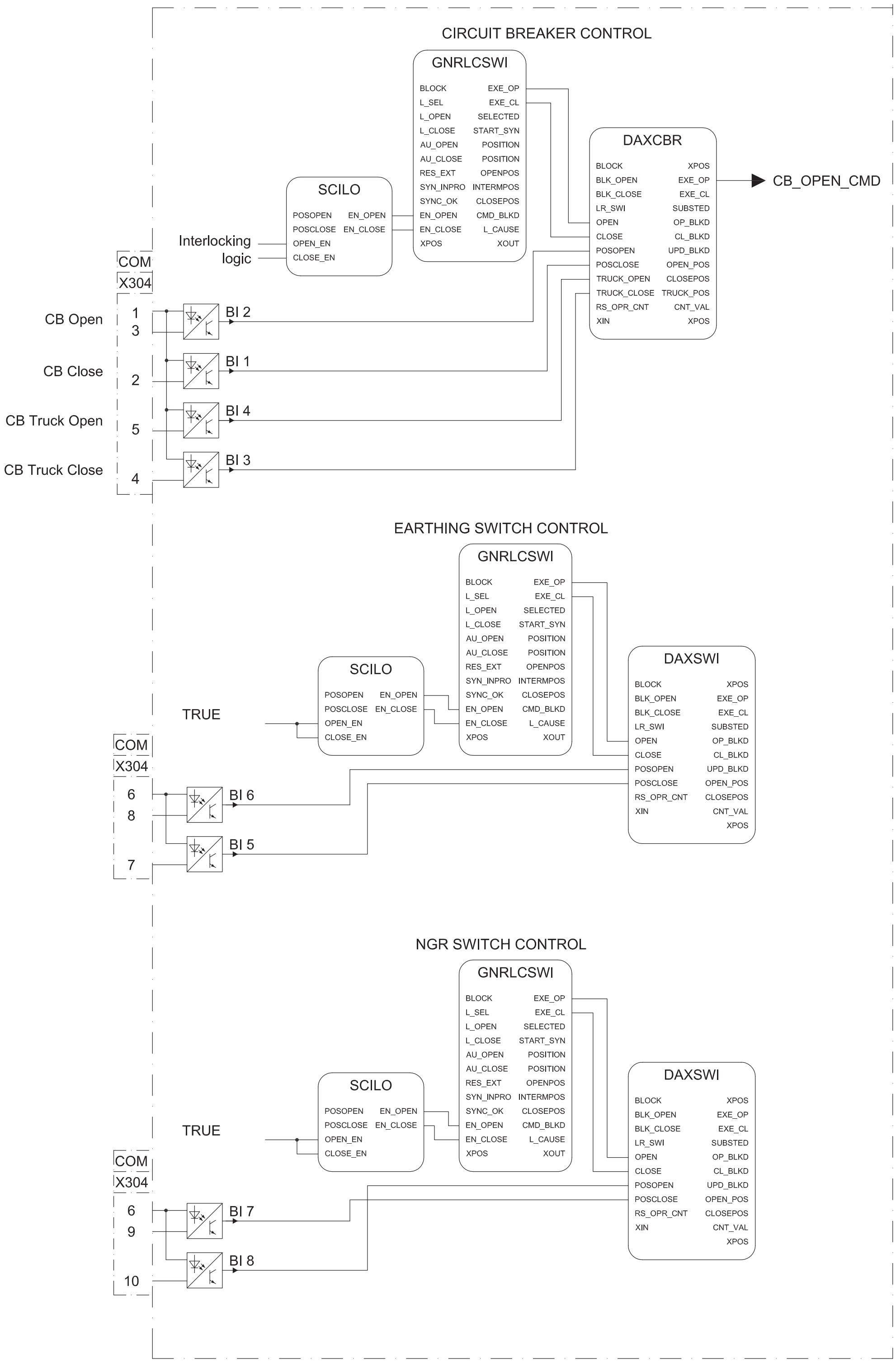


Figure 9: Apparatus control

3.2.6 Protection functions

3.2.6.1 Stabilized three-phase differential protection MPDIF

Stabilized three-phase differential protection with low (biased) stage and high (instantaneous) stage is used for protecting a generator against winding failure. The function includes a DC restraint feature. This feature temporarily decreases the sensitivity of the differential protection to avoid unnecessary disconnection of the generator when DC current is detected. The function also includes a CT saturation based blocking.

The set of three phase currents from the line side I3P, neutral side I3P_N, and the three phase voltages U3P are connected to the inputs.

The operate signal from the low and high stages provides a LED indication on the LHMI. The low stage and high stage operate outputs are connected to the disturbance recorder.

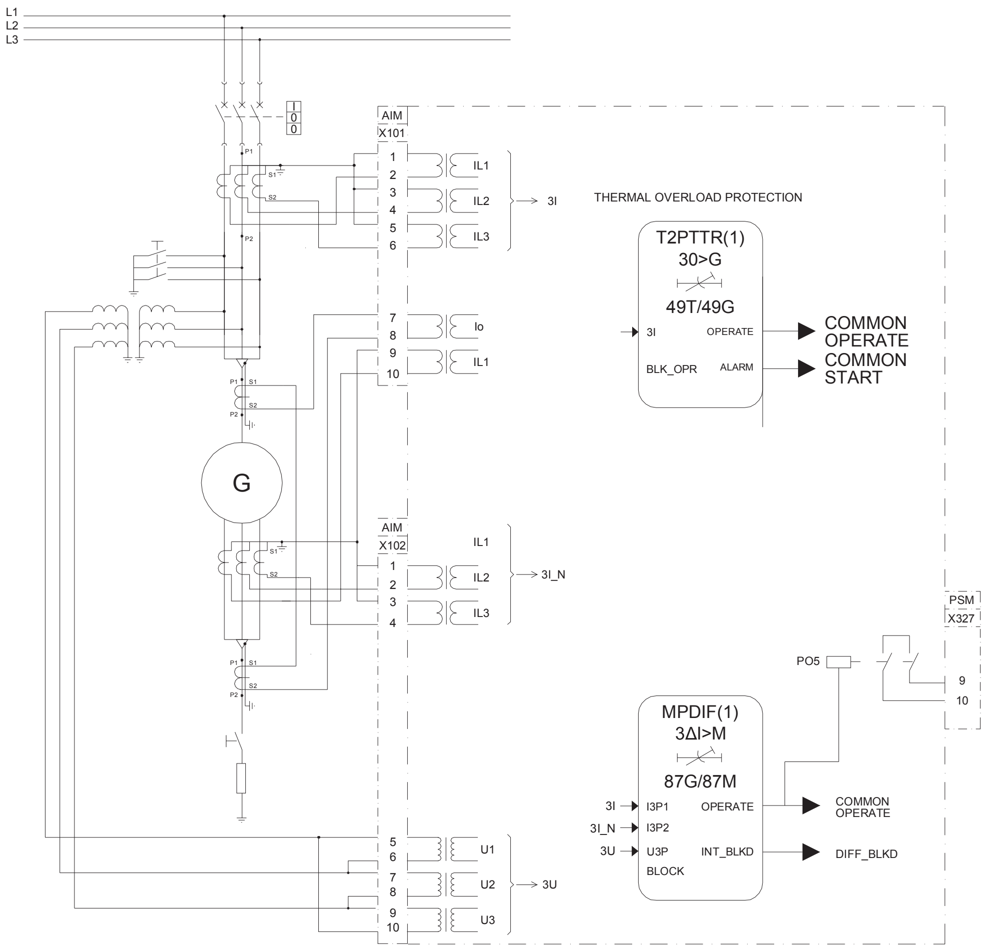


Figure 10: Generator differential and thermal overload protection

3.2.6.2 Thermal overload protection T2PTTR

The three-phase thermal overload protection function is used for thermal protection of generators. The function has adjustable temperature limits for tripping, alarm and reclose inhibit. The applied thermal model uses two time constants and a true RMS current measuring principle. A set of three phase currents, I3P, is connected to the inputs.

The thermal overload alarm and trip signals provide a LED indication on the LHMI. The thermal overload alarm and thermal overload trip are also connected to the disturbance recorders, as well as to common start and common operate respectively.

3.2.6.3 Non-directional overcurrent protection PHxPTOC

The three-phase non-directional overcurrent functions are used for non-directional one-, two- and three-phase stator overcurrent and short-circuit protection with definite-time or various IDMT characteristic. The stage operation is based on three measuring principles: DFT, RMS or peak-to-peak values.

The configuration includes two variants of non-directional overcurrent function blocks: low and high. A set of three phase neutral side currents, I3P_N, is connected to the inputs. The low stage can be used for overcurrent protection, and the high stages protect against short circuit.

A common operate and start signal from the both non-directional overcurrent functions is connected to an OR-gate to form a combined non-directional overcurrent operate and start signal which provides a LED indication on the LHMI. Also a separate start and operate signal from the both overcurrent functions is connected to the disturbance recorder.

3.2.6.4 Machine negative-sequence overcurrent protection MNSPTOC

Two instances of negative-sequence overcurrent function are provided for stator protection against single-phasing, unbalance load or unsymmetrical voltage with DT or IDMT characteristics. A set of three phase neutral side currents, I3P_N, is connected to the inputs.

A common operate and start signal from the both negative-sequence overcurrent functions is connected to an OR-gate to form a combined negative-sequence overcurrent operate and start signal, which is used for providing a LED indication on the LHMI. Also a separate start and operate signal from the both MNSPTOC functions is connected to the disturbance recorder.

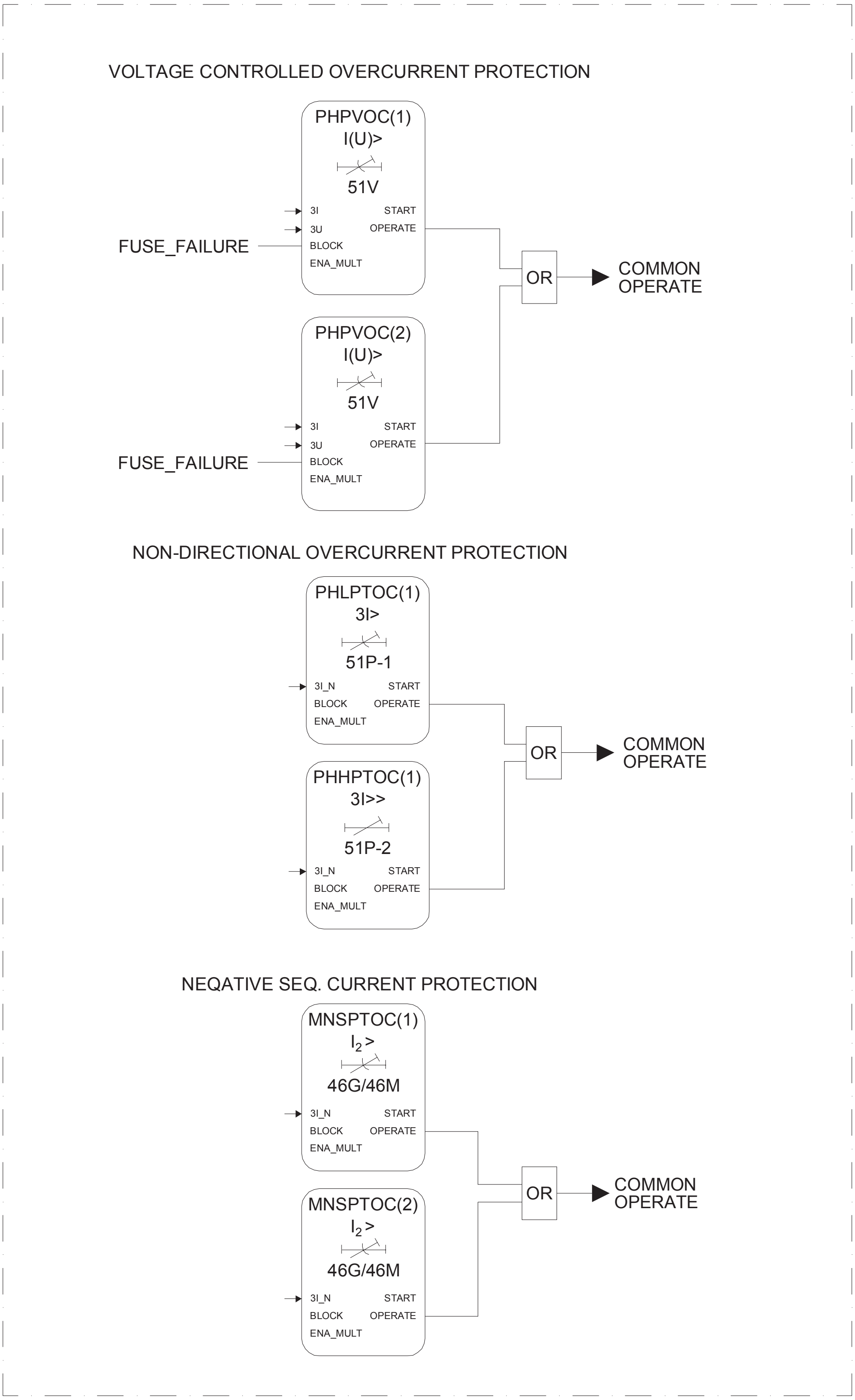


Figure 11: Generator overcurrent protection

3.2.6.5 Voltage-dependent overcurrent protection PHPVOC

Two instances of voltage-dependent overcurrent function are used for protecting generators against overcurrent and short-circuit conditions. The function operates when the current exceeds a limit which is dynamically calculated based on the measured terminal voltage.

The operating characteristics can be selected to be either inverse-definite minimum time or definite-time characteristic. The set of three phase current and voltages, I3P and U3P, are connected to the inputs.

A common operate and start signal from the both voltage-dependent overcurrent functions is connected to an OR-gate to form a combined operate and start signal, which provides a LED indication on the LHMI. Also a separate start and operate signal from the both voltage-dependent overcurrent functions is connected to the disturbance recorder.

The voltage-dependent overcurrent function is blocked on detection of fuse failure.

3.2.6.6 Directional earth-fault protection DEFxPDEF

The directional earth-fault protection functions are used for directional and non-directional earth-fault protection with DT or IDMT characteristic when appropriate.

The configuration includes the high and low variants of the directional earth-fault protection function. The configuration is developed considering that the core balance CT is provided both on line- and neutral-side of the generator. The differential current of the two neutral currents is made externally, and the resultant ΔIo current is connected to the IED's. The set of three-phase voltage and differential neutral current, U3P and DIFF_Io, are connected to the inputs.

A common operate and start signal from both the directional earth-fault functions and residual overvoltage protection are connected to an OR-gate to form a combined earth-fault operate and start signal, which provides a LED indication on the LHMI. Also separate start and operate signals from the both directional earth-fault functions are connected to the disturbance recorder.

The directional earth-fault function is blocked on detection of fuse failure.

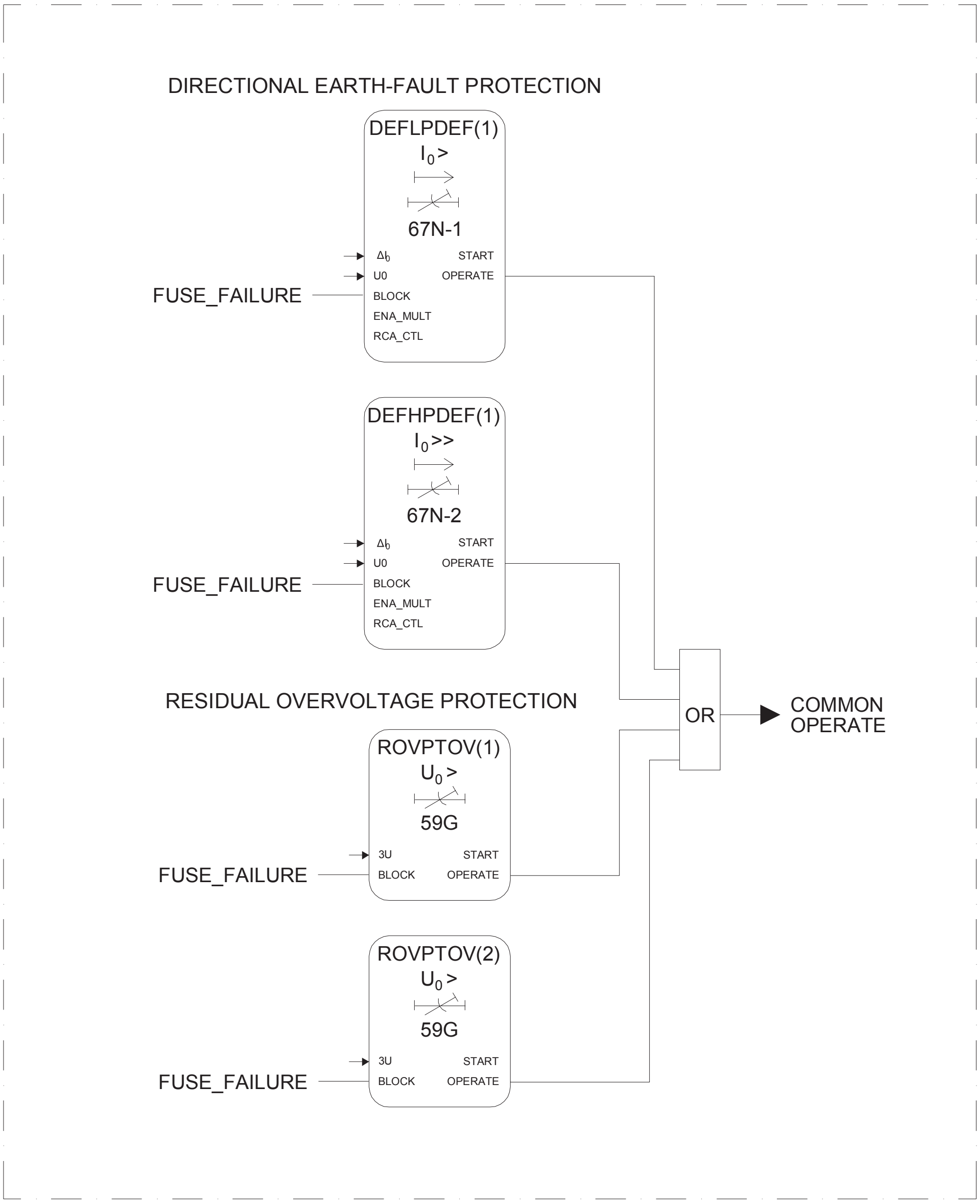


Figure 12: Generator stator earth-fault protection

3.2.6.7 Three-phase residual overvoltage protection ROVPTOV

The residual overvoltage function blocks operate with definite-time characteristics. A set of three phase voltages, U3P, is connected to the inputs. The configuration includes two instances of residual overvoltage protection.

A common operate and start signal from both residual overvoltage protection functions and directional earth fault signals is connected to an OR-gate to form a combined operate and start signal which provides a LED indication on the LHMI.

Also a separate start and operate signal from both instances is connected to the disturbance recorder.

The residual overvoltage function is blocked on detection of fuse failure.

3.2.6.8 Three-phase overvoltage protection PHPTOV

The three-phase overvoltage protection function is used for phase-to-phase or phase-to-earth overvoltage protection with DT or IDMT characteristics.

The configuration includes two instances of phase overvoltage function blocks. A set of three phase voltages, U3P is connected to the inputs.

A common operate and start signal from the both phase overvoltage protection functions are connected to an OR-gate to form a combined phase overvoltage operate and start signal which provides a LED indication on the LHMI. Also a separate start and operate signal from the both instances is connected to the disturbance recorder.

3.2.6.9 Three-phase undervoltage protection PHPTUV

The three-phase undervoltage protection function is used for phase-to-phase or phase-to-earth overvoltage protection with DT or IDMT characteristics.

The configuration includes two instances of undervoltage function blocks. The set of three phase voltages, U3P is connected to the inputs. The undervoltage function is blocked by the fuse failure function.

A common operate and start signal from the both phase undervoltage protection functions is connected to an OR-gate to form a combined phase undervoltage operate and start signal, which provides a LED indication on the LHMI. Also a separate start and operate signal from the both instances is connected to the disturbance recorder.

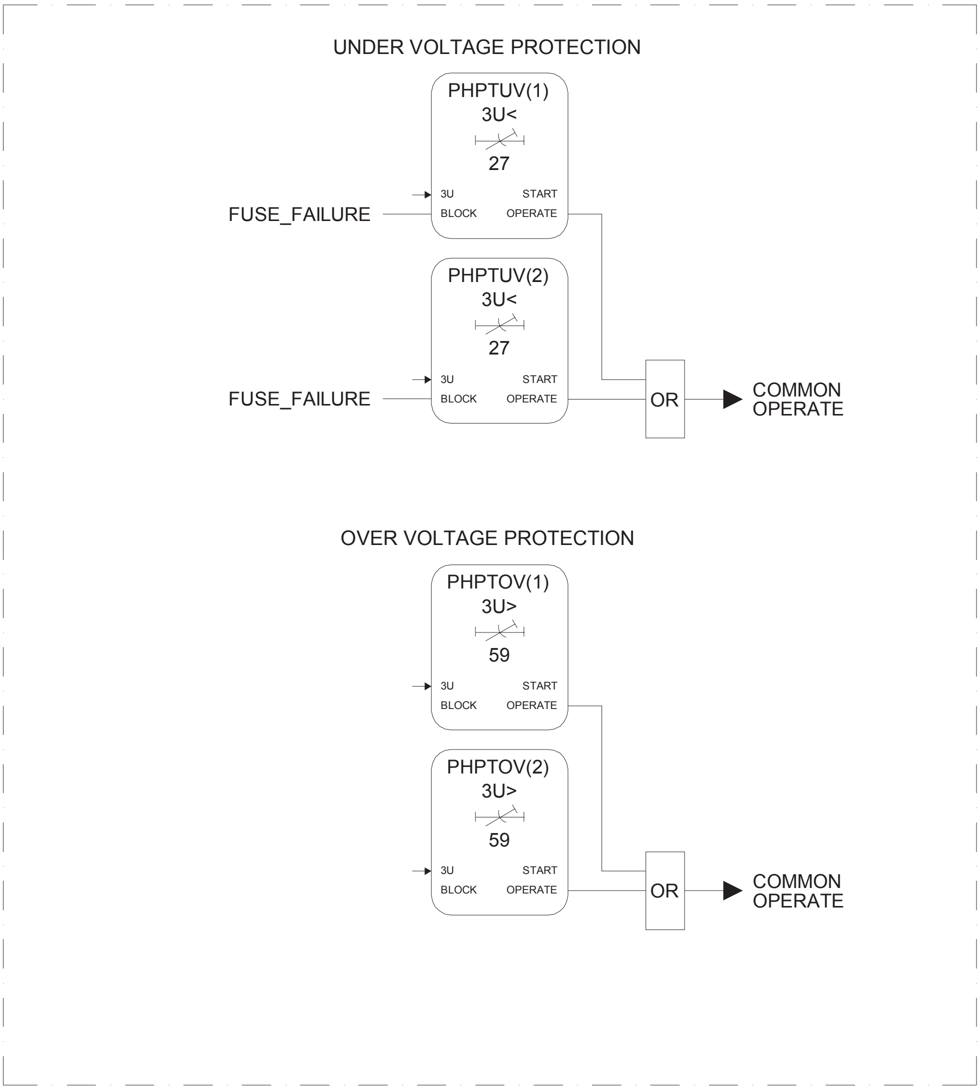


Figure 13: Generator voltage protection

3.2.6.10 Overfrequency protection DAPTOF

Overfrequency protection function is used for protecting a network component from possible damage caused by overfrequency conditions. Two instances of overfrequency functions are used with DT characteristic. The set of three phase voltages, U3P, is connected to the inputs.

A common operate and start signal from the both overfrequency protection functions is connected to an OR-gate to form a combined overfrequency operate and start signal, which provides a LED indication on the LHMI. Also a separate start signal from the both instances is connected to the disturbance recorder. However, the operate signal from both stages is connected to the OR-gate to form a combined overfrequency operate signal, and connected to the disturbance recorder.

3.2.6.11 Underfrequency protection DAPTUF

Underfrequency protection function is used for detecting deficit of generation compared to load. Two instances of underfrequency functions are used with DT characteristic. The set of three phase voltages, U3P, is connected to the inputs.

A common operate and start signal from the both underfrequency protection functions is connected to an OR-gate to form a combined underfrequency operate and start signal, which provides a LED indication on the LHMI. Also a separate start signal from both instances is connected to the disturbance recorder. However, the operate signal from both stages is connected to OR-gate to form a combined underfrequency operate signal, and connected to the disturbance recorder.

The function is blocked when the generator circuit breaker is in open position.

3.2.6.12 Frequency gradient protection DAPFRC

Frequency gradient protection function is used for detecting the increase or decrease of the fast power system frequency at an early stage. Two instances of frequency gradient protection functions are used with DT characteristics. The set of three phase voltages, U3P, is connected to the inputs. The frequency gradient function is blocked when the generator circuit breaker is in open position.

A common operate and start signal from the both frequency gradient protection functions is connected to an OR-gate to form a combined frequency gradient operate and start signal, which provides a LED indication on the LHMI. Also a separate start signal from the both instances is connected to the disturbance recorder. However, the operate signal from both stages is connected to the OR-gate to form a combined frequency gradient operate signal, and connected to the disturbance recorder.

The function is blocked when the generator circuit breaker is in open position.

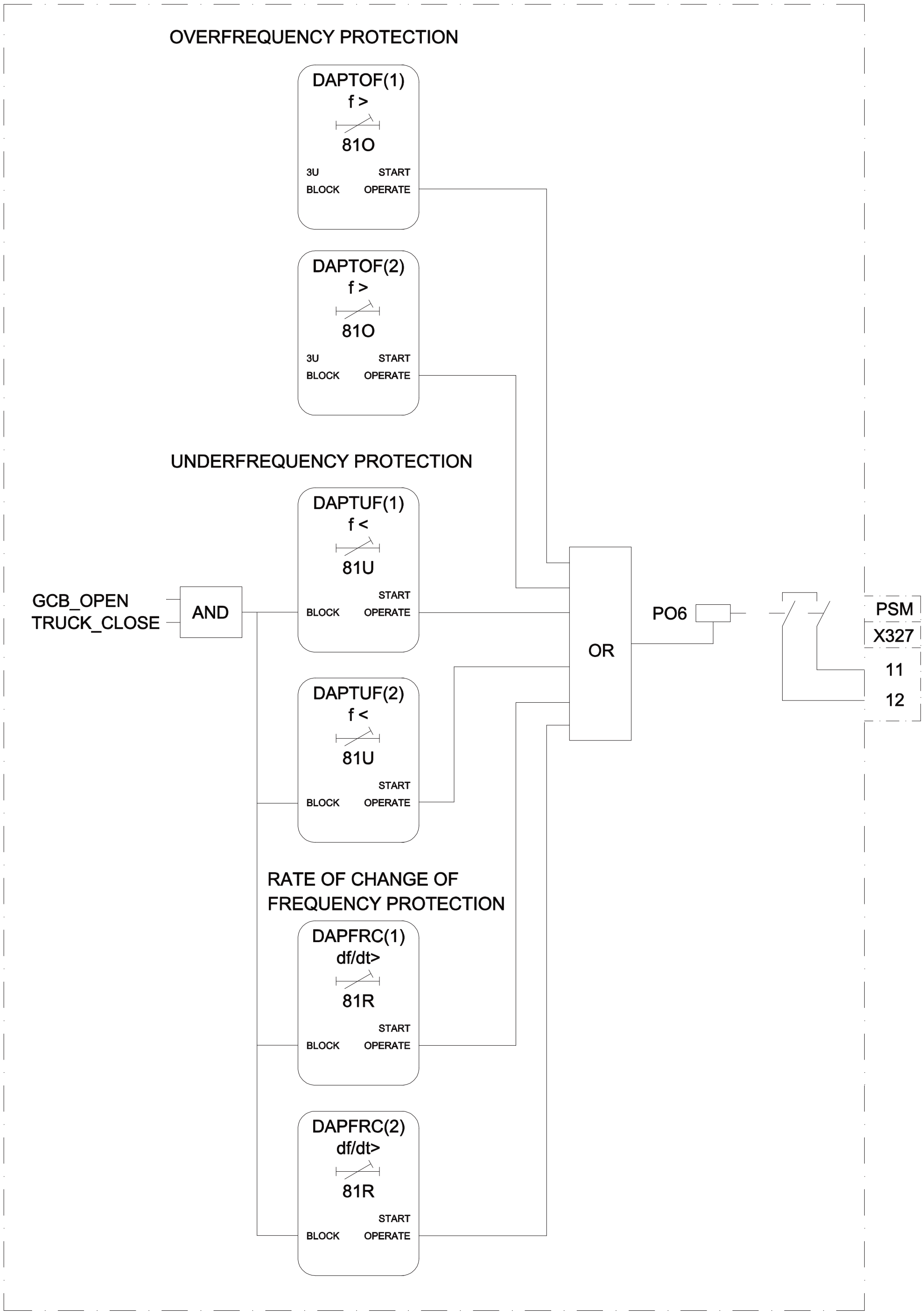


Figure 14: Frequency protection

3.2.6.13 Underexcitation protection UEXPDIS

Underexcitation protection is used for protecting a generator against loss of excitation. The excitation reduction may result into loss of synchronism, and the generator starts to operate like an induction machine. Two instances of underexcitation protection functions are used with DT characteristics. A set of three phase currents and voltages, I3P and U3P, is connected to the inputs.

A common operate and start signal from the both underexcitation protection functions is connected to an OR-gate to form a combined underexcitation operate and start signal, which provides a LED indication on the LHMI. Also a separate start and operate signal from the both instances is connected to the disturbance recorder.

The function is blocked when the generator circuit breaker is in open position or fuse failure is detected.

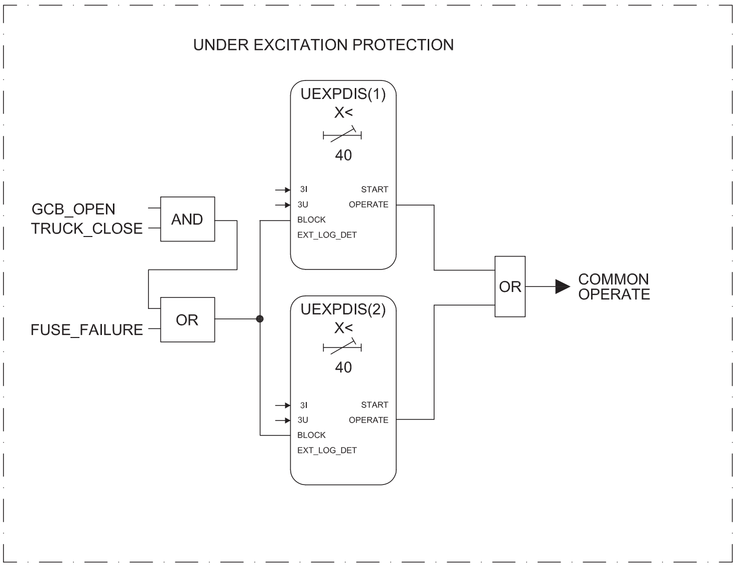


Figure 15: Underexcitation protection

3.2.6.14 Reverse power/directional overpower protection DOPPDPR

Reverse power/directional overpower protection is used for generator protection against the generator running like a motor. However, it can also be used to protect against delivering an excessive power beyond the generator's capacity to the grid. Two instances of reverse power/directional overpower protection functions are used with DT characteristics. A set of three phase currents and voltages, I3P and U3P, is connected to the inputs.

A common operate and start signal from the both reverse power/directional overpower protection functions is connected to an OR-gate to form a combined directional overpower operate and start signal, which provides a LED indication on the LHMI. Also a separate start signal from the both instances is connected to the disturbance recorder. However, the operate signal from the both stages is connected to the OR-gate to form a combined directional overpower operate signal, and connected to the disturbance recorder.

3.2.6.15 Underpower protection DUPPDPR

Underpower protection is used for protecting the generator from very low power output conditions. Two instances of the underpower protection functions are used with DT characteristics. A set of three phase currents and voltages, I3P and U3P, is connected to the inputs.

A common operate and start signal from the both underpower protection functions is connected to an OR-gate to form a combined underpower operate and start signal which provides a LED indication on the LHMI. Also a separate start signal from the both instances is connected to the disturbance recorder. However, the operate signal from the both stages is connected to the OR-gate to form a combined underpower operate signal, and connected to the disturbance recorder.

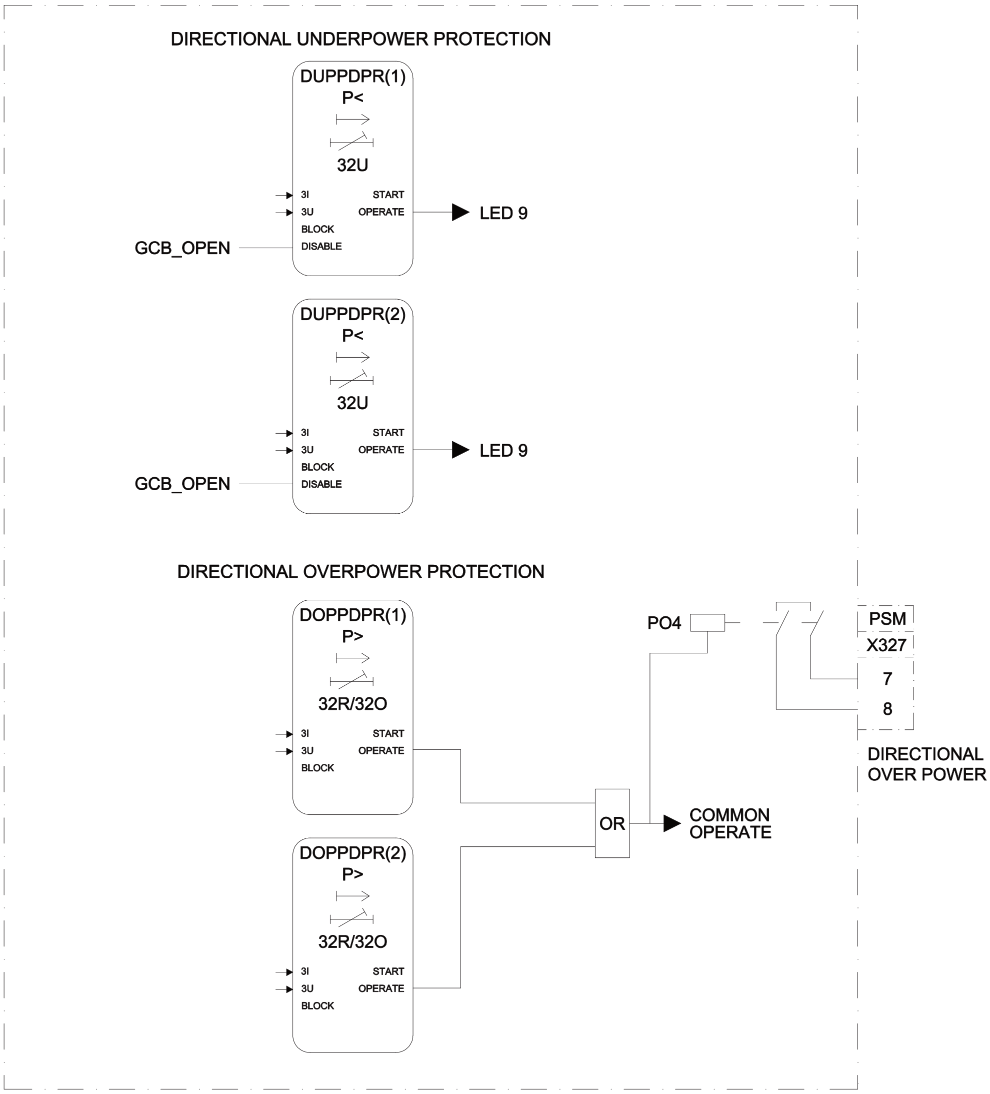


Figure 16: Directional power protection

The start and operate signals from the both underpower protection instances are used only for alarm purposes, not for tripping the generator circuit breaker.

3.2.6.16 Circuit-breaker failure protection CCBRBRF

The function is activated by the common operate command from the protection functions. The breaker failure function issues a retrip command to Master trip 2 if the Master trip 1 fails to trip the protected component. A set of three-phase neutral side current, I3P_N is connected to the input.

A circuit-breaker failure is detected by measuring the current, or by detecting the remaining trip signal. Retrip is used for increasing the circuit breaker's operational reliability. Retrip as well as backup trip are also connected to provide a LED indication on the LHMI. These signals are also connected to the disturbance recorder.

3.2.6.17 Tripping logic TRPPTRC

Tripping logic provides a tripping signal of required duration to the Master trip 1 and Master trip 2 circuits. The Master trip 1 opens the circuit breaker on a receipt of operate signal from the protection function, whereas the Master trip 2 opens the circuit breaker on a receipt of operate signal from the protection function, or a retrip signal from the circuit breaker failure protection.

Two master tripping signals are available at binary output PSM PO1 and PSM PO3. The lockout reset binary input available at COM BI10 is connected to the tripping circuit to reset the circuit-breaker lockout function.

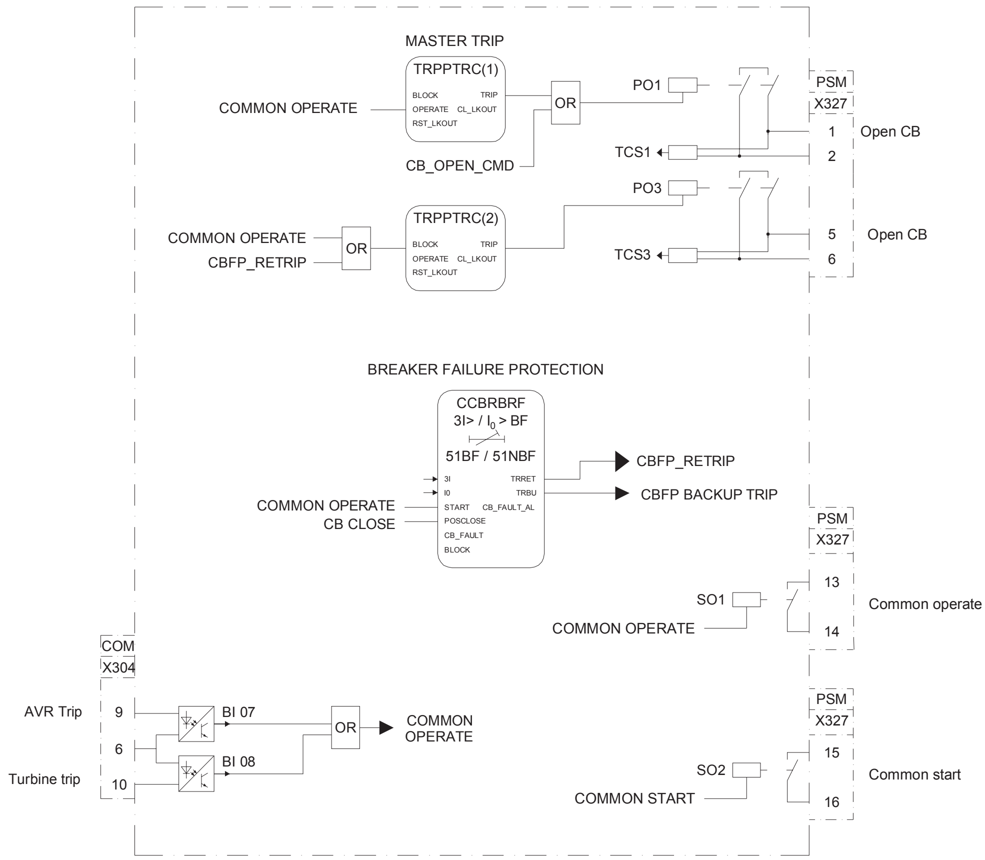


Figure 17: Tripping logic

3.2.6.18 Combined operate and start alarm signal

The operate outputs of all the protection functions (except for underpower protection), and the external trip from AVR and turbine are combined in the OR-gate to get a common Operate output. In addition, the activation of binary input COM101.BI12, that is, the low pressure lockout will also trip the generator circuit breaker. This common operate signal is connected to a tripping logic. It is also available as an alarm binary output, PSM SO1, with a settable minimum alarm delay of 80 ms.

Similarly, a common Start output is derived from the start outputs of all the protection functions (except for underpower protection) combined in an OR-gate. The output is available as an alarm binary output PSM SO2 with a settable minimum alarm delay of 80 ms.

These combined operate and start signals are also connected to trigger the disturbance recorder.

3.2.6.19 Other outputs and alarm signal

- Directional overpower operate signal available at binary output PSM PO4.
- Operate signal from differential protection is available at binary output PSM PO5.
- Combined overfrequency, underfrequency and rate of change of frequency protection operate signal available at binary output PSM PO6.
- Combined trip circuit supervision and CB monitoring alarm available at binary output PSM SO3.

All these outputs are available with a settable minimum alarm delay of 80 ms.

3.2.7 Supervision functions

3.2.7.1 Trip circuit supervision TCSSCBR

Two instances of the trip circuit supervision function are used for supervising Master trip 1 and Master trip 2. The function continuously supervises the trip circuit and alarms in case of failure. The function block does not perform the supervision itself but it is used as an aid for configuration. To prevent unwanted alarms, the function is blocked when any of the protection function's operate signals is active, or when the circuit breaker is in open position.

The alarms due to trip circuit failure and GCB monitoring functions are combined and available at LED alarms, and to binary recorder.

3.2.7.2 Fuse failure supervision SEQRFUF

The fuse failure supervision function gives an alarm in case of open secondary circuits between the voltage transformer and the IED respectively. A set of three phase currents and voltages, I3P_N and U3P, are connected to the inputs.

A LED alarm is available for secondary circuit failures. The alarm is also recorded by a disturbance recorder.

3.2.7.3 Circuit-breaker condition monitoring SSCBR

The circuit-breaker condition monitoring function checks for the healthiness of the circuit breaker. The circuit breaker status is connected to the function via binary inputs. The function requires also a pressure lockout input and a spring-charged input to be connected via binary input COM_101.BI12 and COM_101.BI13 respectively.

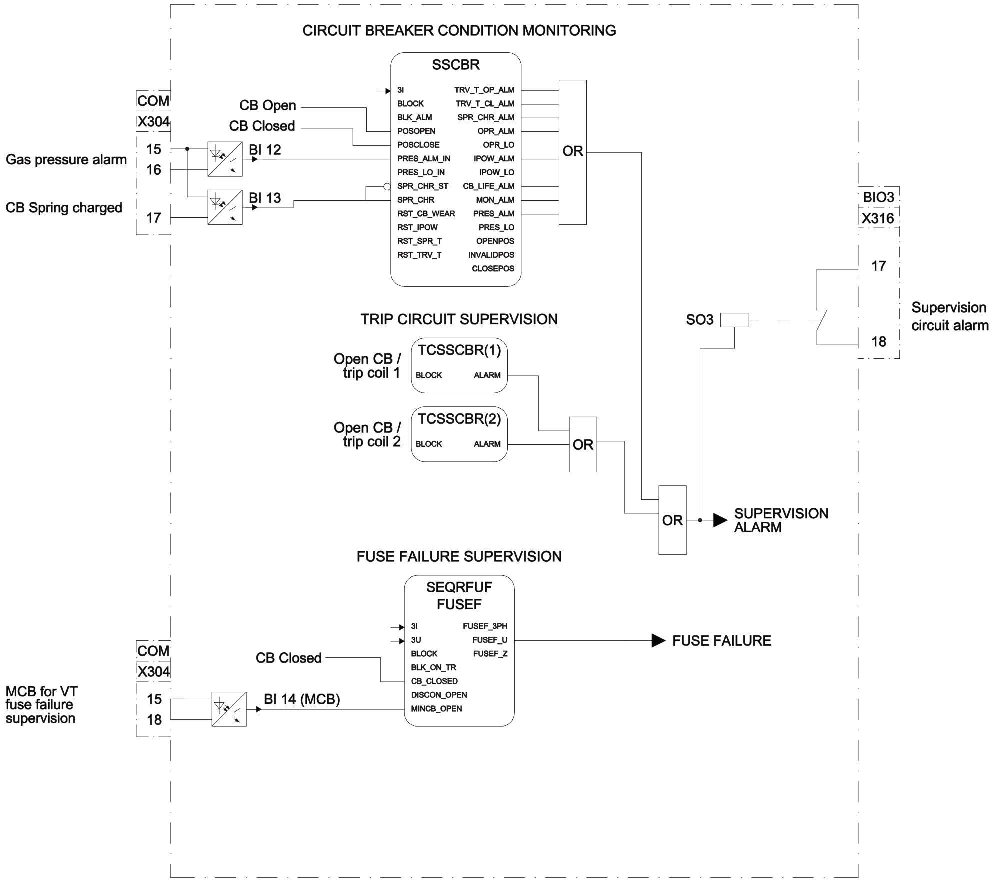


Figure 18: Supervision

3.2.8 Measurement and analog recording functions

The measured quantities in this configuration are:

- Current
- Voltage
- Current sequence component
- Voltage sequence component
- Residual current
- Residual voltage
- Power
- Frequency
- Energy

The measured quantities can be viewed in the measurement menu on the LHMI.

All analog input channels are connected to the analog disturbance recorder. When any of these analog values violate the upper or lower threshold limits, the recorder unit is triggered which in turn will record all the signals connected to the recorder.

Table 9: Signals connected to analog recorder

Channel ID	Description
Channel 1	Line-side current for phase A
Channel 2	Line-side current for phase B
Channel 3	Line-side current for phase C
Channel 4	Differential neutral current ΔIo
Channel 5	Neutral-side current for phase A
Channel 6	Neutral-side current for phase B
Channel 7	Neutral-side current for phase C
Channel 8	Line-side voltage for phase A
Channel 9	Line-side voltage for phase B
Channel 10	Line-side voltage for phase C

The data connected to analog channels contain 20 samples per cycle.

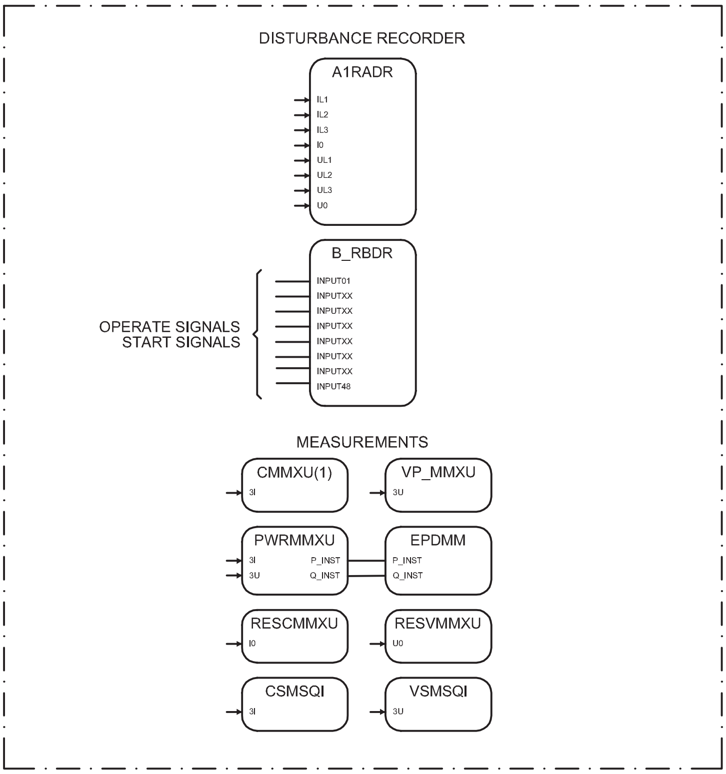


Figure 19: Measurement and analog recording functions

3.2.9 Binary recording and LED configuration

All the start and operate outputs from the respective protection functions, various alarms from supervision functions, and important signals from control and protective functions are connected to a binary recorder. In case of a fault, the binary recorder is triggered and all the signals connected to the recorder are recorded.

Table 10: Signals connected to binary recorder

Channel ID	Description
Channel 1	Operate of differential protection high stage
Channel 2	Operate of differential protection low stage
Channel 3	Differential protection internally blocked
Channel 4	Start of overcurrent low stage
Channel 5	Operate of overcurrent low stage
Channel 6	Start of overcurrent high stage
Channel 7	Operate of overcurrent high stage
Channel 8	Start of voltage controlled overcurrent stage 1
Channel 9	Operate of voltage controlled overcurrent stage 1
Channel 10	Start of voltage controlled overcurrent stage 2
Channel 11	Operate of voltage controlled overcurrent stage 2
Channel 12	Start of negative sequence overcurrent stage 1
Channel 13	Operate of negative sequence overcurrent stage 1
Channel 14	Start of negative sequence overcurrent stage 2
Channel 15	Operate of negative sequence overcurrent stage 2
Channel 16	Thermal overload prior alarm
Channel 17	Operate thermal overload
Channel 18	Start of directional earth fault low stage
Channel 19	Operate of directional earth fault low stage
Channel 20	Start of directional earth fault high stage
Channel 21	Operate of directional earth fault high stage
Channel 22	Start of phase overvoltage protection stage 1
Channel 23	Operate of phase overvoltage protection stage 1
Channel 24	Start of phase overvoltage protection stage 2
Channel 25	Operate of phase overvoltage protection stage 2
Channel 26	Start of phase undervoltage protection stage 1
Channel 27	Operate of phase undervoltage protection stage 1
Channel 28	Start of phase undervoltage protection stage 2
Channel 29	Operate of phase undervoltage protection stage 2
Channel 30	Start of residual overvoltage protection stage 1
Channel 31	Operate of residual overvoltage protection stage 1
Channel 32	Start of residual overvoltage protection stage 2
Table continues on next page	

Channel ID	Description
Channel 33	Operate of residual overvoltage protection stage 2
Channel 34	Start of underfrequency protection stage 1
Channel 35	Start of underfrequency protection stage 2
Channel 36	Combined operate of underfrequency protection
Channel 37	Start of overfrequency protection stage 1
Channel 38	Start of overfrequency protection stage 2
Channel 39	Combined operate of overfrequency protection
Channel 40	Start of rate of change of frequency protection stage 1
Channel 41	Start of rate of change of frequency protection stage 2
Channel 42	Combined operate of rate of change of frequency protection
Channel 43	Start of underexcitation protection stage 1
Channel 44	Operate of underexcitation protection stage 1
Channel 45	Start of underexcitation protection stage 1
Channel 46	Operate of underexcitation protection stage 1
Channel 47	Start of directional overpower protection stage 1
Channel 48	Operate of directional overpower protection stage 1
Channel 49	Start of directional overpower protection stage 2
Channel 50	Operate of directional overpower protection stage 2
Channel 51	Start of underpower protection stage 1
Channel 52	Operate of underpower protection stage 1
Channel 53	Start of underpower protection stage 2
Channel 54	Operate of underpower protection stage 2
Channel 55	Combined CB Supervision alarm
Channel 56	Generator circuit breaker closed
Channel 57	Generator circuit breaker opened
Channel 58	Backup trip from circuit breaker failure protection
Channel 59	Retrip from circuit breaker failure protection
Channel 60	Voltage transformer MCB Open
Channel 61	Fuse failure
Channel 62	External trip command
Channel 63	Combine start
Channel 64	Combine operate

The LEDs are configured for alarm indications.

Table 11: LEDs configured on LHMI LED page 1

LED No	LED color	Description
LED 1	Red	Combined operate from OC
LED 2	Red	Combined operate from NSOC
LED 3	Red	Combined operate from EF
LED 4	Red	Combined operate from VCOC
LED 5	Red	Combined operate from overvoltage
LED 6	Red	Combined operate from undervoltage
LED 7	Red	Combined operate from underexcitation
LED 8	Red	Combined operate from directional overpower
LED 9	Red	Combined operate from underpower
LED 10	Red	Combined operate from over- and underfrequency protection
LED 11	Red	Combined operate from df/dt protection
LED 12	Red	Operate from differential protection
LED 13	Red	Backup trip from circuit-breaker protection function
LED 14	Red	Retrip from circuit-breaker protection function
LED 15	Red	Operate from thermal overload

Table 12: LEDs configured on LHMI LED page 2

LED No	LED color	Description
LED 1	Yellow	Combined start from OC
LED 2	Yellow	Combined start from NSOC
LED 3	Yellow	Combined start from EF
LED 4	Yellow	Combined start from VCOC
LED 5	Yellow	Combined start from overvoltage
LED 6	Yellow	Combined start from undervoltage
LED 7	Yellow	Combined start from underexcitation
LED 8	Yellow	Combined start from directional overpower
LED 9	Yellow	Combined start from underpower
LED 10	Yellow	Combined start from from over- and underfrequency protection
LED 11	Yellow	Combined start from df/dt protection
LED 12	Yellow	Fuse failure supervision
LED 13	Yellow	Trip circuit alarm
LED 14	Yellow	CB monitoring alarm
LED 15	Yellow	Alarm from thermal overload

Table 13: *LEDs configured on LHMI LED page 3*

LED No	LED color	Description
LED 1	Red	Protection function blocked (GCB open and truck close)

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 14: 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 start current settings

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

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

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

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

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

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

Delay in operation caused by saturation of current transformers

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

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

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

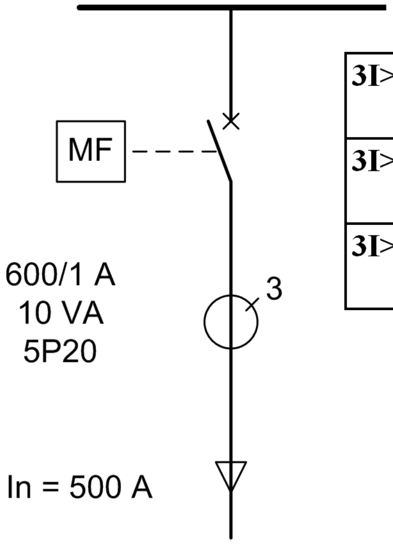
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen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

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

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

4.1.1.3 Example for non-directional overcurrent protection

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



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

Figure 20: Example of three-stage overcurrent protection

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

The start current setting for low-set stage (3I>) is selected to be about twice the nominal current of the cable. The operate time is selected so that it is selective with the next protection relay (not visible in Figure 20). The settings for the high-set stage and instantaneous stage are defined also so that grading is ensured with the downstream protection. In addition, the start current settings have to be defined so that the protection relay operates with the minimum fault current and it does not operate with the maximum load current. The settings for all three stages are as in Figure 20.

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

Section 5 Glossary

100BASE-FX	A physical medium defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fiber optic cabling
ANSI	American National Standards Institute
AVR	Automatic voltage regulator
BI/O	Binary input/output
BIO	Binary input and output
CB	Circuit breaker
COMTRADE	Common format for transient data exchange for power systems. Defined by the IEEE Standard.
Connectivity package	A collection of software and information related to a specific protection and control IED, providing system products and tools to connect and interact with the IED
CPU	Central processing unit
CT	Current transformer
DC	1. Direct current 2. Disconnector 3. Double command
DFT	Discrete Fourier transform
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.
DT	Definite time
EF	Earth fault
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
GCB	1. GOOSE control block 2. Generator circuit breaker
GOOSE	Generic Object-Oriented Substation Event
HMI	Human-machine interface
HW	Hardware

IDMT	Inverse definite minimum time
IEC	International Electrotechnical Commission
IEC 60870-5-103	1. Communication standard for protective equipment 2. A serial master/slave protocol for point-to-point communication
IEC 61850	International standard for substation communication and modeling
IEC 61850-8-1	A communication protocol based on the IEC 61850 standard series
IED	Intelligent electronic device
LAN	Local area network
LC	Connector type for glass fiber cable, IEC 61754-20
LED	Light-emitting diode
LHMI	Local human-machine interface
MCB	Miniature circuit breaker
NGR	Neutral grounding resistor
PCM600	Protection and Control IED Manager
REG630	Generator protection and control relay
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
VT	Voltage transformer
WAN	Wide area network
WHMI	Web human-machine interface

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