RELION® 630 SERIES

Feeder Protection and Control REF630

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

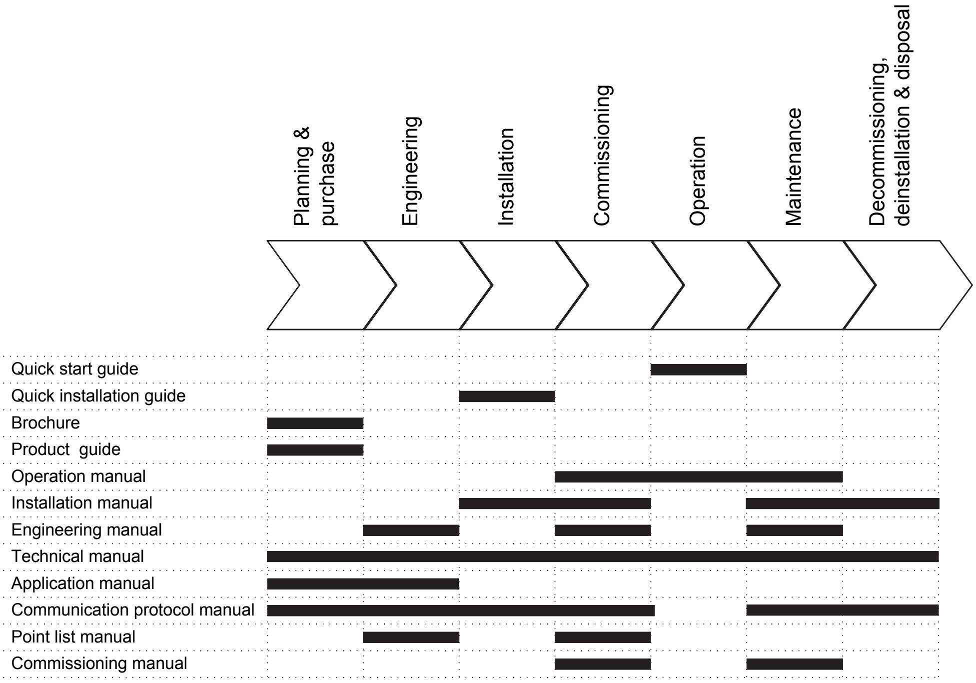


Figure 1: The intended use of documents during the product life cycle

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/2009-09-15	1.0	First release
B/2011-02-23	1.1	Content updated to correspond to the product version
C/2011–05-18	1.1	Content updated
D/2012-08-29	1.2	Content updated to correspond to the product version
E/2014-11-28	1.3	Content updated to correspond to the product version
F/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
Three-phase directional overcurrent protection, low stage	DPHLPDOC	3I> ->	67-1
Three-phase directional overcurrent protection, high stage	DPHHPDOC	3I>> ->	67-2

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Distance protection	DSTPDIS	Z<	21, 21P, 21N
Automatic switch-onto-fault logic	CVRSOF	SOTF	SOTF
Fault locator	SCEFRFLO	FLOC	21FL
Autoreclosing	DARREC	O -> I	79
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
Directional earth-fault protection, low stage	DEFLPDEF	I0> ->	67N-1
Directional earth-fault protection, high stage	DEFHPDEF	I0>> ->	67N-2
Harmonics based earth-fault protection	HAEFPTOC	Io>HA	51NHA
Transient/intermittent earth-fault protection	INTRPTEF	I0> -> IEF	67NIEF
Admittance-based earth-fault protection	EFPADM	Yo>->	21YN
Multi-frequency admittance-based earth-fault protection	MFADPSDE	I0> ->Y	67YN
Wattmetric earth-fault protection	WPWDE	Po>->	32N
Phase discontinuity protection	PDNSPTOC	I2/I1>	46PD
Negative-sequence overcurrent protection	NSPTOC	I2>	46
Three-phase thermal overload protection for feeder	T1PTTR	3Ith>F	49F
Three-phase current inrush detection	INRPHAR	3I2f>	68
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
Frequency gradient protection	DAPFRC	df/dt>	81R
Overfrequency protection	DAPTOF	f>	81O
Underfrequency protection	DAPTUF	f<	81U
Load shedding	LSHDPFRQ	UFLS/R	81LSH
Circuit breaker failure protection	CCBRBRF	3I>/I0>BF	51BF/51NBF
Table continues on next page			

Description	IEC 61850	IEC 60617	ANSI
Tripping logic	TRPPTRC	I -> O	94
Multipurpose analog protection	MAPGAPC	MAP	MAP
Protection-related functions			
Local acceleration logic	DSTPLAL	LAL	LAL
Communication logic for residual overcurrent	RESCPSCH	CLN	85N
Scheme communication logic	DSOCPSCH	CL	85
Current reversal and WEI logic	CRWPSCH	CLCRW	85CRW
Current reversal and WEI logic for residual overcurrent	RCRWPSCH	CLCRWN	85NCRW
Control			
Bay control	QCCBAY	CBAY	CBAY
Interlocking interface	SCILO	3	3
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	-	-
Power quality			
Voltage variation	PHQVVR	PQMU	PQMV
Voltage unbalance	VSQVUB	PQMUBU	PQMUBV

Table continues on next page

Description	IEC 61850	IEC 60617	ANSI
Current harmonics	CMHAI	PQM3I	PQM3I
Voltage harmonics (phase-to-phase)	VPPMHAI	PQM3Upp	PQM3Vpp
Voltage harmonics (phase-to-earth)	VPHMHAI	PQM3Upe	PQM3Vpg
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
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 REF630 overview

2.1 Overview

REF630 is a comprehensive feeder management relay for protection, control, measuring and supervision of utility and industrial distribution substations. REF630 is a member of ABB's Relion® product family and a part of its 630 series characterized by functional scalability and flexible configurability. REF630 also features necessary control functions constituting an ideal solution for feeder bay control.

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

2.1.1 Product version history

Product version	Product history
1.0	First release
1.1	• Support for IEC 60870-5-103 communication protocol • Analog GOOSE • RTD module • Additional arithmetic and logic function support • Admittance-based earth-fault protection • Wattmetric earth-fault protection • Power quality functions
1.2	Reverse power/directional overpower protection
1.3	• Harmonics based EF detection • Reactive power undervoltage protection • Multi-frequency admittance protection • Operation time counter • Comparison functions • 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 REF630 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.

- Distance protection
- Fault locator
- Synchrocheck
- Phase sequence voltage functions
  - Positive-sequence overvoltage protection
  - Positive-sequence undervoltage protection
  - Negative-sequence overvoltage protection
- Power quality functions

- Voltage harmonics
- Current harmonics
- Voltage sags and swells
- Voltage unbalance

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	3 or 4 current inputs (1/5 A) 4 or 5 voltage inputs (100/110/115/120 V) 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.

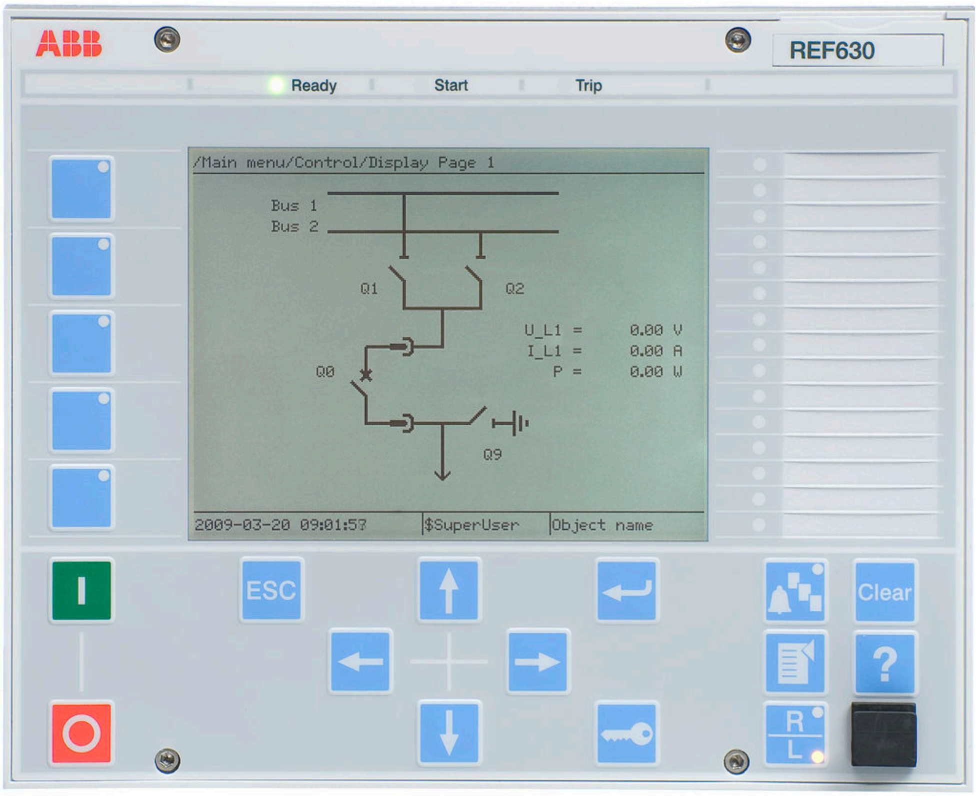


Figure 2: Example of the LHMI

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.

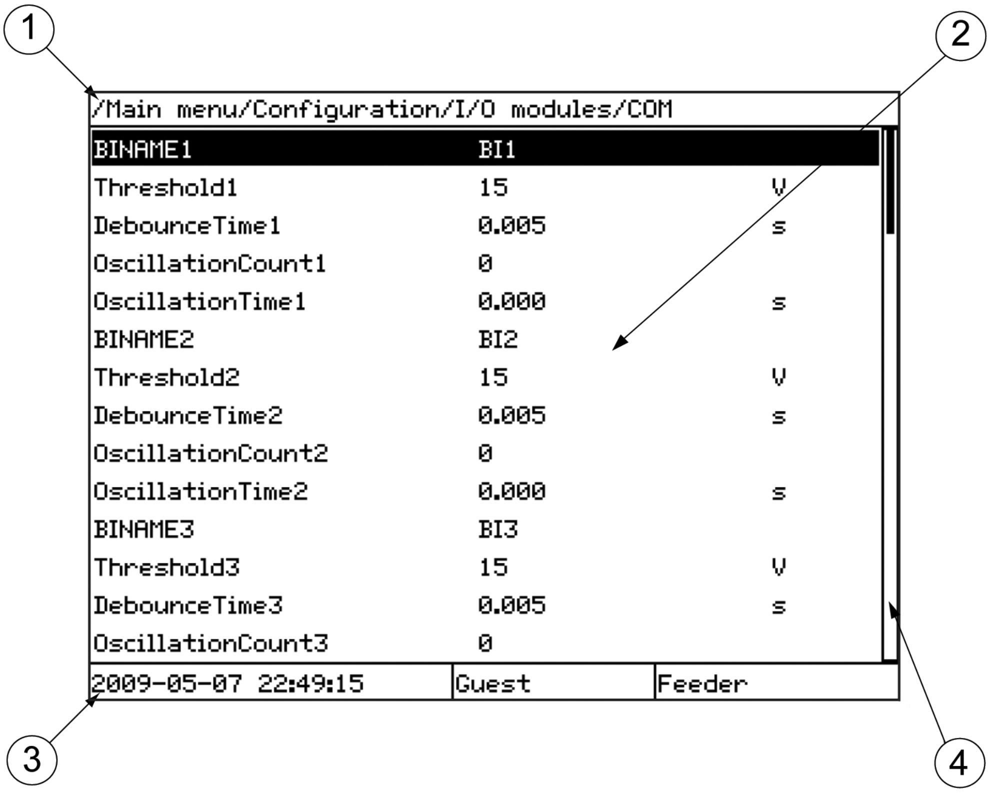


Figure 3: Display layout

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.

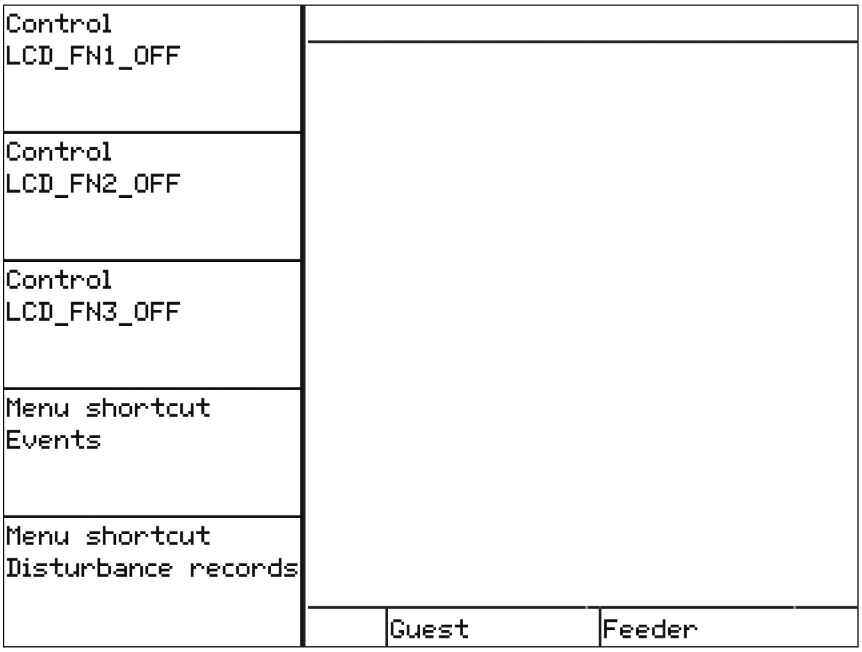


Figure 4: Function button panel

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

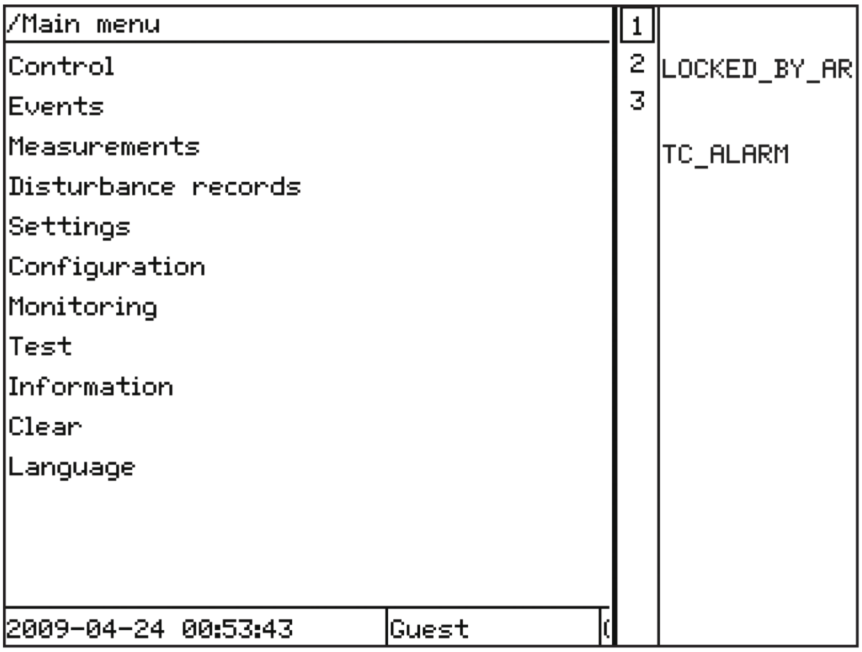


Figure 5: Alarm LED panel

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.

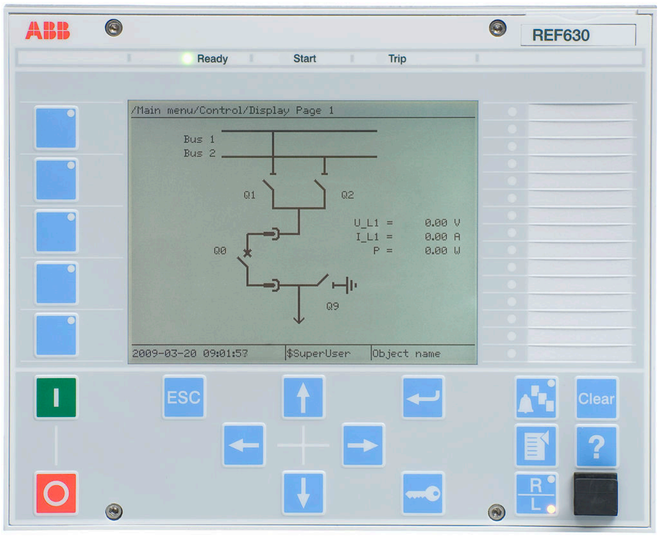


Figure 6: LHMI keypad with object control, navigation and command push-buttons and RJ-45 communication port

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.

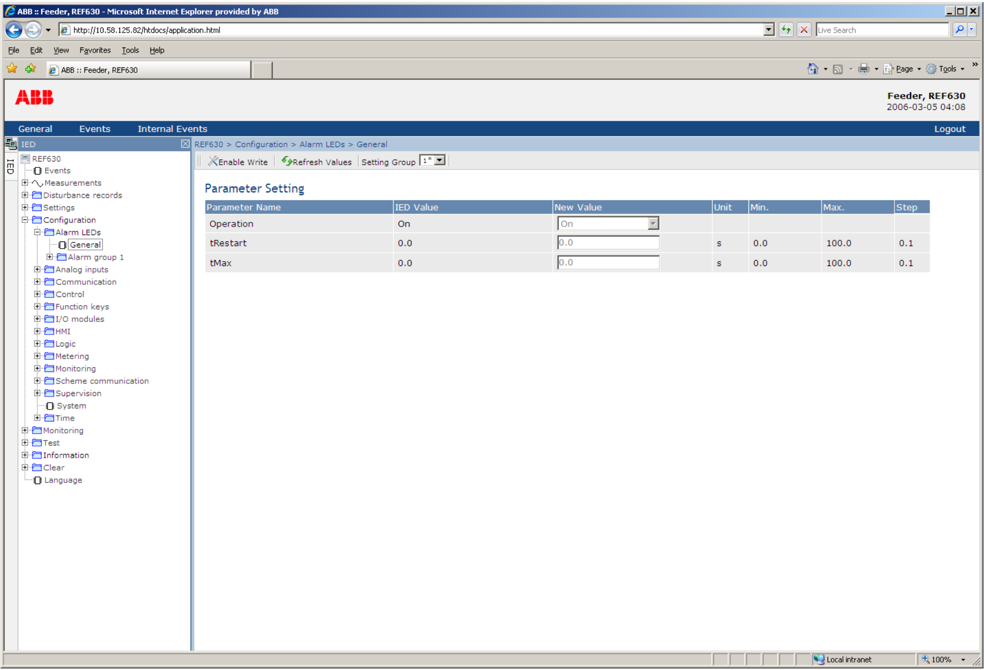


Figure 7: Example view of the WHMI

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. Analog GOOSE messages can also be used in load shedding 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 REF630 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 describe the IED's functionality from the protection, measuring, condition monitoring, disturbance recording, control and interlocking perspective. Diagrams show the default functionality with simple symbol logics forming principle diagrams. The external connections to primary devices are also shown, stating the default connections to measuring transformers. The positive measuring direction of directional protection functions is towards the outgoing feeder.

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: REF630 preconfiguration ordering options

Description	Preconfiguration				
Preconfiguration A for open/closed ring feeder	A				
Preconfiguration B for radial overhead/mixed line feeder		B			
Preconfiguration C for ring/meshed feeder			C		
Preconfiguration D for bus sectionalizer				D	
Number of instances available					n

Table 5: Functions used in preconfigurations

Description	A	B	C	D	n
Protection					
Three-phase non-directional overcurrent protection, low stage	1	1	1	1	1
Three-phase non-directional overcurrent protection, high stage	2	2	2	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	2	-	-	-	2
Three-phase directional overcurrent protection, high stage	1	-	-	-	1
Distance protection	-	-	1	-	1
Automatic switch-onto-fault logic	-	-	1	-	2
Fault locator	-	-	-	-	1
Autoreclosing	1	1	1	-	2
Non-directional earth-fault protection, low stage	-	1	-	1	1
Non-directional earth-fault protection, high stage	1	1	1	1	1
Non-directional earth-fault protection, instantaneous stage	-	1	-	1	1
Directional earth-fault protection, low stage	2	1	3	-	3
Directional earth-fault protection, high stage	1	-	1	-	1
Harmonics based earth-fault protection	-	-	-	-	1
Transient/intermittent earth-fault protection	1	-	-	-	1
Admittance-based earth-fault protection	-	-	-	-	3
Multi-frequency admittance-based earth-fault protection	-	-	-	-	1
Wattmetric earth-fault protection	-	-	-	-	3
Phase discontinuity protection	1	1	1	-	1
Negative-sequence overcurrent protection	2	2	2	2	2
Three-phase thermal overload protection for feeder	1	1	1	-	1
Three-phase current inrush detection	1	1	1	1	1
Three-phase overvoltage protection	-	-	3	-	3
Three-phase undervoltage protection	-	-	3	-	3
Positive-sequence overvoltage protection	-	-	-	-	2
Table continues on next page					

Description	A	B	C	D	n
Positive-sequence undervoltage protection	-	-	-	-	2
Negative-sequence overvoltage protection	-	-	-	-	2
Residual overvoltage protection	-	-	3	-	3
Directional reactive power undervoltage protection	-	-	-	-	2
Reverse power/directional overpower protection	-	-	-	-	3
Frequency gradient protection	-	-	-	-	5
Overfrequency protection	-	-	-	-	5
Underfrequency protection	-	-	-	-	5
Load shedding	-	-	-	-	6
Circuit breaker failure protection	1	1	1	1	2
Tripping logic	1	1	1	1	2
Multipurpose analog protection	-	-	-	-	16
Protection-related functions					
Local acceleration logic	-	-	1	-	1
Communication logic for residual overcurrent	-	-	1	-	1
Scheme communication logic	-	-	1	-	1
Current reversal and WEI logic	-	-	1	-	1
Current reversal and WEI logic for residual overcurrent	-	-	1	-	1
Control					
Bay control	1	1	1	1	1
Interlocking interface	4	4	4	1	10
Circuit breaker/disconnector control	4	4	4	1	10
Circuit breaker	1	1	1	1	2
Disconnector	3	3	3	-	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	1	1	1	2
Fuse failure supervision	1	1	1	-	2

Table continues on next page

Description	A	B	C	D	n
Current circuit supervision	1	1	1	-	2
Trip-circuit supervision	3	3	3	3	3
Station battery supervision	-	-	-	-	1
Energy monitoring	-	-	-	-	1
Measured value limit supervision	-	-	-	-	40
Power quality					
Voltage variation	-	-	-	-	1
Voltage unbalance	-	-	-	-	1
Current harmonics	-	-	-	-	1
Voltage harmonics (phase-to-phase)	-	-	-	-	1
Voltage harmonics (phase-to-earth)	-	-	-	-	1
Measurement					
Three-phase current measurement	1	1	1	1	1
Three-phase voltage measurement (phase-to-earth)	1	1	1	1	2
Three-phase voltage measurement (phase-to-phase)	-	-	-	-	2
Residual current measurement	1	1	1	1	1
Residual voltage measurement	1	1	1	-	1
Power monitoring with P, Q, S, power factor, frequency	1	1	1	1	1
Sequence current measurement	1	1	1	1	1
Sequence voltage measurement	1	1	1	1	1
Disturbance recorder function					
Analog channels 1-10 (samples)	1	1	1	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	1	1	1
Binary channels 17-32	1	1	1	1	1
Binary channels 33-48	1	1	1	1	1
Binary channels 49-64	1	-	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 open/closed ring feeder

3.2.1 Application

The functionality of the IED is designed to be used for selective short-circuit, overcurrent and earth-fault protection of radial outgoing feeders on double busbar systems with one circuit breaker. The configuration can be used in isolated neutral networks, resistant-earthed networks and compensated networks.

The objects controlled by the IED are the circuit breaker and the disconnector. The earth switch is considered to be operated manually. The open, close and undefined states of the circuit breaker, disconnectors and the earth switch are indicated on the LHMI.

Required interlocking is configured in the IED.

The preconfiguration includes:

- Control functions
- Current protection functions
- Supervision functions
- Disturbance recorders
- LEDs' configuration
- Measurement functions

3.2.2 Functions

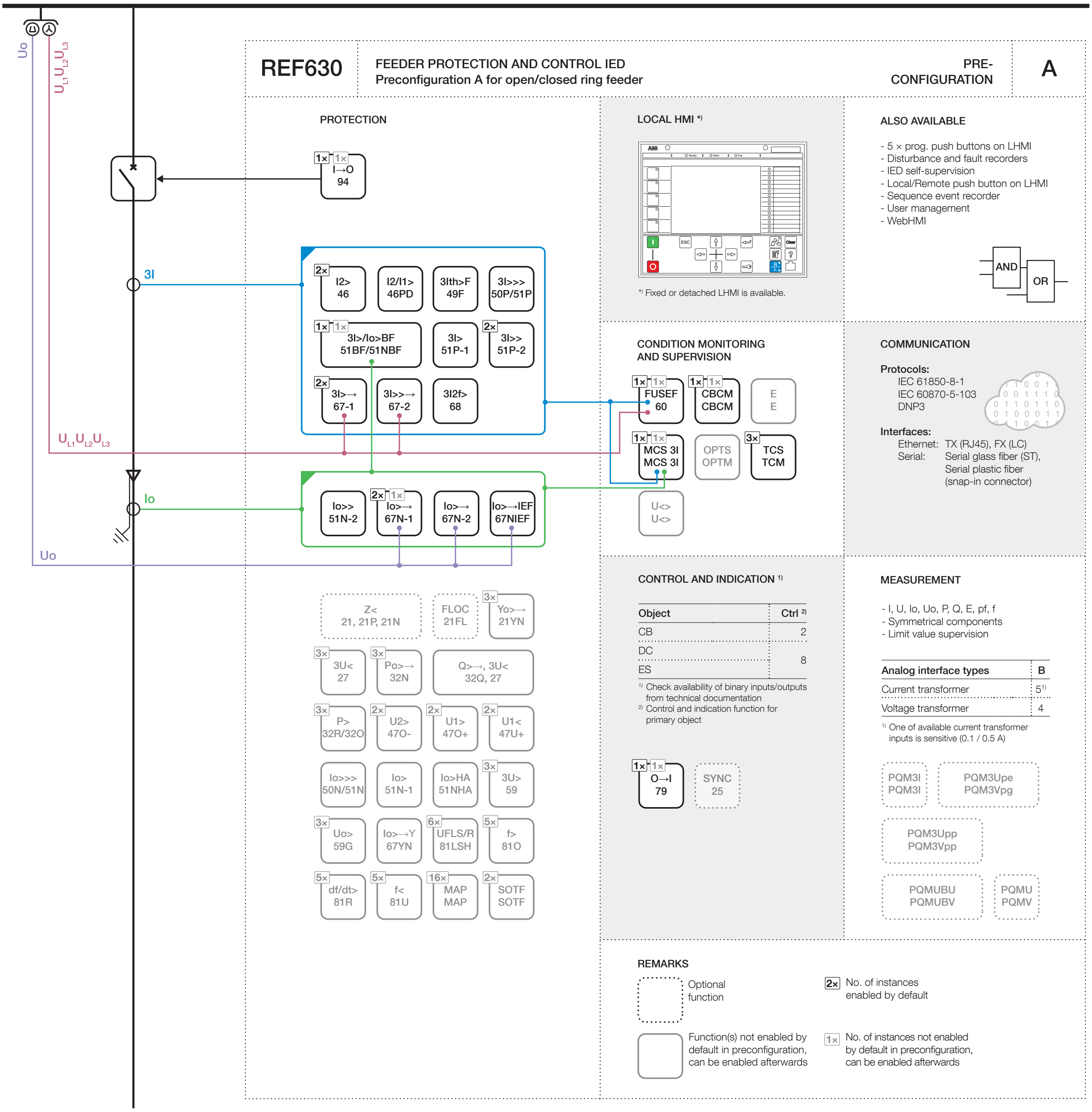


Figure 8: Functionality overview for preconfiguration A

3.2.3 Input/output signal interfaces

Table 6: Interface of binary inputs

Hardware module instance	Hardware channel	Description
COM	BI1	Circuit breaker closed
COM	BI2	Circuit breaker open
COM	BI3	Disconnector 1 closed
COM	BI4	Disconnector 1 open
COM	BI5	Earth switch closed
COM	BI6	Earth switch open
COM	BI7	Disconnector 2 closed
COM	BI8	Disconnector 2 open
COM	BI9	Circuit breaker truck closed
COM	BI10	Circuit breaker truck open
COM	BI11	External start of circuit breaker failure protection
COM	BI12	Pressure low from circuit breaker
COM	BI13	Spring charged from circuit breaker
COM	BI14	MCB for fuse failure supervision
BIO_3	BI1	Relay characteristics angle (RCA) control
BIO_3	BI2...BI9	Not connected

The outputs of the IED are categorized as power outputs (POx) and signal outputs (SOx). The power outputs can be used for closing and tripping of circuit breakers and disconnector control. The signal outputs are not heavy-duty outputs. They are used for alarm or signaling purposes.

Table 7: Interface of binary outputs

Hardware module instance	Hardware channel	Description
PSM	BO1_PO	Master trip 1 (circuit breaker open)
PSM	BO2_PO	Master close (circuit breaker closed)
PSM	BO3_PO	Master trip 2 (circuit breaker open)
PSM	BO4_PO	Disconnector 1 open
PSM	BO5_PO	Disconnector 1 closed
PSM	BO6_PO	Not connected
PSM	BO7_SO	OC/DOC operate alarm
PSM	BO8_SO	EF/DEF operate alarm
PSM	BO9_SO	Common start
BIO_3	BO1_PO	Disconnector 2 open
BIO_3	BO2_PO	Disconnector 2 closed
BIO_3	BO3_PO	Backup trip

Table continues on next page

Hardware module instance	Hardware channel	Description
BIO_3	BO4_SO	Upstream OC/DOC block
BIO_3	BO5_SO	Common operate
BIO_3	BO6_SO	Not connected
BIO_3	BO7_SO	Circuit breaker monitoring alarm
BIO_3	BO8_SO	Supervision circuit alarm
BIO_3	BO9_SO	Not connected

The IED measures the analog signals needed for protection and measuring functions via galvanically isolated matching transformers. The matching transformer input channels 1…4 are intended for current measuring and channels 7...10 for voltage measuring.

Table 8: Interface of analog inputs

Hardware module instance	Hardware channel	Description
AIM_2	CH1	Phase current IL1
AIM_2	CH2	Phase current IL2
AIM_2	CH3	Phase current IL3
AIM_2	CH4	Neutral current I_0
AIM_2	CH5	Not connected
AIM_2	CH6	Not available
AIM_2	CH7	Phase voltage UL1
AIM_2	CH8	Phase voltage UL2
AIM_2	CH9	Phase voltage UL3
AIM_2	CH10	Neutral voltage U_0

3.2.4 Preprocessing blocks and fixed signals

The analog current and voltage signals coming to the IED are processed by preprocessing blocks. There are two types of preprocessing blocks based on 20 samples per cycle and 80 samples per cycle. All function blocks functioning at 5 ms task time need 80 samples per cycle whereas all the rest need 20 samples per cycle.

A fixed signal block providing a logical TRUE and a logical FALSE output has been used. Outputs are connected internally to other functional blocks when needed.

Even if the *AnalogInputType* setting of a SMAI block is set to “Current”, the *MinValFreqMeas* setting is still visible. This means that the minimum level for current amplitude is based on UBase. As an example, if UBase is 20 kV, the minimum amplitude for current is 20000 × 10% = 2000 A.

3.2.5 Control functions

3.2.5.1 Bay control QCCBAY

Bay control is used to handle the selection of the operator place per bay. It provides blocking functions that can be distributed to different apparatuses within the bay. Bay control sends information about the permitted source to operate (PSTO) and blocking conditions to other functions within the bay, for example switch control functions.

3.2.5.2 Apparatus control SCILO, GNRLCSWI, DAXCBR, DAXSWI

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

Circuit-breaker control function

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

The position information of the circuit breaker and the truck are connected to DAXCBR. The interlocking logics for the circuit breaker have been programmed to open at any time, provided that the gas pressure inside the circuit breaker is above the lockout limit. Closing of the circuit breaker is always prevented if the gas pressure inside the circuit breaker is below the lockout limit or the truck is open or spring charge time is above the set limit. In case the earth switch is closed, check that both disconnectors are open while closing the circuit breaker.

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

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

Disconnector 1, disconnector 2 and earth switch control function

Disconnector 1, disconnector 2, and earth switch are controlled by a combination of SCILO, GNRLCSWI and DAXSWI functions. Each apparatus requires one set of these functions.

The position information of the disconnectors and the earth switch are connected to respective DAXSWI functions via binary inputs. The interlocking logics for the disconnector have been programmed so that it can be opened or closed only if other three apparatuses, that is circuit breaker, earth switch and one of the disconnectors, are open. Interlocking for the earth switch depends on the circuit-breaker condition. If the circuit breaker is open, it is possible to open or close the earth switch at any time. If the circuit breaker is in closed, it is required that the other two disconnectors are open.

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

The open, closed and undefined states of the disconnector 1, disconnector 2 and earth switch are indicated on the LHMI.

The interlocking condition for the disconnector can be different in case a bus sectionalizer is available in the system.

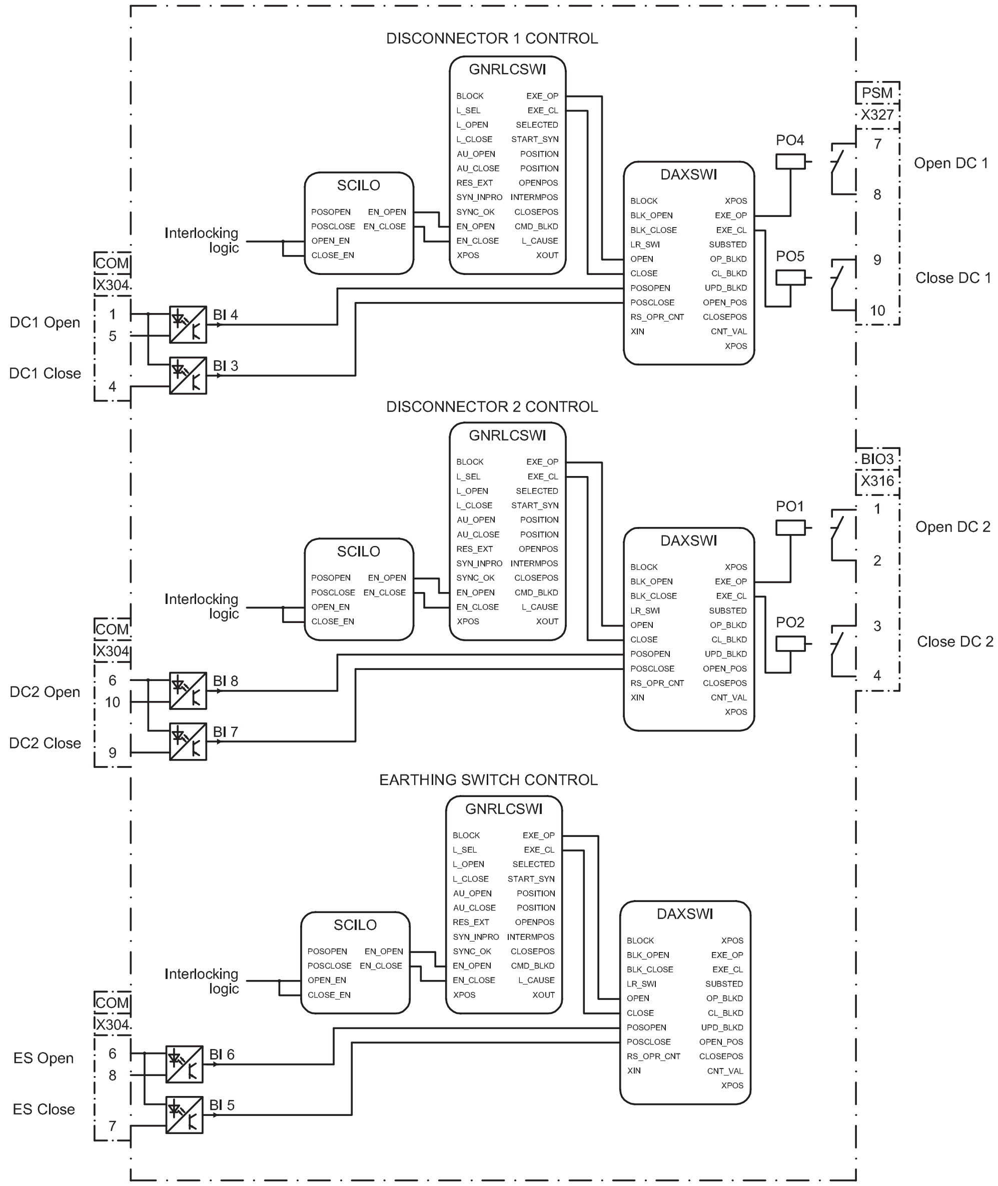


Figure 9: Apparatus control

3.2.5.3 Autoreclosing DARREC

Majority of medium voltage overhead line faults are transient and automatically cleared by momentarily de-energizing the line, whereas the rest of the faults, 15 to 20 percent, are cleared by longer interruptions. The de-energization of the fault place for a wanted period of time is implemented by autoreclosing relays or functions. Automatic reclosing is capable of clearing most of the faults. At a permanent fault, autoreclosing is followed by the final tripping. A permanent fault has to be located and cleared before the fault location can be re-energized.

The function block provides five programmable autoreclose shots for creating autoreclosings of wanted type and duration, such as one high-speed and one delayed autoreclosing. The function consists of six individual initiation lines INIT_1... INIT 6 from which lines INIT_1...3 are used in the preconfiguration. It is possible to create an individual autoreclosing sequence for each input.

In this preconfiguration the autoreclosing function is initiated (lines INIT_1..3) from the operation of protection functions. The autoreclosing function allows also initiation from the start of the protection function, then opening the circuit breaker (OPEN CB) and performing a fast final trip.

The autoreclosing function can be inhibited with the INHIBIT_RECL input. Operate signals of negative sequence overcurrent, phase discontinuity, intermittent earth fault and circuit-breaker gas pressure lock are connected to INHIBIT_RECL input. Spring charged input available from the circuit breaker at binary input COM_101 BI13 is used to check the ready status of circuit breaker before autoreclosing. Inhibit autoreclose signal from the thermal overload protection is connected to BLK_THERM input.

The outputs describing closing command (reclose) to a circuit breaker, unsuccessful autoreclosing and autoreclosing locked-out (CLOSE CB, UNSUC_AR, and LOCKED) are connected to binary recorders. Whereas autoreclosing ready, autoreclosing in progress and autoreclosing locked-out (READY, INPRO and LOCKED) outputs are connected to LED indication on the LHMI.

Status indicating that circuit breaker in open state is connected to the CB_POS inputs. With this connection the setting is *CB closed Pos status* = FALSE.

CLOSE CB output is used for closing the circuit breaker. Before any autoreclosing signal is activated the function block checks for the circuit breaker ready status.

If an industrial feeder employs cables it may not be advisable to use autoreclosing, as cable faults are not transient but permanent.

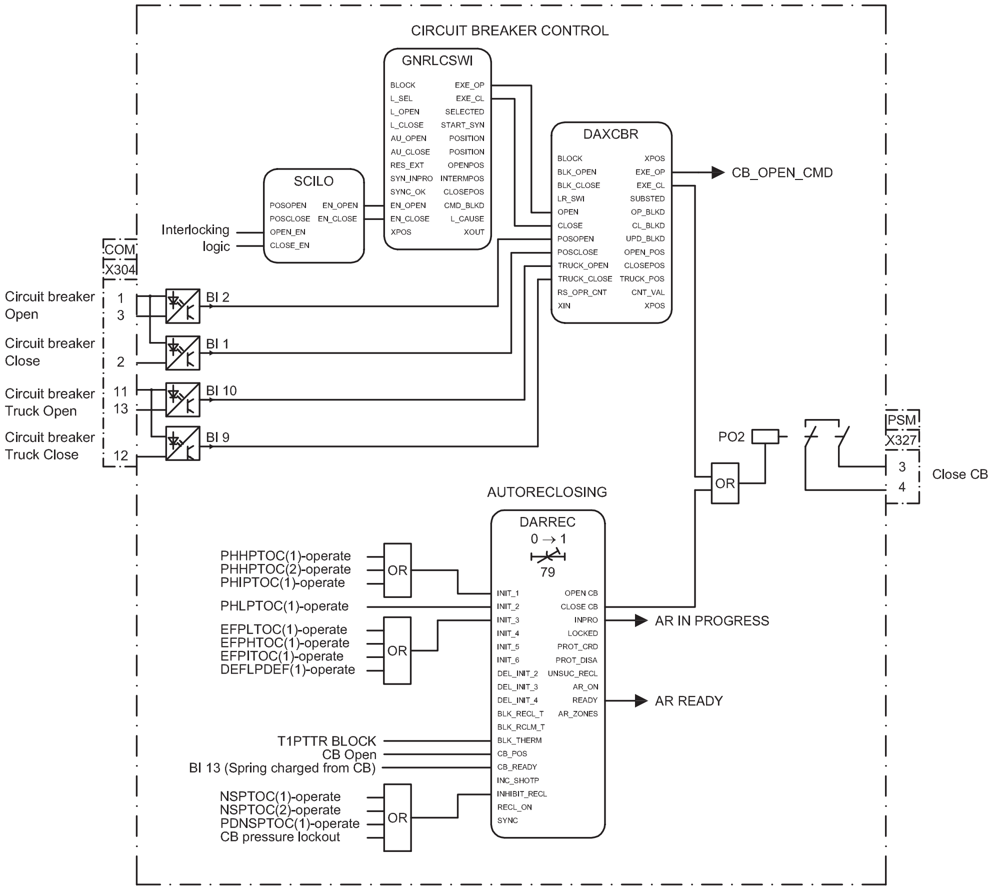


Figure 10: Autoreclosing

3.2.6 Protection functions

3.2.6.1 Three-phase current inrush detection INRPHAR

The configuration includes a three-phase current inrush detection function. The function can be used for increasing, typically double, the set start value of the directional overcurrent (DOC) as well as non-directional overcurrent stage (OC) during inrush condition. This is done by the ENA_MULT input and the *Start value mult* setting in the corresponding function blocks. The default multiplier setting is 1.0.

3.2.6.2 Non-directional overcurrent protection PHxPTOC

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

The configuration includes four variants of non-directional overcurrent functions: high 1, high 2, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs. The inrush function can increase the start value of each overcurrent function.

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

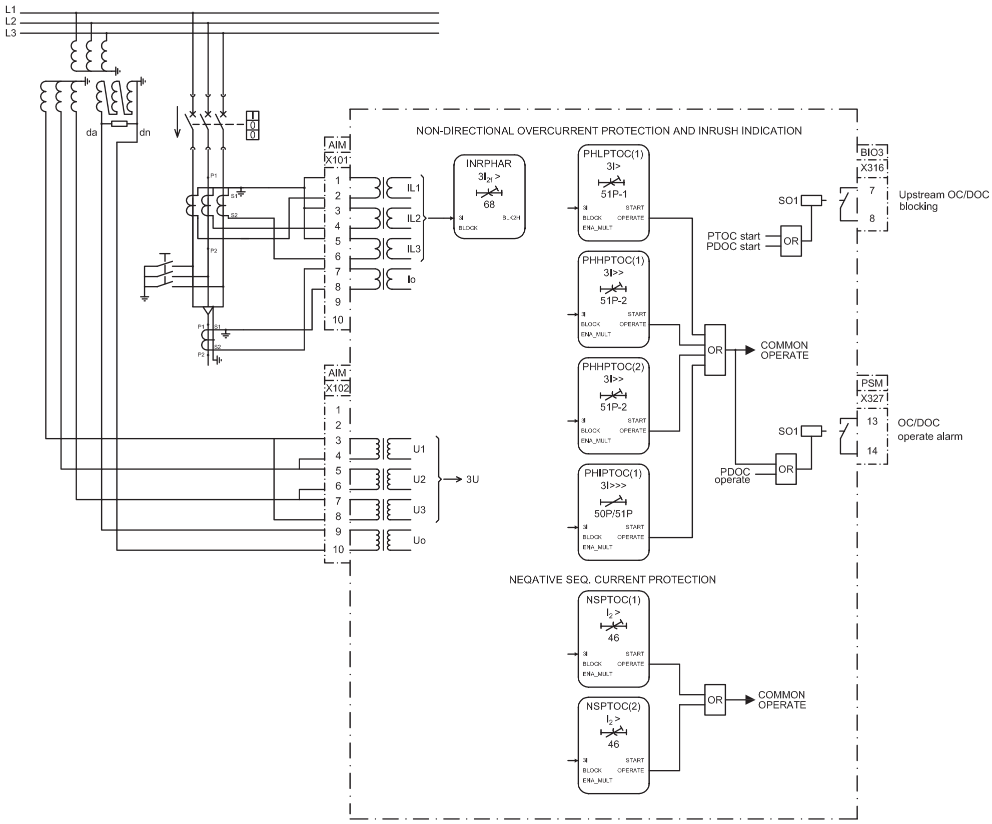


Figure 11: Non-directional overcurrent and negative-sequence overcurrent protection

3.2.6.3 Directional overcurrent protection DPHxPDOC

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

The configuration includes three variants of directional overcurrent functions: high, low 1 and low 2. The polarizing quantity can be phase-to-phase voltage, phase-to-ground voltage, positive-sequence voltage or negative-sequence voltage. The set of three phase currents and voltages, I3P and U3P, is connected to the inputs. The inrush function can increase the start value of each overcurrent function.

A common operate and start signal from all the three overcurrent functions are connected to an OR-gate to form a combined directional overcurrent operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from all the three DOC functions are connected to a disturbance recorder.

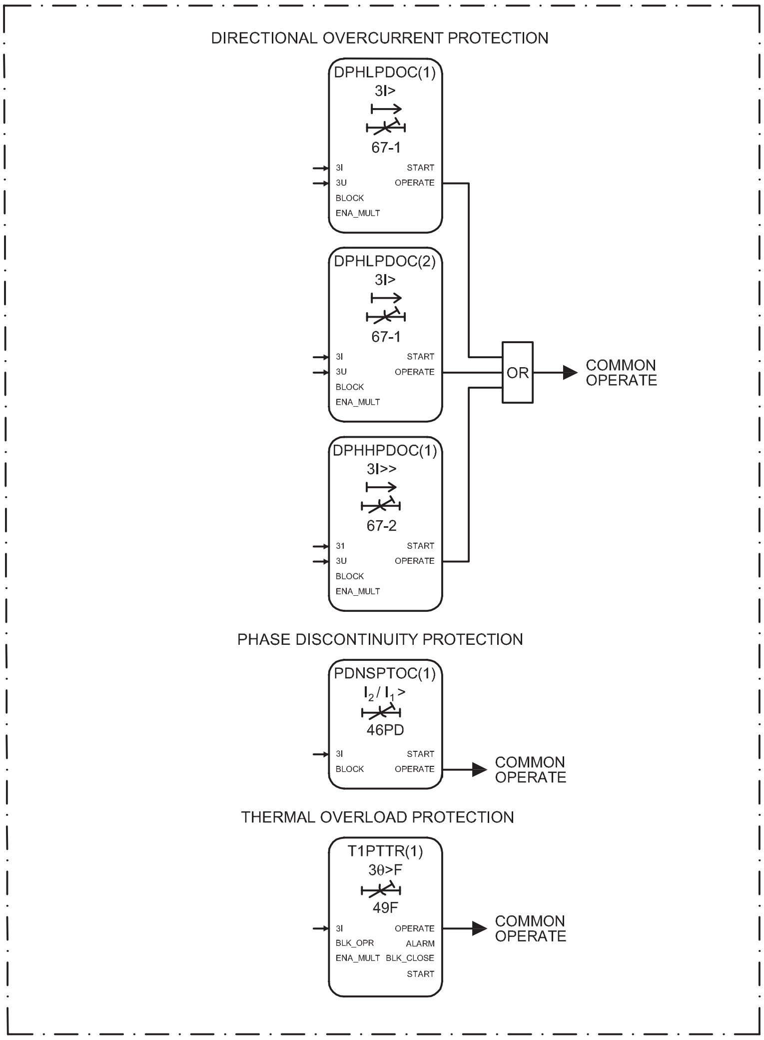


Figure 12: Directional overcurrent, phase discontinuity and thermal overload protection

3.2.6.4 Negative-sequence overcurrent protection NSPTOC

Two instances of negative-sequence overcurrent detection are provided, for protection against single-phasing, unbalanced load or asymmetrical feeder voltage. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from both NSPTOC functions are connected to an OR-gate to form a combined negative-sequence overcurrent operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from the NSPTOC function is connected to the disturbance recorder.

3.2.6.5 Phase discontinuity protection PDNSPTOC

The phase discontinuity protection functions are used for protection against broken phase conductors in distribution networks. Definite-time (DT) characteristic is always used. Operation of the stage is based on ratio of 2^{nd} harmonic and fundamental frequency of phase currents.

The set of three phase currents, I3P, is connected to the inputs. Operate and start signals are used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.2.6.6 Non-directional earth-fault protection EFxPTOC

The non-directional earth-fault protection functions are used for protection under earth-fault conditions with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values. The configuration includes high-stage non-directional current functions. The set of three phase currents, I3P, is connected to the inputs.

The start and operate signals from the high-stage non-directional current function is connected to the disturbance recorder.

3.2.6.7 Intermittent earth-fault protection INTRPTEF

Intermittent earth-fault function is a dedicated earth-fault protection function in intermittent and transient earth faults occurring in distribution networks. Definite time (DT) characteristic is always used. In the configuration, the intermittent function is used in parallel with directional earth-fault protection. Directional earth-fault function is blocked by an intermittent earth-fault function to prevent erroneous trips when the function is set to operate with “Intermittent EF" mode.

The start and operate signals from INTRPTEF is connected to the disturbance recorder. Also a common operate and start signal from the high-stage earth-fault protection and intermittent earth-fault functions are connected to an OR-gate to form a combined non-directional earth-fault operate and start signal which is used to provide a LED indication on the LHMI.

3.2.6.8 Directional earth-fault protection DEFxPDEF

The directional earth-fault protection functions are used for directional earth-fault protection with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The set of three phase currents, I3P, is connected to the inputs. The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values.

The configuration includes three variants of directional earth-fault protection function: high, low 1 and low 2. The set of three phase currents and voltages, I3P and U3P, are connected to the inputs. The directional earth-fault protections are blocked by an intermittent earth-fault function.

The IED's characteristics angle control can be done by binary input BIO_3 BI1. A common operate and start signal from all three directional earth-faults are connected to an OR-gate to form a combined directional earth-fault operate and start signal which are further used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

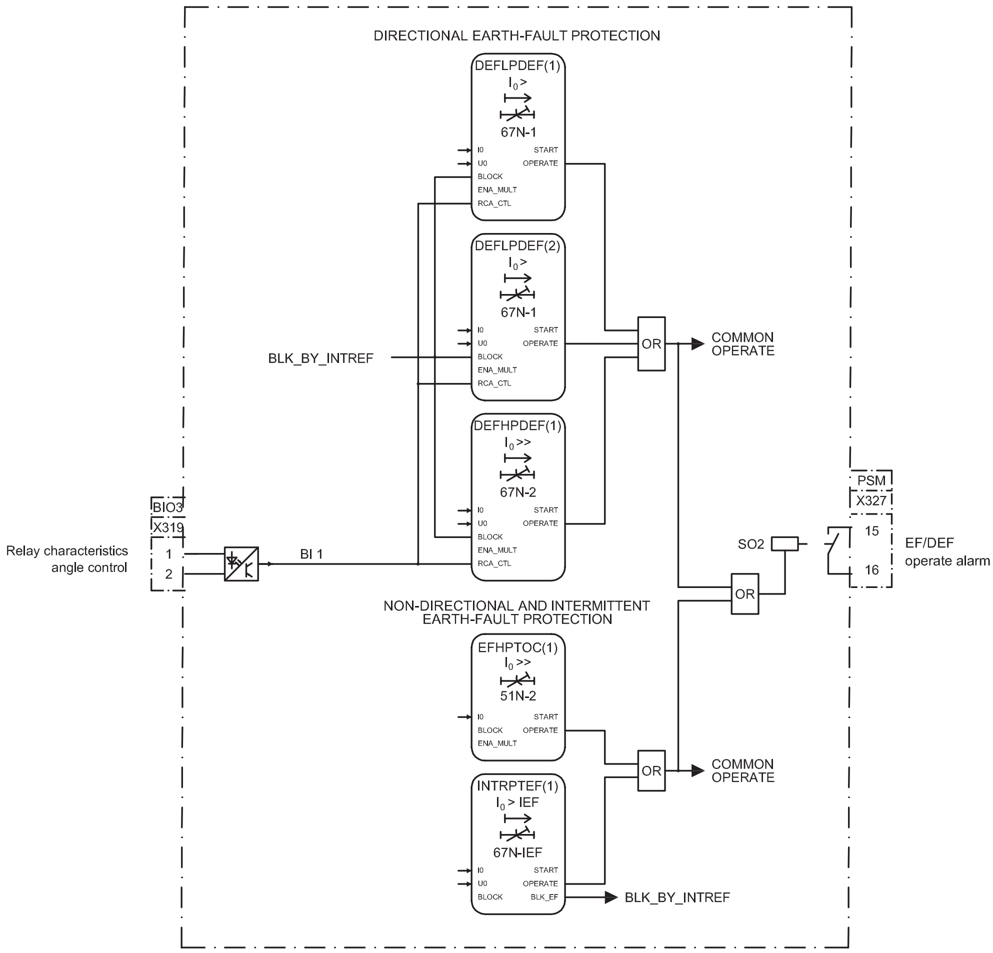


Figure 13: Earth-fault protection

3.2.6.9 Thermal overload protection T1PTTR

The three-phase thermal overload protection function is used for thermal protection of the three-phase power cables and overhead lines. It has adjustable temperature limits for tripping, alarm and reclose inhibit. The thermal model applied uses one time constant and the true RMS current measuring principle.

The operate signal from the thermal overload protection is further used to trigger the disturbance recorder. Both the operate and alarm signals provide a LED indication on the LHMI.

3.2.6.10 Circuit-breaker failure protection CCBRBRF

The function is activated by the common operate command from the protection functions. The breaker failure function issues a backup trip command to adjacent circuit breakers in case the main circuit breaker fails to trip for the protected component. The backup trip is connected at binary output BIO_3 PO3.

A failure of a circuit breaker is detected by measuring the current or by detecting the remaining trip signal. Function also provides retrip. Retrip is used along with the main trip, and is activated before the backup trip signal is generated in case the main breaker fails to open. Retrip is used to increase the operational reliability of the circuit breaker.

3.2.6.11 Tripping logic TRPPTRC

Tripping logic has been configured to provide tripping signal of required duration. The tripping circuit opens the circuit breaker on

- Receipt of operate signal from the protection function or
- Retrip signal from the circuit-breaker failure protection.

Two master tripping signals are available at binary output PSM PO1 and PSM PO3.

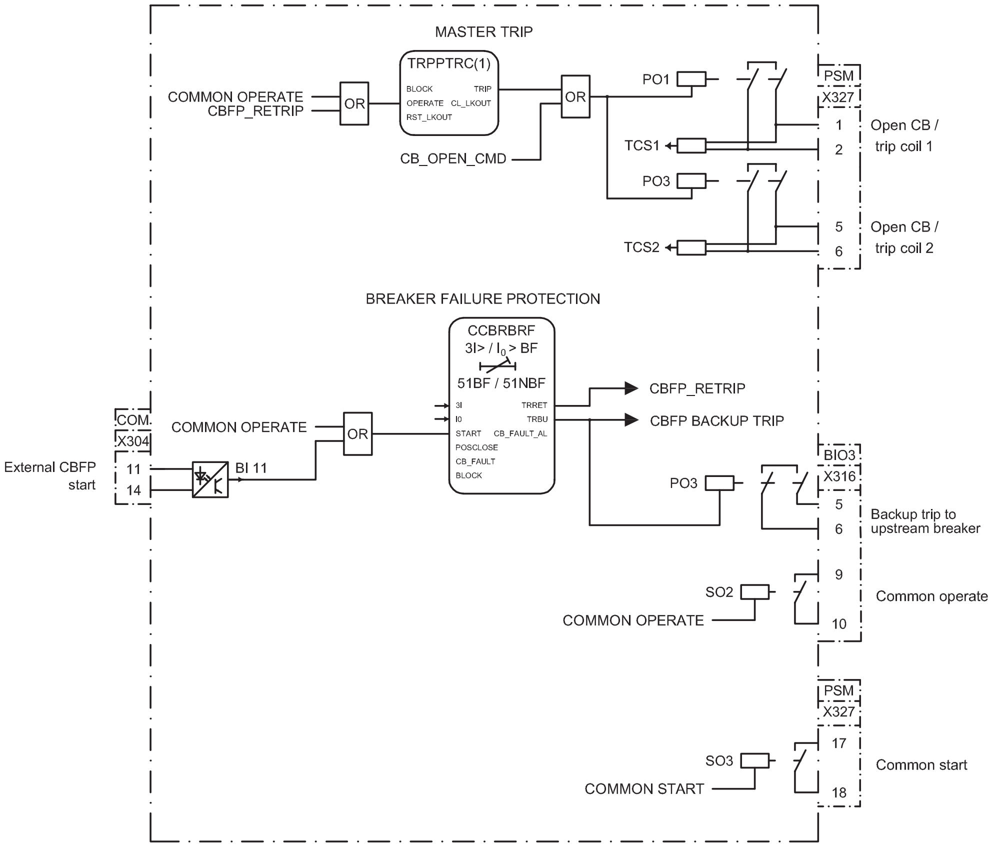


Figure 14: Tripping logic and breaker failure protection

3.2.6.12 Combined operate and start alarm signal

The operate outputs of all protection functions are combined in an OR-gate to get a common Operate output. This common operate signal is connected to a tripping logic. It is also available as an alarm binary output, BIO_3_SO2, with a settable minimum alarm delay of 80 ms. Also, a common Start output is derived from the start outputs of protection functions combined in an OR-gate. The output is available as an alarm binary output PSM SO3 with a settable minimum alarm delay of 80 ms.

3.2.6.13 Other output and alarm signals

- Combined directional and non-directional overcurrent (OC/DOC) operate signal available at binary output PSM SO1
- Combined directional and non-directional earth-fault (EF/DEF) operate signal available at binary output PSM SO2
- Combined alarm signal from circuit-breaker monitoring function available at binary output BIO_3 SO4
- Combined alarm signal from various supervision functions available at binary output BIO_3 SO5
- Upstream directional and non-directional overcurrent (OC/DOC) blocking signal available at binary output BIO_3 SO1

3.2.7 Supervision functions

3.2.7.1 Trip circuit supervision TCSSCBR

Two instances of trip circuit supervision function are used for supervising Master trip 1 and Master trip 2. Function continuously supervises trip circuit and an alarm is issued in case of a failure of a trip circuit. The function does not perform the supervision itself but it is used as an aid for configuration.

Function gives an indication via a LED on the LHMI on detection of any of the trip circuit failure. To prevent unwanted alarms, the function is blocked when the circuit breaker is open, one of the protection function operate signals is active.

An instance of trip circuit supervision is used to check the proper functioning of closing circuit of the circuit breaker. This function is blocked when the circuit breaker is in closed position to prevent unwanted alarms.

3.2.7.2 Fuse failure and current circuit supervision SEQRFUF, CCRDIF

The fuse failure and current circuit supervision functions give an alarm in case of a failure in the secondary circuits between the voltage transformer or current transformer and the IED respectively. The set of three phase currents and voltages, I3P and U3P, are connected to the inputs.

An alarm is available on failure of the secondary circuits. Alarms are recorded by a disturbance recorder.

3.2.7.3 Circuit-breaker condition monitoring SSCBR

The circuit-breaker condition monitoring function checks for the health of the circuit breaker. The circuit breaker status is connected to the function via binary inputs. Function requires also pressure lockout input and spring charged input connected via binary input COM_101.BI12 and COM_101.BI13 respectively. Various alarm outputs from the function are combined in an OR-gate to create a master circuit-breaker monitoring alarm, which is available at binary output BIO_3 SO4.

All of the alarms are separately connected to the binary recorder and a combined alarm is available as an indication via a LED on the LHMI.

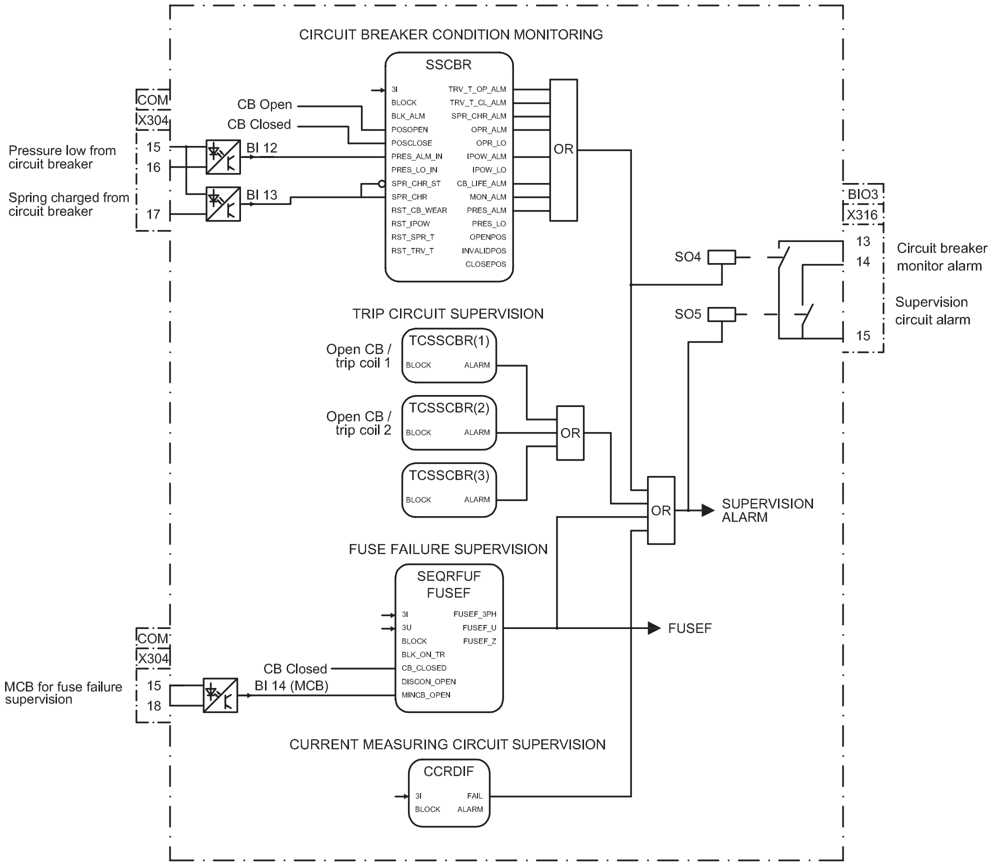


Figure 15: Circuit-breaker condition monitoring and trip-circuit, fuse failure and current measuring circuit supervision

3.2.8 Measurement and analog recording functions

The measured quantities in this configuration are:

- Sequence current
- Sequence voltage
- Residual voltage
- Residual current
- Energy
- Phase current
- Phase voltage
- Line voltage
- Power with frequency

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 the analog recorder

Channel ID	Description
Channel 1	Phase A current
Channel 2	Phase B current
Channel 3	Phase C current
Channel 4	Neutral current
Channel 5	Phase A voltage
Channel 6	Phase B voltage
Channel 7	Phase C voltage
Channel 8	Neutral voltage

Data connected to analog channels contain 20 samples per cycle.

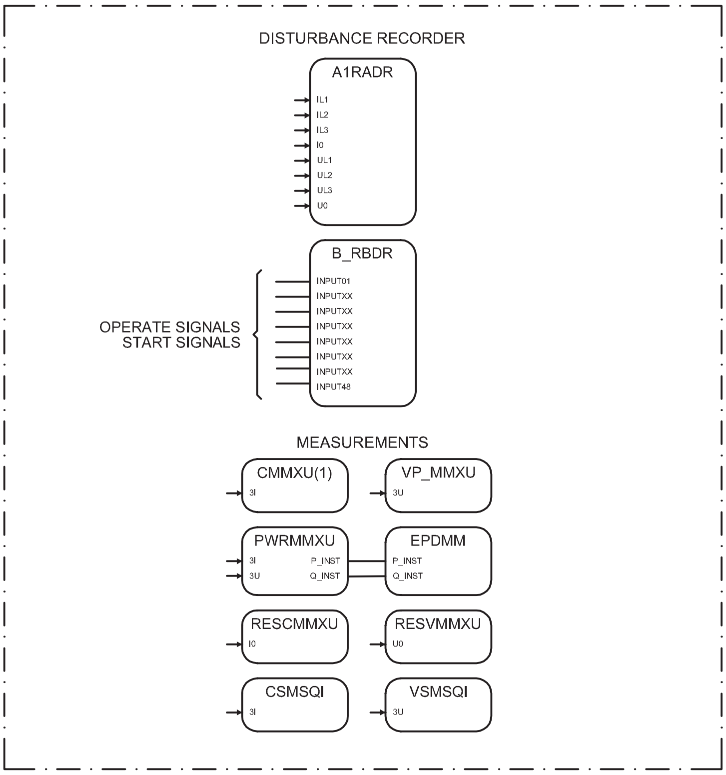


Figure 16: Measurement and analog recording functions

3.2.9 Binary recording and LED configuration

All of 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 which in turn will record all the signals connected to the recorder.

Table 10: Signals connected to the binary recorder

Channel ID	Description
Channel 1	Block by inrush protection
Channel 2	Start of directional overcurrent high stage
Channel 3	Operate of directional overcurrent high stage
Channel 4	Start of directional overcurrent low stage 1
Channel 5	Operate of directional overcurrent low stage 1
Channel 6	Start of directional overcurrent low stage 2
Channel 7	Operate of directional overcurrent low stage 2
Channel 8	Start of overcurrent high stage 1
Channel 9	Operate of overcurrent high stage 1
Channel 10	Start of overcurrent high stage 2
Channel 11	Operate of overcurrent high stage 2
Channel 12	Start of instantaneous overcurrent stage
Channel 13	Operate of instantaneous overcurrent stage
Channel 14	Start of overcurrent low stage
Channel 15	Operate of overcurrent low stage
Channel 16	Operate of thermal overload
Channel 17	Start of negative-sequence overcurrent stage 1
Channel 18	Operate of negative-sequence overcurrent stage 1
Channel 19	Start of negative-sequence overcurrent stage 2
Channel 20	Operate of negative-sequence overcurrent stage 2
Channel 21	Start of directional earth fault high stage
Channel 22	Operate of directional earth fault high stage
Channel 23	Start of directional earth fault low stage 1
Channel 24	Operate of directional earth fault low stage 1
Channel 25	Start of directional earth fault low stage 2
Channel 26	Operate of directional earth fault low stage 2
Channel 27	Start of earth-fault high stage
Channel 28	Operate of earth-fault high stage
Channel 29	Start of intermittent earth fault
Channel 30	Operate of intermittent earth fault
Channel 31	Start of phase-discontinuity protection
Channel 32	Operate of phase-discontinuity protection
Table continues on next page	

Channel ID	Description
Channel 33	Circuit breaker closed
Channel 34	Circuit breaker is open
Channel 35	Unsuccessful autoreclosing
Channel 36	Autoreclosing function locked out
Channel 37	Reclose by autoreclosing
Channel 38	Backup trip from circuit-breaker failure protection
Channel 39	Retrip from circuit-breaker failure protection
Channel 40	Trip circuit alarm 1 (supervising master trip 1)
Channel 41	Trip circuit alarm 2 (supervising master trip 2)
Channel 42	Trip circuit alarm 3 (supervising closing circuit)
Channel 43	Current circuit supervision alarm
Channel 44	Fuse failure
Channel 45	Closing time of circuit breaker exceeded the limit
Channel 46	Opening time of circuit breaker exceeded the limit
Channel 47	Spring charge time of circuit breaker exceeded the limit
Channel 48	Number of circuit breaker operation exceeded the set limit
Channel 49	Pressure in circuit breaker below lockout limit
Channel 50	Circuit breaker maintenance alarm: number of operations exceeds the set limit
Channel 51	Circuit breaker maintenance alarm: accumulated energy exceeds the set limit
Channel 52	Circuit breaker not operated since long

The LEDs are configured for alarm indications.

Table 11: LEDs configured on LHMI alarm page 1

LED No	LED color	Description
LED 1	Yellow	Combine start from DOC
LED 1	Red	Combine operate from DOC
LED 2	Yellow	Combine start from OC
LED 2	Red	Combine operate from OC
LED 3	Yellow	Combine start from NSOC
LED 3	Red	Combine operate from NSOC
LED 4	Yellow	Combine start from EF
LED 4	Red	Combine operate from EF
LED 5	Yellow	Combine start from DEF
LED 5	Red	Combine operate from DEF
LED 6	Yellow	Start from phase discontinuity
LED 6	Red	Operate from phase discontinuity
LED 7	Yellow	Operate from thermal overload
LED 7	Red	Alarm from thermal overload
Table continues on next page		

LED No	LED color	Description
LED 8	Green	Autoreclosing ready
LED 8	Yellow	Autoreclosing in progress
LED 8	Red	Autoreclosing function locked out
LED 9	Red	Combine trip circuit supervision alarm
LED 10	Red	Backup trip from circuit-breaker protection function
LED 11	Red	Retrip from circuit-breaker protection function
LED 12	Red	Alarm from circuit-breaker monitoring function
LED 13	Red	Fuse failure supervision
LED 14	Red	Current circuit supervision alarm

3.3 Preconfiguration B for radial overhead/mixed line feeder

3.3.1 Application

The functionality of the IED is designed to be used for selective short-circuit, overcurrent and earth-fault protection of impedance grounded population feeders on double busbar systems with one circuit breaker.

The objects controlled by the IED are the circuit breaker and the disconnector. The earth switch is considered to be operated manually. The open, close and undefined states of the circuit breaker, disconnectors and the earth switch are indicated on the LHMI.

Required interlocking is configured in the IED.

The preconfiguration includes:

- Control functions
- Current protection functions
- Supervision functions
- Disturbance recorders
- LEDs' configuration
- Measurement functions

3.3.2 Functions

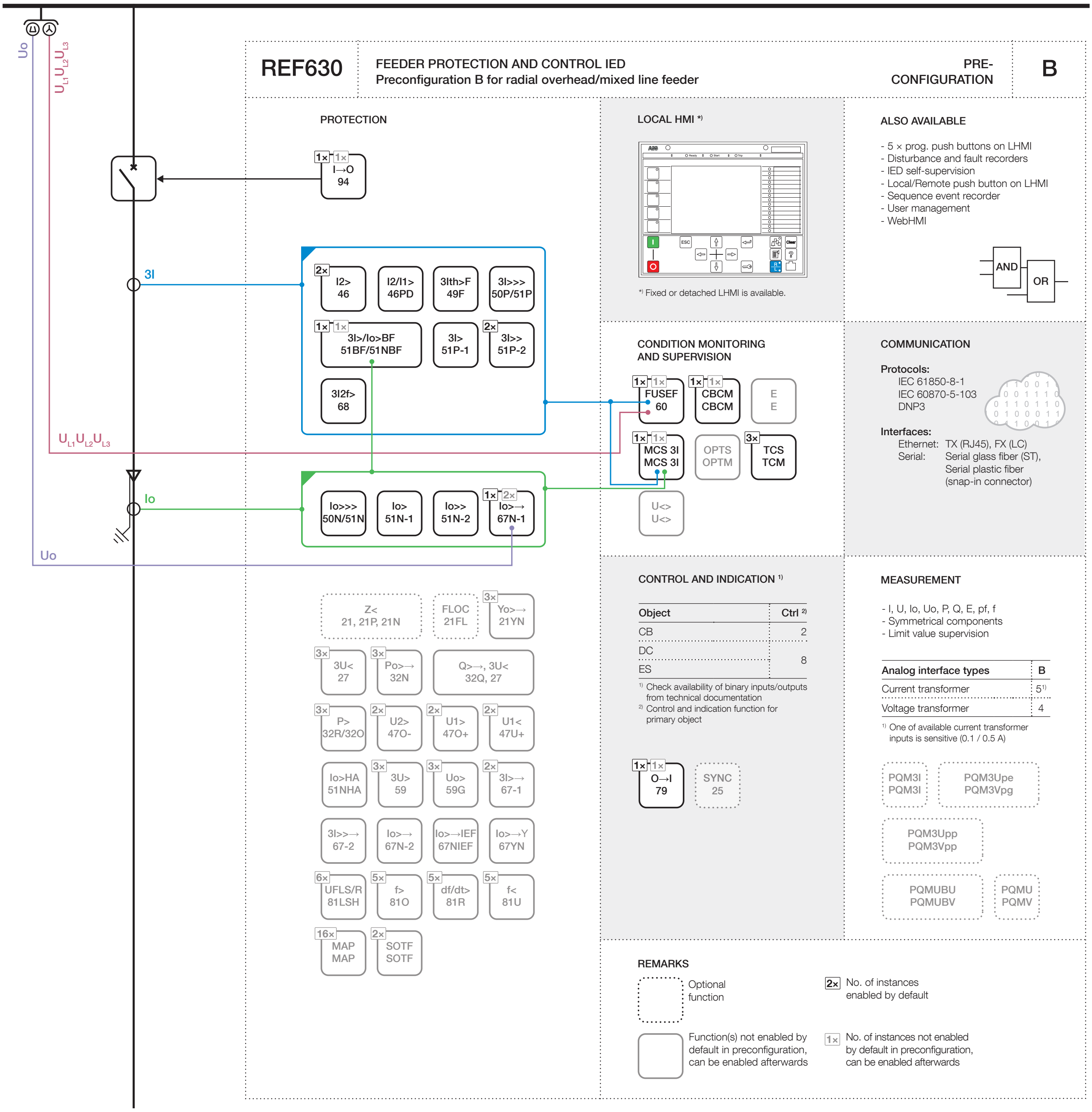


Figure 17: Functionality overview for preconfiguration B

3.3.3 Input/output signal interfaces

Table 12: Interface of binary inputs

Hardware module instance	Hardware channel	Description
COM	BI1	Circuit breaker closed
COM	BI2	Circuit breaker open
COM	BI3	Disconnector 1 closed
COM	BI4	Disconnector 1 open
COM	BI5	Earth switch closed
COM	BI6	Earth switch open
COM	BI7	Disconnector 2 closed
COM	BI8	Disconnector 2 open
COM	BI9	Circuit breaker truck closed
COM	BI10	Circuit breaker truck open
COM	BI11	External start of circuit-breaker failure protection
COM	BI12	Pressure low from circuit breaker
COM	BI13	Spring charged from circuit breaker
COM	BI14	MCB for fuse failure supervision

The outputs of the IED are categorized as power outputs (POx) and signal outputs (SOx). The power outputs can be used for closing and tripping of circuit breakers and disconnector control. The signal outputs are not heavy-duty outputs. They are used for alarm or signaling purposes.

Table 13: Interface of binary outputs

Hardware module instance	Hardware channel	Description
PSM	BO1_PO	Master trip 1 (circuit breaker open)
PSM	BO2_PO	Master close (circuit breaker closed)
PSM	BO3_PO	Master trip 2 (circuit breaker open)
PSM	BO4_PO	Disconnector 1 open
PSM	BO5_PO	Disconnector 1 closed
PSM	BO6_PO	Not connected
PSM	BO7_SO	OC operate alarm
PSM	BO8_SO	EF/DEF operate alarm
PSM	BO9_SO	Common start
BIO_3	BO1_PO	Disconnector 2 open
BIO_3	BO2_PO	Disconnector 2 closed
BIO_3	BO3_PO	Backup trip
BIO_3	BO4_SO	Upstream OC block
BIO_3	BO5_SO	Common operate
Table continues on next page		

Hardware module instance	Hardware channel	Description
BIO_3	BO6_SO	Not connected
BIO_3	BO7_SO	Circuit-breaker monitoring alarm
BIO_3	BO8_SO	Supervision circuit alarm
BIO_3	BO9_SO	Not connected

The IED measures the analog signals needed for protection and measuring functions via galvanically isolated matching transformers. The matching transformer input channels 1…4 are intended for current measuring and channels 7...10 for voltage measuring.

Table 14: Interface of analog inputs

Hardware module instance	Hardware channel	Description
AIM_2	CH1	Phase current IL1
AIM_2	CH2	Phase current IL2
AIM_2	CH3	Phase current IL3
AIM_2	CH4	Neutral current I_0
AIM_2	CH5	Current I_0 from CBCT
AIM_2	CH6	Not available
AIM_2	CH7	Phase voltage UL1
AIM_2	CH8	Phase voltage UL2
AIM_2	CH9	Phase voltage UL3
AIM_2	CH10	Neutral voltage U_0

3.3.4 Preprocessing blocks and fixed signals

The analog current and voltage signals coming to the IED are processed by preprocessing blocks. There are two types of preprocessing blocks based on 20 samples per cycle and 80 samples per cycle. All function blocks functioning at 5 ms task time need 80 samples per cycle whereas all the rest need 20 samples per cycle.

A fixed signal block providing a logical TRUE and a logical FALSE output has been used. Outputs are connected internally to other functional blocks when needed.

Even if the *AnalogInputType* setting of a SMAI block is set to “Current”, the *MinValFreqMeas* setting is still visible. This means that the minimum level for current amplitude is based on UBase. As an example, if UBase is 20 kV, the minimum amplitude for current is 20000 × 10% = 2000 A.

3.3.5 Control functions

3.3.5.1 Bay control QCCBAY

Bay control is used to handle the selection of the operator place per bay. It provides blocking functions that can be distributed to different apparatuses within the bay. Bay control sends information about the permitted source to operate (PSTO) and blocking conditions to other functions within the bay, for example switch control functions.

3.3.5.2 Apparatus control SCILO, GNRLCSWI, DAXCBR, DAXSWI

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

Circuit-breaker control function

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

The position information of the circuit breaker and the truck are connected to DAXCBR. The interlocking logics for the circuit breaker have been programmed to open at any time, provided that the gas pressure inside the circuit breaker is above the lockout limit. Closing of the circuit breaker is always prevented if the gas pressure inside the circuit breaker is below the lockout limit or the truck is open or spring charge time is above the set limit. In case the earth switch is closed, check that both disconnectors are open while closing the circuit breaker.

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

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

Disconnector 1, disconnector 2 and earth switch control function

Disconnector 1, disconnector 2, and earth switch are controlled by a combination of SCILO, GNRLCSWI and DAXSWI functions. Each apparatus requires one set of these functions.

The position information of the disconnectors and the earth switch are connected to respective DAXSWI functions via binary inputs. The interlocking logics for the disconnector have been programmed so that it can be opened or closed only if other three apparatuses, that is circuit breaker, earth switch and one of the disconnectors, are open. Interlocking for the earth switch depends on the circuit-breaker condition. If the circuit breaker is open, it is possible to open or close the earth switch at any time. If the circuit breaker is in closed, it is required that the other two disconnectors are open.

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

The open, closed and undefined states of the disconnector 1, disconnector 2 and earth switch are indicated on the LHMI.

The interlocking condition for the disconnector can be different in case a bus sectionalizer is available in the system.

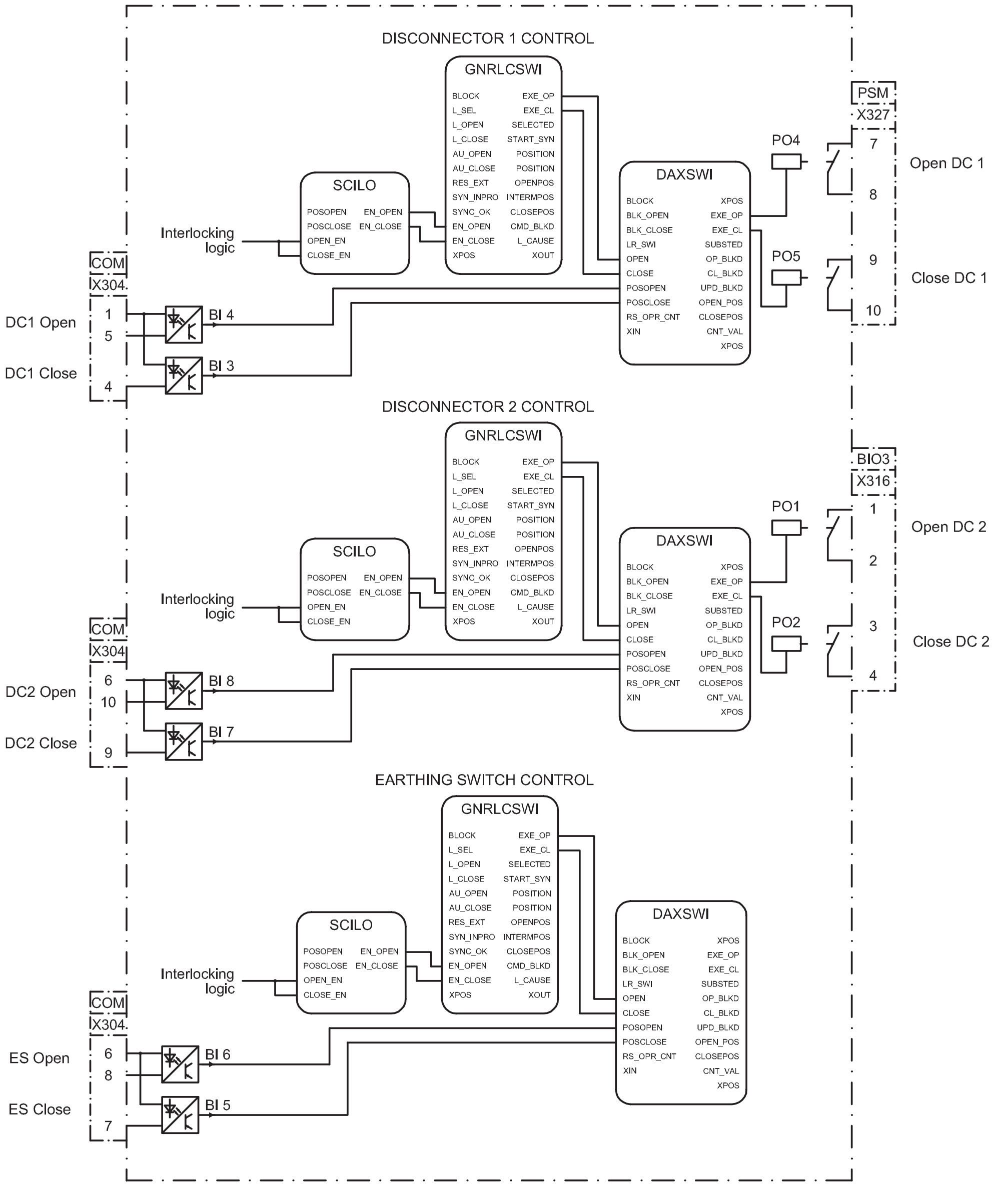


Figure 18: Apparatus control

3.3.5.3 Autoreclosing DARREC

Majority of medium voltage overhead line faults are transient and automatically cleared by momentarily de-energizing the line, whereas the rest of the faults, 15 to 20 percent, are cleared by longer interruptions. The de-energization of the fault place for a wanted period of time is implemented by autoreclosing relays or functions. Automatic reclosing is capable of clearing most of the faults. At a permanent fault, autoreclosing is followed by the final tripping. A permanent fault has to be located and cleared before the fault location can be re-energized.

The function block provides five programmable autoreclose shots for creating autoreclosings of wanted type and duration, such as one high-speed and one delayed autoreclosing. The function consists of six individual initiation lines INIT_1... INIT 6 from which lines INIT_1...3 are used in the preconfiguration. It is possible to create an individual autoreclosing sequence for each input.

In this preconfiguration the autoreclosing function is initiated (lines INIT_1..3) from the operation of protection functions. The autoreclosing function allows also initiation from the start of the protection function, then opening the circuit breaker (OPEN CB) and performing a fast final trip.

The autoreclosing function can be inhibited with the INHIBIT_RECL input. Operate signals of negative sequence overcurrent, phase discontinuity, intermittent earth fault and circuit-breaker gas pressure lock are connected to INHIBIT_RECL input. Spring charged input available from the circuit breaker at binary input COM_101 BI13 is used to check the ready status of circuit breaker before autoreclosing. Inhibit autoreclose signal from the thermal overload protection is connected to BLK_THERM input.

The outputs describing closing command (reclose) to a circuit breaker, unsuccessful autoreclosing and autoreclosing locked-out (CLOSE CB, UNSUC_AR, and LOCKED) are connected to binary recorders. Whereas autoreclosing ready, autoreclosing in progress and autoreclosing locked-out (READY, INPRO and LOCKED) outputs are connected to LED indication on the LHMI.

Status indicating that circuit breaker in open state is connected to the CB_POS inputs. With this connection the setting is *CB closed Pos status* = FALSE.

CLOSE CB output is used for closing the circuit breaker. Before any autoreclosing signal is activated the function block checks for the circuit breaker ready status.

If an industrial feeder employs cables it may not be advisable to use autoreclosing, as cable faults are not transient but permanent.

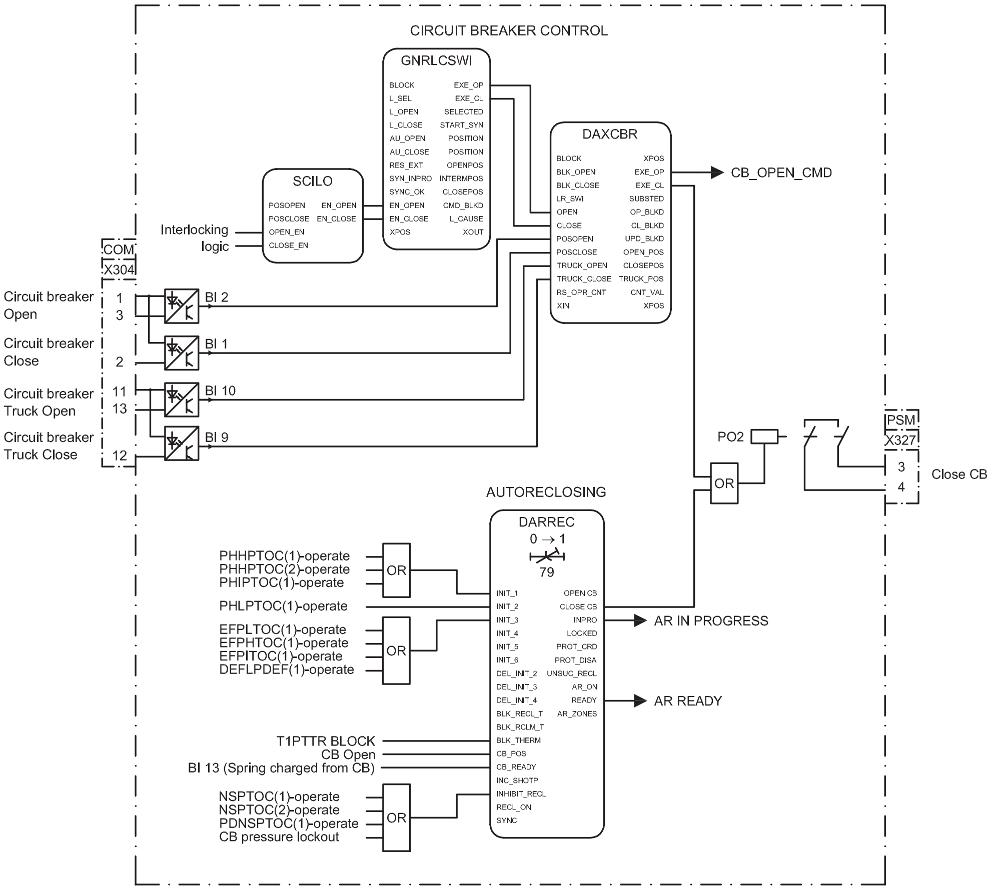


Figure 19: Autoreclosing

3.3.6 Protection functions

3.3.6.1 Three-phase current inrush detection INRPHAR

The configuration includes a three-phase current inrush detection function. The function can be used for increasing, typically double, the set start value of the non-directional overcurrent stage (OC) during inrush condition. This is done by the ENA_MULT input and the *Start value mult* setting in the corresponding function blocks. The default multiplier setting is 1.0.

3.3.6.2 Non-directional overcurrent protection PHxPTOC

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

The configuration includes four variants of non-directional overcurrent functions: high 1, high 2, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs. The inrush function can increase the start value of each overcurrent function.

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

3.3.6.3 Negative-sequence overcurrent protection NSPTOC

Two instances of negative-sequence overcurrent detection are provided, for protection against single-phasing, unbalanced load or asymmetrical feeder voltage. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from both NSPTOC functions are connected to an OR-gate to form a combined negative-sequence overcurrent operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from the NSPTOC function is connected to the disturbance recorder.

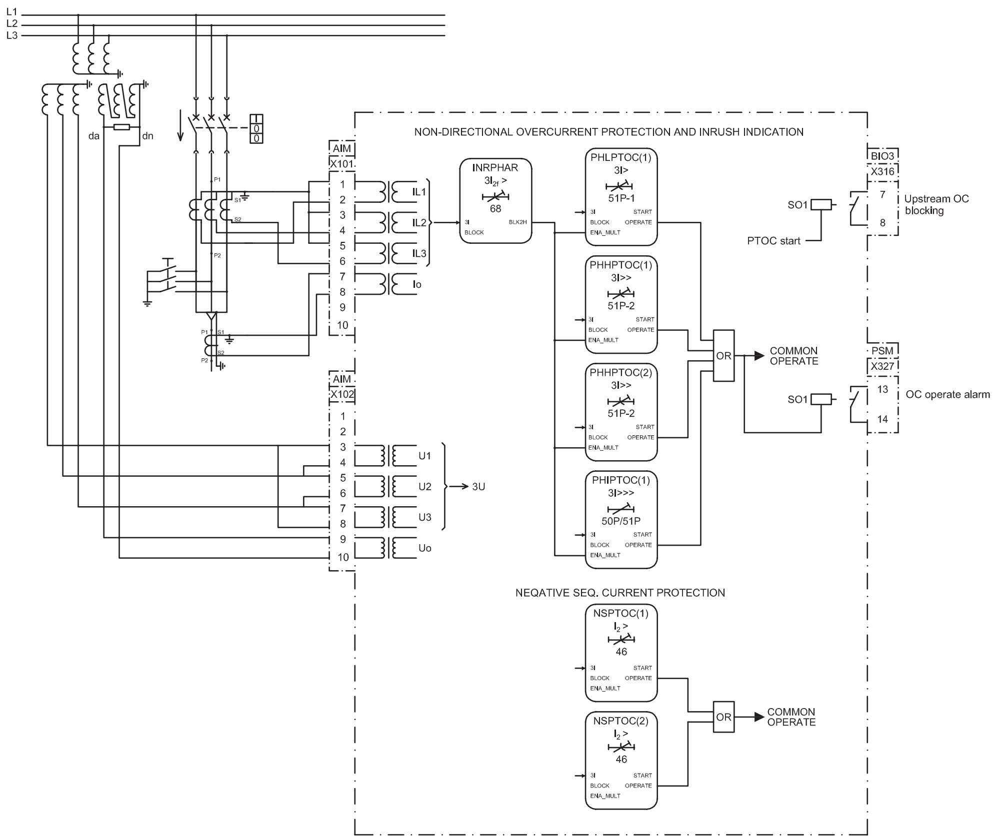


Figure 20: Non-directional overcurrent and negative-sequence overcurrent protection

3.3.6.4 Phase discontinuity protection PDNSPTOC

The phase discontinuity protection functions are used for protection against broken phase conductors in distribution networks. Definite-time (DT) characteristic is always used. Operation of the stage is based on ratio of 2^{nd} harmonic and fundamental frequency of phase currents.

The set of three phase currents, I3P, is connected to the inputs. Operate and start signals are used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.3.6.5 Non-directional earth-fault protection EFxPTOC

The non-directional earth-fault protection functions are used for protection under earth fault conditions with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values. The configuration includes three variants of non-directional earth-fault functions: high, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from all the three non-directional earth-fault functions are connected to an OR-block to form a combined non-directional earth-fault operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from all the three EF functions are connected to the disturbance recorder.

3.3.6.6 Directional earth-fault protection DEFxPDEF

The directional earth-fault protection function block is set to operate as non-directional earth-fault protection, with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The set of three phase currents and voltages, I3P and U3P, are connected to the inputs. The operation of the stage can be based on three measuring principles: DFT, RMS or peak-to-peak values.

The configuration includes low-stage directional earth-fault protection. The residual current inputs are obtained through residual connection of three numbers of single phase current transformers or a core-balanced current transformer or through a single current transformer connected to neutral of a star-connected transformer. To achieve the highest sensitivity and accuracy, use a separate neutral current transformer connection to sensitive dedicated current channel 5 of the IED.

A directional earth-fault operate and start signal is used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.3.6.7 Thermal overload protection T1PTTR

The three-phase thermal overload protection function is used for thermal protection of the three-phase power cables and overhead lines. It has adjustable temperature limits for tripping, alarm and reclose inhibit. The thermal model applied uses one time constant and the true RMS current measuring principle.

The operate signal from the thermal overload protection is further used to trigger the disturbance recorder. Both the operate and alarm signals provide a LED indication on the LHMI.

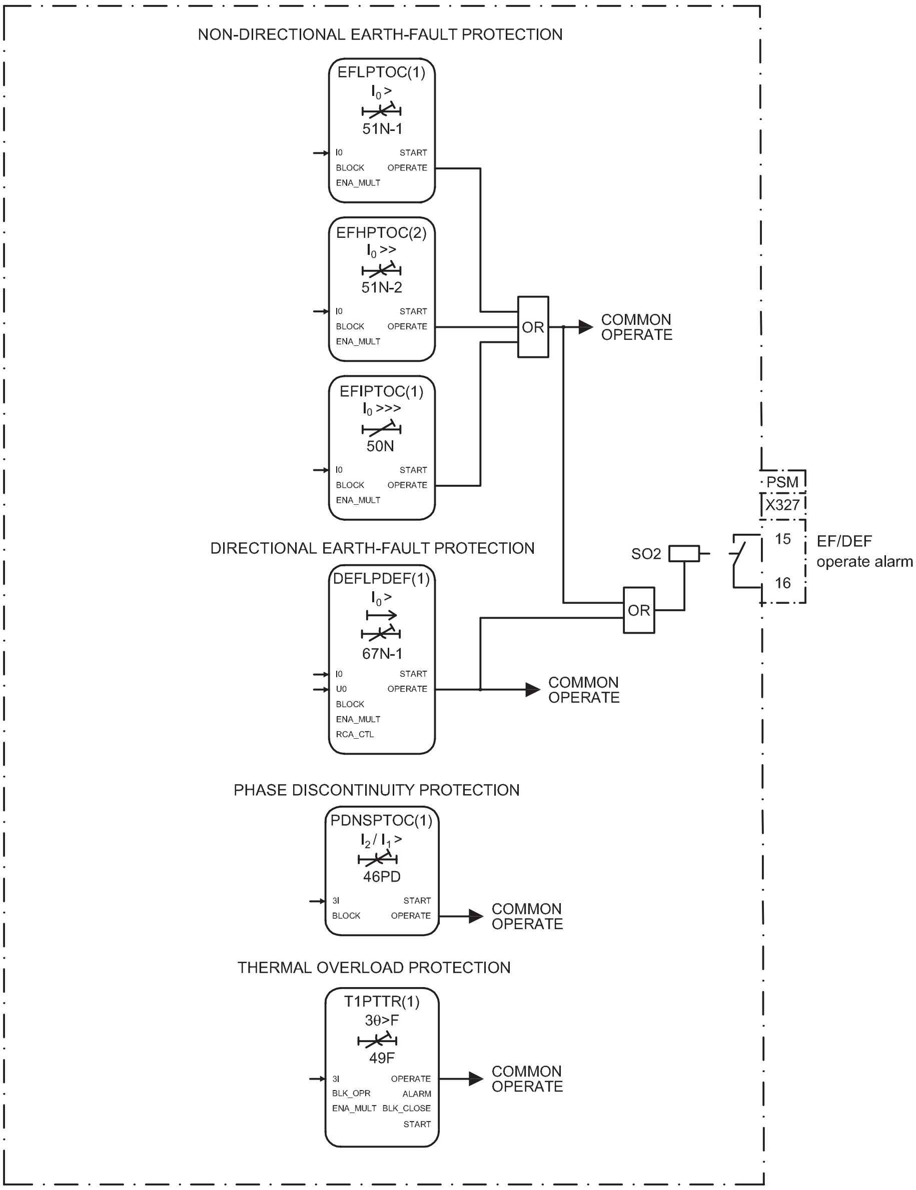


Figure 21: Earth-fault, phase discontinuity and thermal overload protection

3.3.6.8 Circuit-breaker failure protection CCBRBRF

The function is activated by the common operate command from the protection functions. The breaker failure function issues a backup trip command to adjacent circuit breakers in case the main circuit breaker fails to trip for the protected component. The backup trip is connected at binary output BIO_3 PO3.

A failure of a circuit breaker is detected by measuring the current or by detecting the remaining trip signal. Function also provides retrip. Retrip is used along with the main trip, and is activated before the backup trip signal is generated in case the main breaker fails to open. Retrip is used to increase the operational reliability of the circuit breaker.

3.3.6.9 Tripping logic TRPPTRC

Tripping logic has been configured to provide tripping signal of required duration. The tripping circuit opens the circuit breaker on

- Receipt of operate signal from the protection function or
- Retrip signal from the circuit-breaker failure protection.

Two master tripping signals are available at binary output PSM PO1 and PSM PO3.

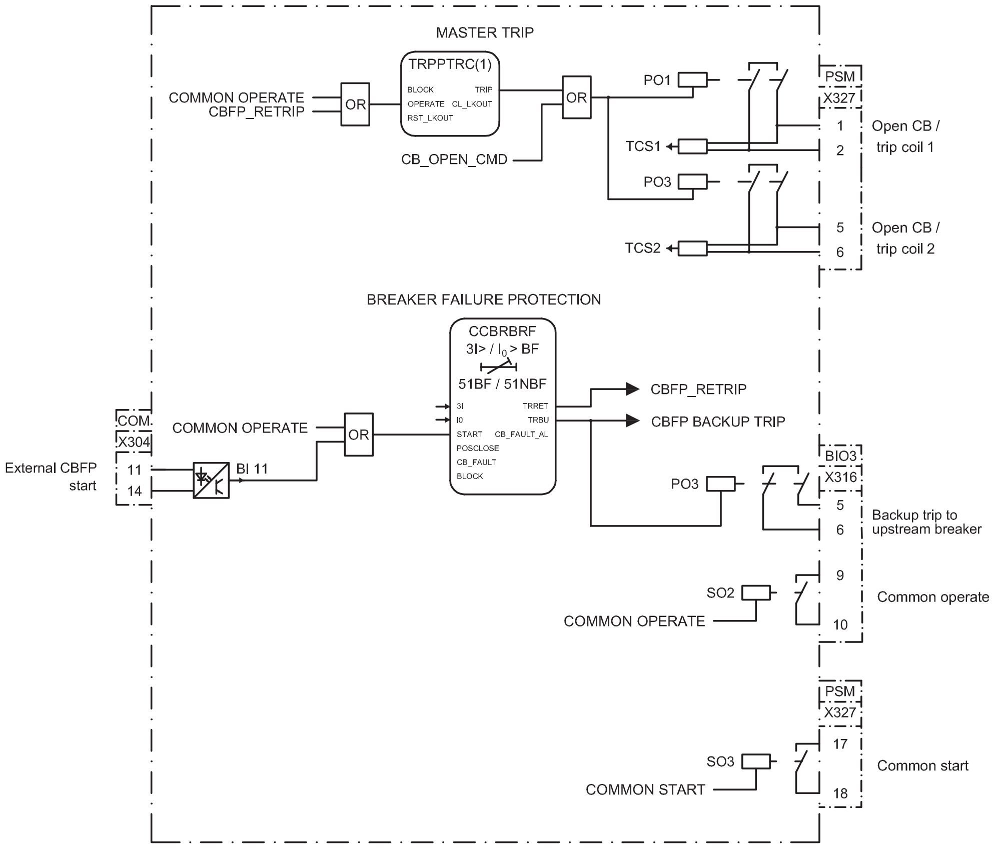


Figure 22: Tripping logic and breaker failure protection

3.3.6.10 Combined operate and start alarm signal

The operate outputs of all protection functions are combined in an OR-gate to get a common Operate output. This common operate signal is connected to a tripping logic. It is also available as an alarm binary output, BIO_3_SO2, with a settable minimum alarm delay of 80 ms. Also, a common Start output is derived from the start outputs of protection functions combined in an OR-gate. The output is available as an alarm binary output PSM SO3 with a settable minimum alarm delay of 80 ms.

3.3.6.11 Other output and alarm signals

- Combined overcurrent (OC) operate signal available at binary output PSM SO1
- Combined earth fault and sensitive earth-fault (EF/DEF) operate signal available at binary output PSM SO2
- Combined alarm signal from circuit-breaker monitoring function available at binary output BIO_3 SO4
- Combined alarm signal from various supervision functions available at binary output BIO_3 SO5
- Upstream overcurrent (OC) blocking signal available at binary output BIO_3 SO1

3.3.7 Supervision functions

3.3.7.1 Trip circuit supervision TCSSCBR

Two instances of trip circuit supervision function are used for supervising Master trip 1 and Master trip 2. Function continuously supervises trip circuit and an alarm is issued in case of a failure of a trip circuit. The function does not perform the supervision itself but it is used as an aid for configuration.

Function gives an indication via a LED on the LHMI on detection of any of the trip circuit failure. To prevent unwanted alarms, the function is blocked when the circuit breaker is open, one of the protection function operate signals is active.

An instance of trip circuit supervision is used to check the proper functioning of closing circuit of the circuit breaker. This function is blocked when the circuit breaker is in closed position to prevent unwanted alarms.

3.3.7.2 Fuse failure and current circuit supervision SEQRFUF, CCRDIF

The fuse failure and current circuit supervision functions give an alarm in case of a failure in the secondary circuits between the voltage transformer or current transformer and the IED respectively. The set of three phase currents and voltages, I3P and U3P, are connected to the inputs.

An alarm is available on failure of the secondary circuits. Alarms are recorded by a disturbance recorder.

3.3.7.3 Circuit-breaker condition monitoring SSCBR

The circuit-breaker condition monitoring function checks for the health of the circuit breaker. The circuit breaker status is connected to the function via binary inputs. Function requires also pressure lockout input and spring charged input connected via binary input COM_101.BI12 and COM_101.BI13 respectively. Various alarm outputs from the function are combined in an OR-gate to create a master circuit-breaker monitoring alarm, which is available at binary output BIO_3 SO4.

All of the alarms are separately connected to the binary recorder and a combined alarm is available as an indication via a LED on the LHMI.

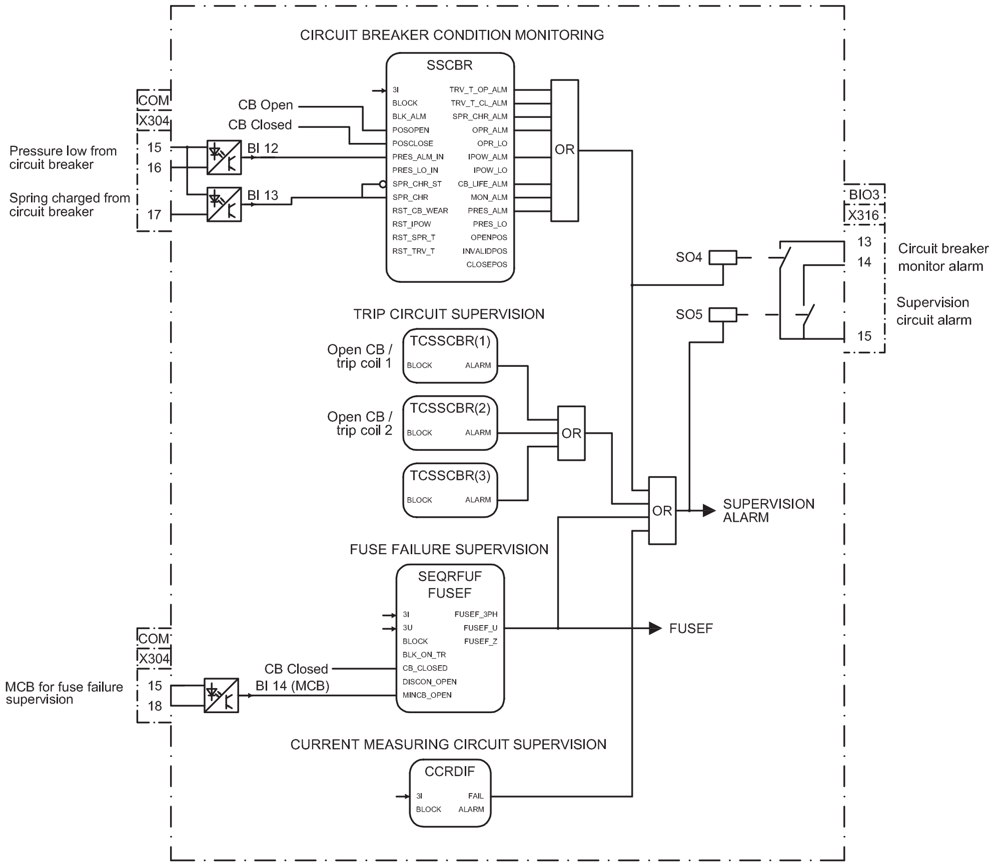


Figure 23: Circuit-breaker condition monitoring and trip-circuit, fuse failure and current measuring circuit supervision

3.3.8 Measurement and analog recording functions

The measured quantities in this configuration are:

- Sequence current
- Sequence voltage
- Residual voltage
- Residual current

- Energy
- Phase current
- Phase voltage
- Line voltage
- Power with frequency

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 15: Signals connected to the analog recorder

Channel ID	Description
Channel 1	Phase A current
Channel 2	Phase B current
Channel 3	Phase C current
Channel 4	Neutral current
Channel 5	Neutral current from CBCT
Channel 6	Phase A voltage
Channel 7	Phase B voltage
Channel 8	Phase C voltage
Channel 9	Neutral voltage

Data connected to analog channels contain 20 samples per cycle.

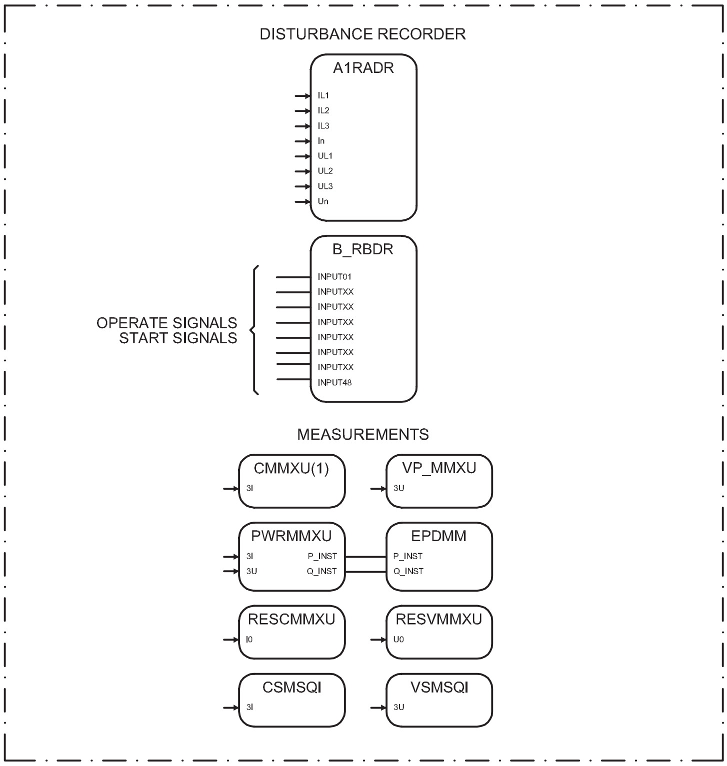


Figure 24: Measurement and analog recording

3.3.9 Binary recording and LED configuration

All of 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 which in turn will record all the signals connected to the recorder.

Table 16: Signals connected to the binary recorder

Channel ID	Description
Channel 1	Block by inrush protection
Channel 2	Start of overcurrent high stage 1
Channel 3	Operate of overcurrent high stage 1
Channel 4	Start of overcurrent high stage 2
Channel 5	Operate of overcurrent high stage 2
Channel 6	Start of instantaneous overcurrent stage
Channel 7	Operate of instantaneous overcurrent stage
Channel 8	Start of overcurrent low stage
Channel 9	Operate of overcurrent low stage
Channel 10	Start of instantaneous earth-fault stage
Table continues on next page	

Channel ID	Description
Channel 11	Operate of instantaneous earth-fault stage
Channel 12	Start of earth-fault high stage
Channel 13	Operate of earth-fault high stage
Channel 14	Start of earth-fault low stage
Channel 15	Operate of earth-fault low stage
Channel 16	Operate of thermal overload
Channel 17	Start of negative-sequence overcurrent stage 1
Channel 18	Operate of negative-sequence overcurrent stage 1
Channel 19	Start of negative-sequence overcurrent stage 2
Channel 20	Operate of negative-sequence overcurrent stage 2
Channel 21	Start of directional earth-fault, low stage
Channel 22	Operate of directional earth-fault, low stage
Channel 23	Start of phase discontinuity protection
Channel 24	Operate of phase discontinuity protection
Channel 25	Circuit breaker closed
Channel 26	Circuit breaker is open
Channel 27	Unsuccessful autoreclosing
Channel 28	Autoreclosing function locked out
Channel 29	Reclose by autoreclosing
Channel 30	Backup trip from circuit-breaker failure protection
Channel 31	Retrip from circuit-breaker failure protection
Channel 32	Trip circuit alarm 1 (supervising master trip 1)
Channel 33	Trip circuit alarm 2 (supervising master trip 2)
Channel 34	Trip circuit alarm 3 (supervising closing circuit)
Channel 35	Current circuit supervision alarm
Channel 36	Fuse failure
Channel 37	Closing time of circuit breaker exceeded the limit
Channel 38	Opening time of circuit breaker exceeded the limit
Channel 39	Spring charge time of circuit breaker exceeded the limit
Channel 40	Number of circuit breaker operation exceeded the set limit
Channel 41	Pressure in circuit breaker below lockout limit
Channel 42	Circuit breaker maintenance alarm: number of operations exceeds the set limit
Channel 43	Circuit breaker maintenance alarm: accumulated energy exceeds the set limit
Channel 44	Circuit breaker not operated since long

The LEDs are configured for alarm indications.

Table 17: LEDs configured on LHMI alarm page 1

LED No	LED color	Description
LED 1	Yellow	Combine start from OC
LED 1	Red	Combine operate from OC
LED 2	Yellow	Combine start from NSOC
LED 2	Red	Combine operate from NSOC
LED 3	Yellow	Combine start from EF
LED 3	Red	Combine operate from EF
LED 4	Yellow	Start from DEF
LED 4	Red	Operate from DEF
LED 5	Yellow	Start from phase discontinuity
LED 5	Red	Operate from phase discontinuity
LED 6	Yellow	Operate from thermal overload
LED 6	Red	Alarm from thermal overload
LED 7	Green	Autoreclosing ready
LED 7	Yellow	Autoreclosing in progress
LED 7	Red	Autoreclosing function locked out
LED 8	Red	Combine trip circuit supervision alarm
LED 9	Red	Backup trip from circuit-breaker protection function
LED 10	Red	Retrip from circuit-breaker protection function
LED 11	Red	Alarm from circuit-breaker monitoring function
LED 12	Red	Fuse failure supervision
LED 13	Red	Current circuit supervision

3.4 Preconfiguration C for ring/meshed feeder

3.4.1 Application

The functionality of the IED is designed to provide selective, fast and reliable protection to be used for overhead lines and power cables in interconnected systems, where distance protection is generally applied. These systems are typically operated in ring or meshed type of configurations, where the switching state can be changed frequently due to daily operation and load flow considerations making it impossible to apply simple overcurrent-based protection. The configuration can also be applied for radial feeders to increase the sensitivity of the protection especially if the short-circuit power of the source is low or it is changing due to network operation. In addition to the comprehensive distance protection, the configuration includes a multi-stage non-directional overcurrent protection as a back-up protection in cases where distance protection is unavailable, for example, due to failure in voltage measuring circuits.

To enchance the selectivity and operating speed even more, the configuration enables the application of scheme communication logic for distance protection and for directional residual overcurrent protection. The application of the scheme communication logic requires a communication link between the line ends, for which a simple auxiliary voltage based arrangement, or a third-party communication bus--based solutions capable of transmitting binary signals to both directions, can be applied. If there is a risk of losing the synchronism between the bus and line-side sources, for example, during the dead time of the autoreclosing due to effects of local generation, the configuration can be completed with the synchrocheck/voltagecheck functionality.

In solidly or low-impedance-earthed networks, the phase-to-earth measuring elements provide selective and fast protection against earth faults. However, the sensitivity of this protection may not be adequate due to the possibility of fault resistance. Therefore, the configuration includes a multi-stage non-directional and directional residual overcurrent protection to ensure adequate sensitivity of the protection. This protection also operates as a back-up earth-fault protection for the distance protection, and the low-set stage of these functions can be used to provide a dedicated sensitive earth-fault protection.

In high-impedance-earthed networks, it is typical that the phase-to-earth elements of the distance protection become blocked by the internal logic of the function when a single-phase-to-earth fault is detected. Otherwise, a correct and adequate operation of the distance protection during single-phase-to-earth faults cannot be ensured. Therefore, if the configuration is used in case of unearthed or compensated neutral point networks, sensitive and selective protection against earth faults can be achieved by the multi-stage directional residual overcurrent protection completed with possible scheme communication logic to fulfill the set sensitivity and operating speed requirements. In addition, the configuration can further be completed with transient based earth-fault protection function, which also detects so called intermittent or re-striking earth faults.

The objects controlled by the IED are the circuit breaker and the disconnector. The earth switch is considered to be operated manually. The open, close and undefined states of the circuit breaker, disconnectors and the earth switch are indicated on the LHMI.

Required interlocking is configured in the IED.

The preconfiguration includes:

- Control functions
- Current protection functions
- Supervision functions
- Disturbance recorders
- LEDs' configuration
- Measurement functions

3.4.2 Functions

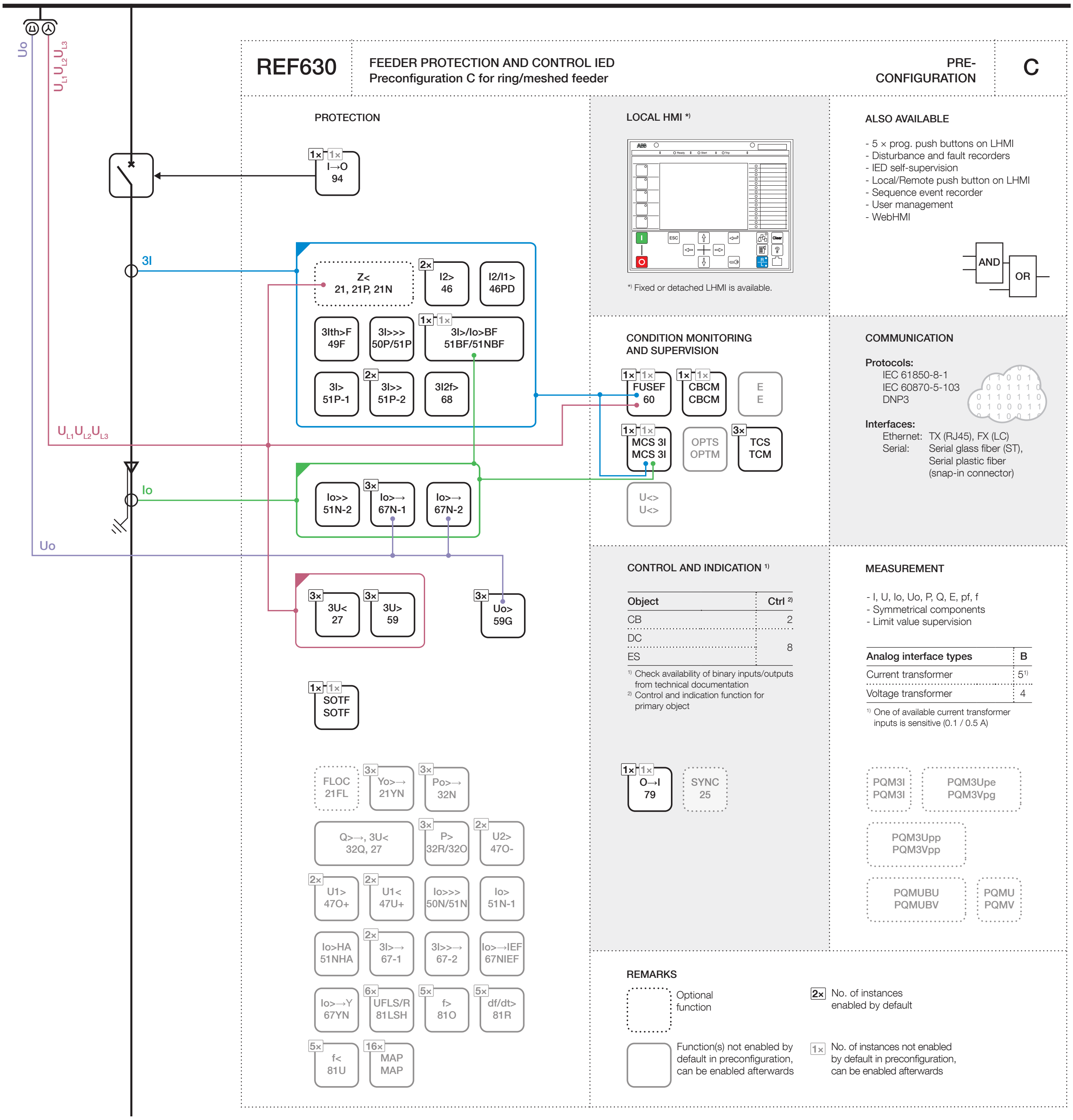


Figure 25: Functionality overview for preconfiguration C

3.4.3 Input/output signal interfaces

Table 18: Interface of binary inputs

Hardware module instance	Hardware channel	Description
COM	BI1	Circuit breaker closed
COM	BI2	Circuit breaker open
COM	BI3	Disconnector 1 closed
COM	BI4	Disconnector 1 open
COM	BI5	Earth switch closed
COM	BI6	Earth switch open
COM	BI7	Disconnector 2 closed
COM	BI8	Disconnector 2 open
COM	BI9	Circuit breaker truck closed
COM	BI10	Circuit breaker truck open
COM	BI11	External start of circuit-breaker failure protection
COM	BI12	Pressure low from circuit breaker
COM	BI13	Spring charged from circuit breaker
COM	BI14	MCB (for fuse failure supervision)
BIO_3	BI1	Relay characteristics angle (RCA) control
BIO_3	BI2	Carrier received - RESCPSCH
BIO_3	BI3	Carrier guard received
BIO_3	BI4	Carrier received - DSOCPSCH
BIO_3	BI5...BI9	Not connected

The outputs of the IED are categorized as power outputs (POx) and signal outputs (SOx). The power outputs can be used for closing and tripping of circuit breakers and disconnector control. The signal outputs are not heavy-duty outputs. They are used for alarm or signaling purposes.

Table 19: Interface of binary outputs

Hardware module instance	Hardware channel	Description
PSM	BO1_PO	Master Trip 1 (circuit breaker open)
PSM	BO2_PO	Master Close (circuit breaker closed)
PSM	BO3_PO	Master Trip 2 (circuit breaker open)
PSM	BO4_PO	Disconnector 1 open
PSM	BO5_PO	Disconnector 1 closed
PSM	BO6_PO	Not connected
PSM	BO7_SO	Not connected
PSM	BO8_SO	Not connected
PSM	BO9_SO	Common start
Table continues on next page		

Hardware module instance	Hardware channel	Description
BIO_3	BO1_PO	Disconnector 2 open
BIO_3	BO2_PO	Disconnector 2 closed
BIO_3	BO3_PO	Backup trip
BIO_3	BO4_SO	Carrier send - RESCPSCH
BIO_3	BO5_SO	Common operate
BIO_3	BO6_SO	Carrier send - DSOCPSCH
BIO_3	BO7_SO	Circuit breaker monitoring alarm
BIO_3	BO8_SO	Supervision circuit alarm
BIO_3	BO9_SO	Carrier guard send

The IED measures the analog signals needed for protection and measuring functions via galvanically isolated matching transformers. The matching transformer input channels 1…4 are intended for current measuring and channels 7...10 for voltage measuring.

Table 20: Interface of analog inputs

Hardware module instance	Hardware channel	Description
AIM_2	CH1	Phase current IL1
AIM_2	CH2	Phase current IL2
AIM_2	CH3	Phase current IL3
AIM_2	CH4	Neutral current I_0
AIM_2	CH5	Not connected
AIM_2	CH6	Not available
AIM_2	CH7	Phase voltage UL1
AIM_2	CH8	Phase voltage UL2
AIM_2	CH9	Phase voltage UL3
AIM_2	CH10	Neutral voltage U_0

3.4.4 Preprocessing blocks and fixed signals

The analog current and voltage signals coming to the IED are processed by preprocessing blocks. There are two types of preprocessing blocks based on 20 samples per cycle and 80 samples per cycle. All function blocks functioning at 5 ms task time need 80 samples per cycle whereas all the rest need 20 samples per cycle.

A fixed signal block providing a logical TRUE and a logical FALSE output has been used. Outputs are connected internally to other functional blocks when needed.

Even if the *AnalogInputType* setting of a SMAI block is set to “Current”, the *MinValFreqMeas* setting is still visible. This means that the minimum level for current amplitude is based on UBase. As an example, if UBase is 20 kV, the minimum amplitude for current is 20000 × 10% = 2000 A.

3.4.5 Control functions

3.4.5.1 Bay control QCCBAY

Bay control is used to handle the selection of the operator place per bay. It provides blocking functions that can be distributed to different apparatuses within the bay. Bay control sends information about the permitted source to operate (PSTO) and blocking conditions to other functions within the bay, for example switch control functions.

3.4.5.2 Apparatus control SCILO, GNRLCSWI, DAXCBR, DAXSWI

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

Circuit-breaker control function

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

The position information of the circuit breaker and the truck are connected to DAXCBR. The interlocking logics for the circuit breaker have been programmed to open at any time, provided that the gas pressure inside the circuit breaker is above the lockout limit. Closing of the circuit breaker is always prevented if the gas pressure inside the circuit breaker is below the lockout limit or the truck is open or spring charge time is above the set limit. In case the earth switch is closed, check that both disconnectors are open while closing the circuit breaker.

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

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

Disconnector 1, disconnector 2 and earth switch control function

Disconnector 1, disconnector 2, and earth switch are controlled by a combination of SCILO, GNRLCSWI and DAXSWI functions. Each apparatus requires one set of these functions.

The position information of the disconnectors and the earth switch are connected to respective DAXSWI functions via binary inputs. The interlocking logics for the disconnector have been programmed so that it can be opened or closed only if other three apparatuses, that is circuit breaker, earth switch and one of the disconnectors, are open. Interlocking for the earth switch depends on the circuit-breaker condition. If the circuit breaker is open, it is possible to open or close the earth switch at any time. If the circuit breaker is in closed, it is required that the other two disconnectors are open.

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

The open, closed and undefined states of the disconnector 1, disconnector 2 and earth switch are indicated on the LHMI.

The interlocking condition for the disconnector can be different in case a bus sectionalizer is available in the system.

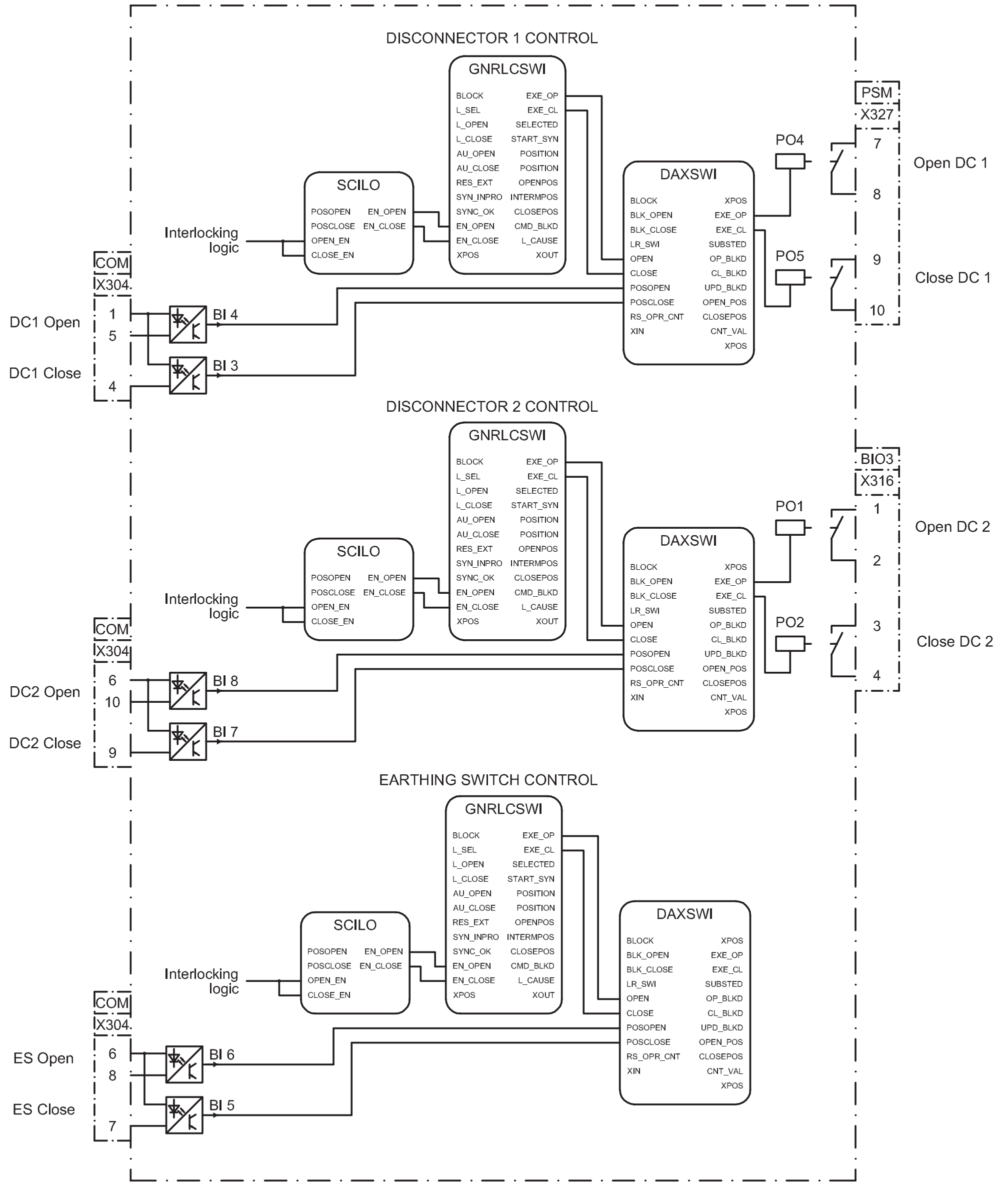


Figure 26: Apparatus control

3.4.5.3 Autoreclosing DARREC

Majority of medium voltage overhead line faults are transient and automatically cleared by momentarily de-energizing the line, whereas the rest of the faults, 15 to 20 percent, are cleared by longer interruptions. The de-energization of the fault place for a wanted period of time is implemented by autoreclosing relays or functions. Automatic reclosing is capable of clearing most of the faults. In the event of a permanent fault, autoreclosing is followed by the final tripping. A permanent fault has to be located and cleared before the fault location can be re-energized.

The function block provides five programmable autoreclose shots for creating autoreclosings of wanted type and duration, such as one high-speed and one delayed autoreclosing. The function consists of six individual initiation lines INIT_1... INIT 6 from which lines lines INIT_1...4 are used in the preconfiguration. It is possible to create an individual autoreclosing sequence for each input.

In this preconfiguration the autoreclosing function is initiated (lines INIT_1..4) from the operation of protection functions. The autoreclosing function allows also initiation from the start of the protection function, then opening the circuit breaker (OPEN CB) and performing a fast final trip.

The autoreclosing function can be inhibited with the INHIBIT_RECL input. Operate signals of negative sequence overcurrent, phase discontinuity, intermittent earth fault and circuit-breaker gas pressure lock are connected to INHIBIT_RECL input. Spring charged input available from the circuit breaker at binary input COM_101 BI13 is used to check the ready status of circuit breaker before autoreclosing. Inhibit autoreclosing signal from the thermal overload protection is connected to BLK_THERM input.

The outputs describing closing command (reclose) to a circuit breaker, unsuccessful autoreclosing and autoreclosing locked-out (CLOSE CB, UNSUC_AR, and LOCKED) are connected to binary recorders. Where as autoreclosing ready, autoreclosing in progress and autoreclosing locked-out (READY, INPRO and LOCKED) outputs are connected to LED indication on the LHMI.

Status indicating that circuit breaker in open state is connected to the CB_POS inputs. With this connection the setting is *CB closed Pos status* = FALSE.

CLOSE CB output is used for closing the circuit breaker. Before any autoreclosing signal is activated the function block checks for the circuit breaker ready status.

If an industrial feeder employs cables it may not be advisable to use autoreclosing, as cable faults are not transient but permanent.

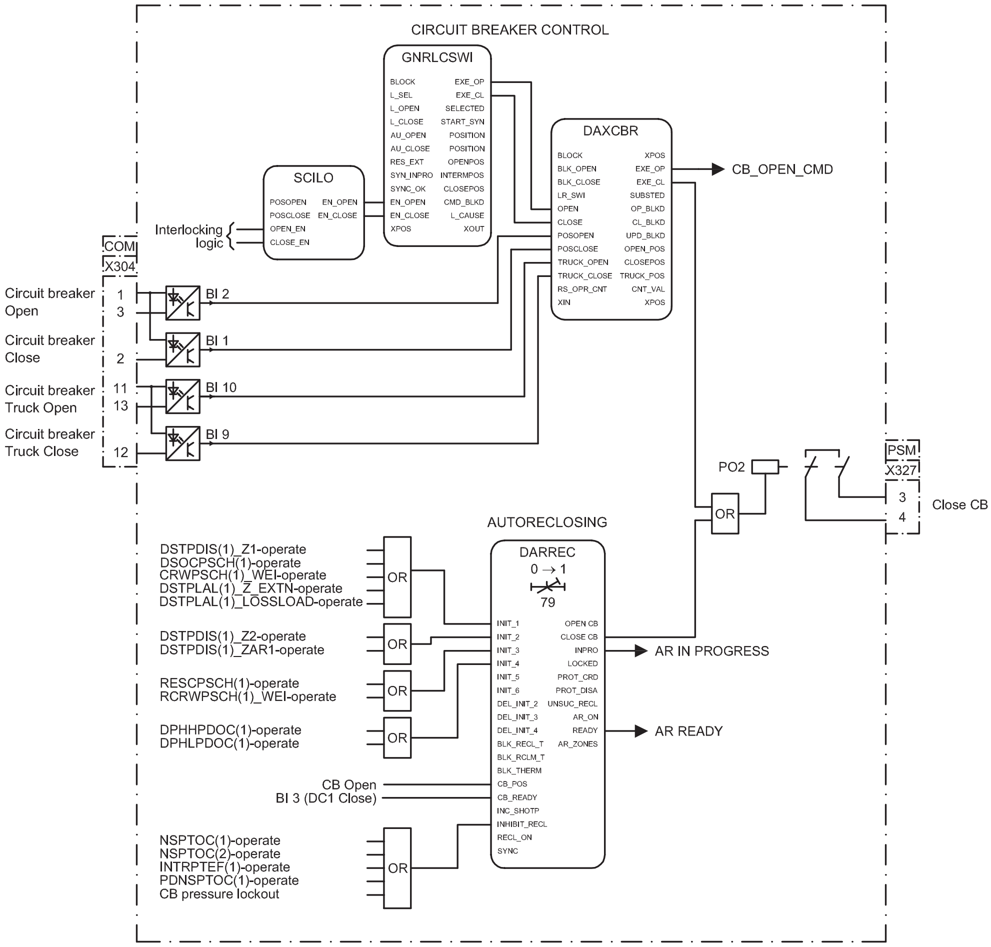


Figure 27: Autoreclosing

3.4.6 Protection functions

3.4.6.1 Three-phase current inrush detection INRPHAR

The configuration includes a three-phase current inrush detection function. The function can be used for increasing, typically double, the set start value of the non-directional overcurrent stage (OC) during inrush condition. This is done by the ENA_MULT input and the *Start value mult* setting in the corresponding function blocks. The default multiplier setting is 1.0.

3.4.6.2 Non-directional overcurrent protection PHxPTOC

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

The configuration includes four variants of non-directional overcurrent functions: high 1, high 2, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs. The inrush function can increase the start value of each overcurrent function.

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

3.4.6.3 Negative-sequence overcurrent protection NSPTOC

Two instances of negative-sequence overcurrent detection are provided, for protection against single-phasing, unbalanced load or asymmetrical feeder voltage. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from both NSPTOC functions are connected to an OR-gate to form a combined negative-sequence overcurrent operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from the NSPTOC function is connected to the disturbance recorder.

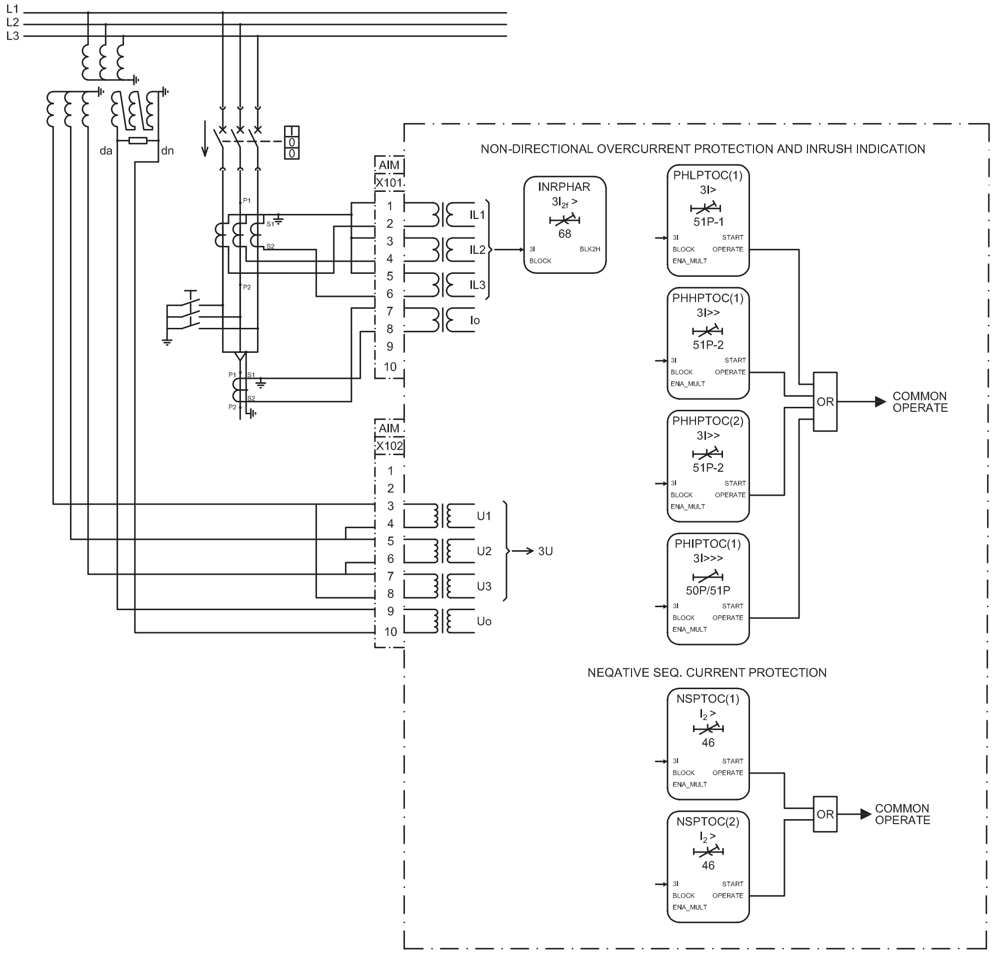


Figure 28: Non-directional overcurrent and negative-sequence overcurrent protection

3.4.6.4 Phase discontinuity protection PDNSPTOC

The phase discontinuity protection functions are used for protection against broken phase conductors in distribution networks. Definite-time (DT) characteristic is always used. Operation of the stage is based on ratio of 2nd harmonic and fundamental frequency of phase currents.

The set of three phase currents, I3P, is connected to the inputs. Operate and start signals are used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.4.6.5 Non-directional earth-fault protection EFxPTOC

The non-directional earth-fault protection functions are used for protection under earth-fault conditions with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values. The configuration includes high-stage non-directional current functions. The set of three phase currents, I3P, is connected to the inputs.

The start and operate signals from the high-stage non-directional current function is connected to the disturbance recorder.

3.4.6.6 Directional earth-fault protection DEFxPDEF

The directional earth-fault protection functions are used for directional earth-fault protection with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values.

The configuration includes four variants of directional earth-fault protection function: high, low 1, low 2 and low 3. The low stage directional earth-fault protection is configured to operate in forward, reverse and forward direction respectively. The set of three phase currents and voltages, I3P and U3P, are connected to the inputs. One stage is used as a non-directional sensitive stage.

The IED's characteristics angle control can be done by binary input BIO_3 BI1. A common operate and start signal from all four directional earth-faults are connected to an OR-gate to form a combined directional earth-fault operate and start signal which are further used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

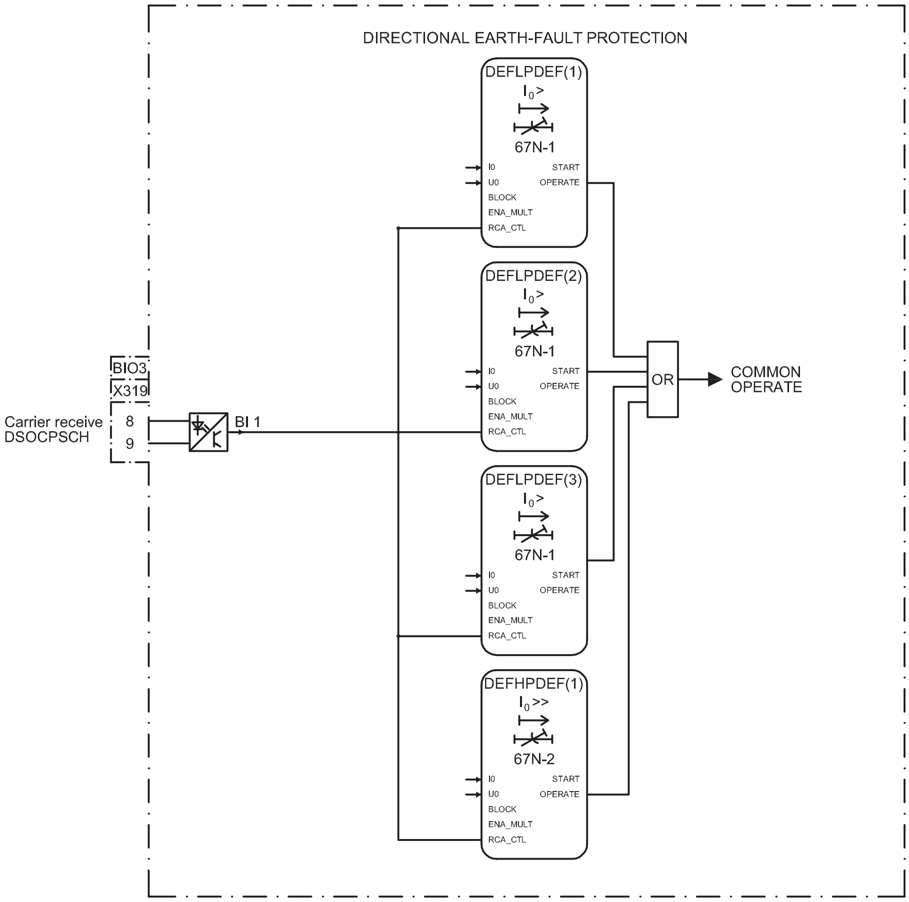


Figure 29: Directional earth-fault protection

3.4.6.7 Three-phase overvoltage protection PHPTOV

The three-phase overvoltage protection function is designed to be used for phase-to-phase or phase-to-earth overvoltage protection with definite time or inverse definite minimum time (IDMT) characteristic.

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

A common operate and start signal from all the three instances of phase overvoltage protection are connected to an OR-gate to form a combined phase overvoltage operate and start signal which is used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.4.6.8 Three-phase undervoltage protection PHPTUV

The three-phase undervoltage protection function is designed to be used for phase-to-phase or phase-to-earth overvoltage protection with definite time or inverse definite minimum time (IDMT) characteristic.

The configuration includes three instances of undervoltage protection function blocks. The set of three phase voltages, U3P, is connected to the inputs. The undervoltage protection is blocked in case of detection of fuse failure.

A common operate and start signal from all the three instances of undervoltage protection are connected to an OR-gate to form a combined phase undervoltage operate and start signal which is used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

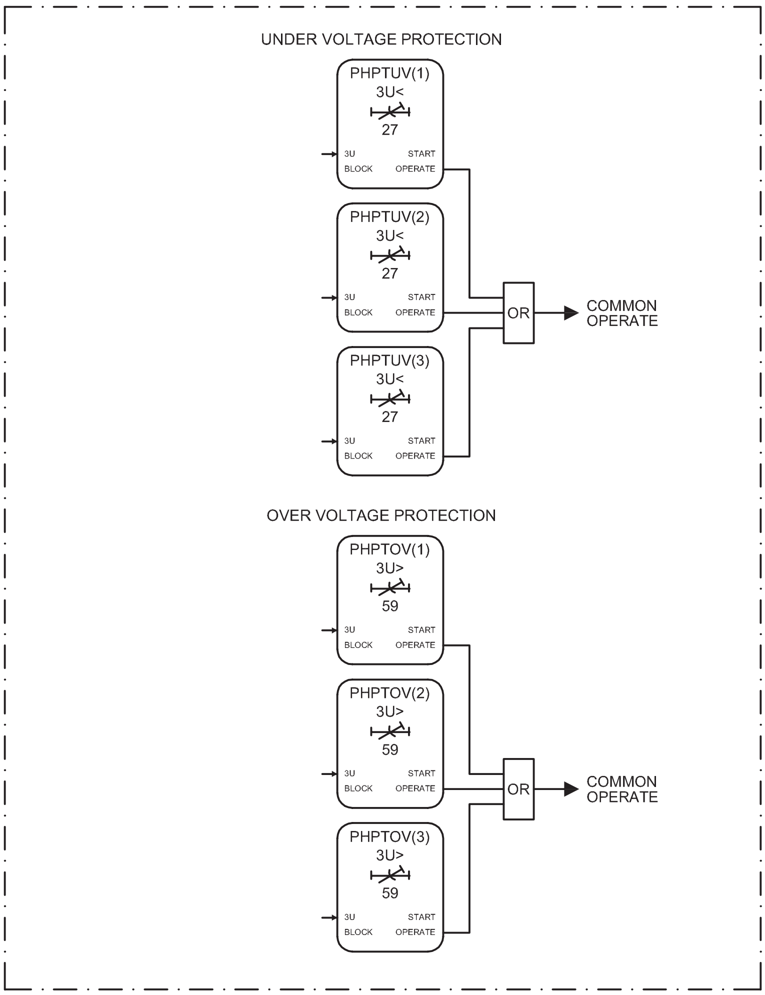


Figure 30: Under- and overvoltage protection

3.4.6.9 Three-phase residual overvoltage protection ROVPTOV

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

The common operate and start signal from all the three instances of residual overvoltage protection are connected to an OR-gate to form a combined residual overvoltage operate and start signal which is further used to trigger a disturbance recorder.

A common LED indication is provided on the LHMI for residual and phase overvoltage.

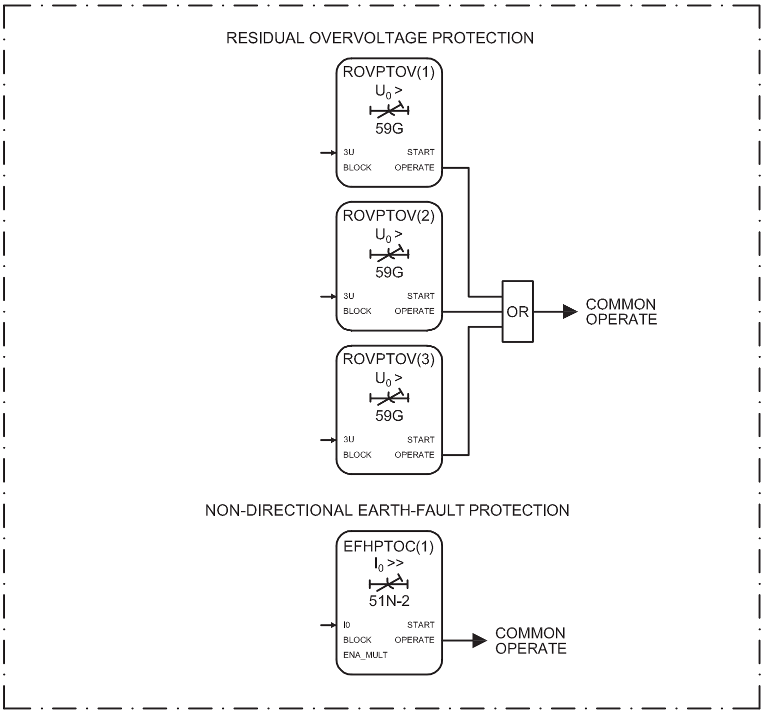


Figure 31: Residual overvoltage and non-directional earth-fault protection

3.4.6.10 Distance protection DSTPDIS

Distance protection has three flexible, configurable impedance zones for protection (Z1, Z2 and Z3) and two impedance zones for autoreclosing schemes (AR1 and AR2).

The set of three phase voltages, U3P, and phase currents, I3P, are connected to the inputs. The inputs I3P_PAR and I3P_REF are connected to the fixed GRP_OFF signal as they are not required with the present configuration. The distance protection is blocked in case of fuse failure.

The AR zones are activated only if AR_ZONES is connected to AR_ZONES from autoreclosing function and the autoreclosing is ON.

The operate and start signals from all five zones along with GFC are connected to an OR-gate to form a distance protection operate and start signal which is used to provide a common LED indication on the LHMI. Separate operate and start signals from all five zones along with GFC are used to trigger the disturbance recorder.

The real and imaginary part of fault impedance value for zone Z1 is connected to the disturbance recorder.

3.4.6.11 Automatic switch onto fault logic CVRSOF

CVRSOF is used as a complement to distance protection to accelerate the operation of the protection, ensuring a fast trip when the breaker is closed during a fault. The function has been configured to start its operation on receipt of start from GFC of distance protection.

The set of three phase voltages, U3P and I3P, is connected to the inputs. The function is blocked when autoreclosing is in progress.

The operate signal from CVRSOF is connected to a LED indication on the LHMI and also to trigger the disturbance recorder.

3.4.6.12 Local acceleration logic DSTPLAL

DSTPLAL is a complementary function to the distance protection function. It is not intended for stand-alone use. DSTPLAL enables fast fault clearing independent of the fault location on the protected feeder when no communication channel is available between the local and remote terminals. DSTPLAL cannot fully replace communication scheme logic. DSTPLAL can be controlled either by the autorecloser (zone extension logic) or by monitoring the loss of load currents (loss of load logic). Both operation modes can be enabled independently.

The set of three phase currents, I3P, is connected to the inputs. Overreaching zone, which is used for acceleration, is connected to zone extension and loss of load inputs EX_ACC and LOSSLOAD_ACC respectively. The start signal from the non-directional zone is connected to the NONDIR_ST input. In case the set reclaim time of the autoreclose function expires before the fault has been cleared, the NONDIR_ST signal blocks the activation of the zone acceleration. This ensures that the accelerated trip followed by the AR initiation is not repeated for the same fault regardless of the reclaim time setting and the reach of the overreaching zone connected to EX_ACC. Otherwise this could lead to pumping of the circuit breaker, that is, repetition of the first shot without being able to complete the wanted AR sequence.

The operate signals, OP_LOSSLOAD and OP_Z_EXTN, are connected to the disturbance recorder. These outputs along with other operate signals from distance support functions are connected to an OR-block to from a combined operate signal from distance support functions.

3.4.6.13 Scheme communication logic for distance protection DSOCPSCH

To achieve instantaneous fault clearing independent of the fault location on the protected feeder, a scheme communication logic DSOCPSCH is provided.

There are different types of communication schemes available.

- Direct intertrip (DUTT)
- Permissive underreach (PUTT)
- Permissive overreach (POTT)
- Directional comparison blocking (DCB)

The directional comparison unblocking scheme (DCUB) can also be provided by complementing the permissive schemes by an additional logic called the unblocking function, which is also included in DSOCPSCH.

If the permissive overreaching scheme is used, some power system conditions require additional special logic circuits, like current reversal logic and weak-end infeed logic (WEI) for distance protection CRWPSCH.

The BLK_CS input connected to the operate signal from current reversal logic is used to block the carrier send signal from overreaching zone. It is applicable in directional comparison blocking scheme (DCB) and in the permissive overreach schemes (POTT).

The CSBLK input connected to the START signal from a reverse looking zone Z3 is used in the directional comparison blocking scheme (DCB) in order to create a carrier send signal CS.

The CACC input connected to the START signal from an overreaching zone Z2 is used in the permissive underreach scheme (PUTT) and in the directional comparison blocking scheme (DCB).

The CSOR input connected to the START signal from an overreaching zone Z2 is used in the permissive overreach scheme (POTT).

The CSUR input connected to the START signal from an underreaching zone Z1 is used in the direct intertrip scheme (DUTT) and in the permissive underreach scheme (PUTT). It can also be used in the permissive overreach scheme (POTT).

The CR input is a carrier received signal from the IED available at the opposite end of the feeder via binary input BI0_3 BI4. Similarly, the CRG input is a carrier guard signal used in the directional comparison unblocking scheme (DCUB) available from the IED at the opposite end of the feeder via binary input BI0_3 BI3.

The CS output is the carrier send signal, send to the IED available at the opposite end of the feeder and send via binary output BI0_3 SO3.

The operate signal OPERATE along with carrier guard received, DSOCPSCH carrier received and DSOCPSCH carrier send signals available at binary input BI0_3 BI3, BI0_3 BI4 and binary output BI0_3 SO3 are connected to the disturbance recorder.

The OPERATE output along with other operate signals from the distance support functions are connected to an OR-block to form a combined operate signal from the distance support functions.

3.4.6.14 Current reversal and weak-end infeed logic for distance protection CRWPSCH

Scheme communication logic for distance protection (DSOCPSCH) may require additional logics in order to operate correctly in all possible power system conditions. These logics include for example current reversal logic and weak-end infeed logic which are combined to the function block CRWPSCH.

The main purpose of the current reversal logic is to prevent unwanted operation of the distance protection. In parallel feeder applications, the direction of fault current on a healthy feeder can change when the circuit breaker on the faulty feeder opens to clear the fault. This can lead to unwanted operation of the distance protection on the healthy parallel feeder when scheme communication logic (DSOCPSCH) with permissive overreach scheme is used.

Permissive communication schemes can operate only when the protection function in the remote terminal can detect the fault. Detection requires a sufficient minimum fault current. If such current is not available due to too weak remote-end source, the weak-end infeed logic can be used to overcome the situation and to trip the remote-end breaker.

The set of three phase voltages, U3P, is connected to the inputs.

The BLK_IRV input connected to START signals from a forward directional zones Z1 and Z2 is used to block the activation of the OPR_IRV output. The BLK_WEI1 input connected to START signals from the non-directional start signal from GFC is used to block the operate signal from WEI logic. The IRV input is connected to the reverse looking zone Z3 to recognize that the fault is in the reverse direction, that is, in the parallel feeder. Input CR is connected to carrier received signal. This is obtained from scheme communication logic from distance protection (DSOCPSCH). The CB_OPEN input is connected to binary input COM_101 BI2.

The OPR_IRV output indicates current reversal detection and it is used in scheme communication logic from distance protection (DSOCPSCH) in order to block the sending of the carrier send signal (CS) and block the activation of the OPERATE output of the communication logic.

OPR_WEI is connected to the disturbance recorder and also to an OR-block to from a combined operate signal from distance support functions.

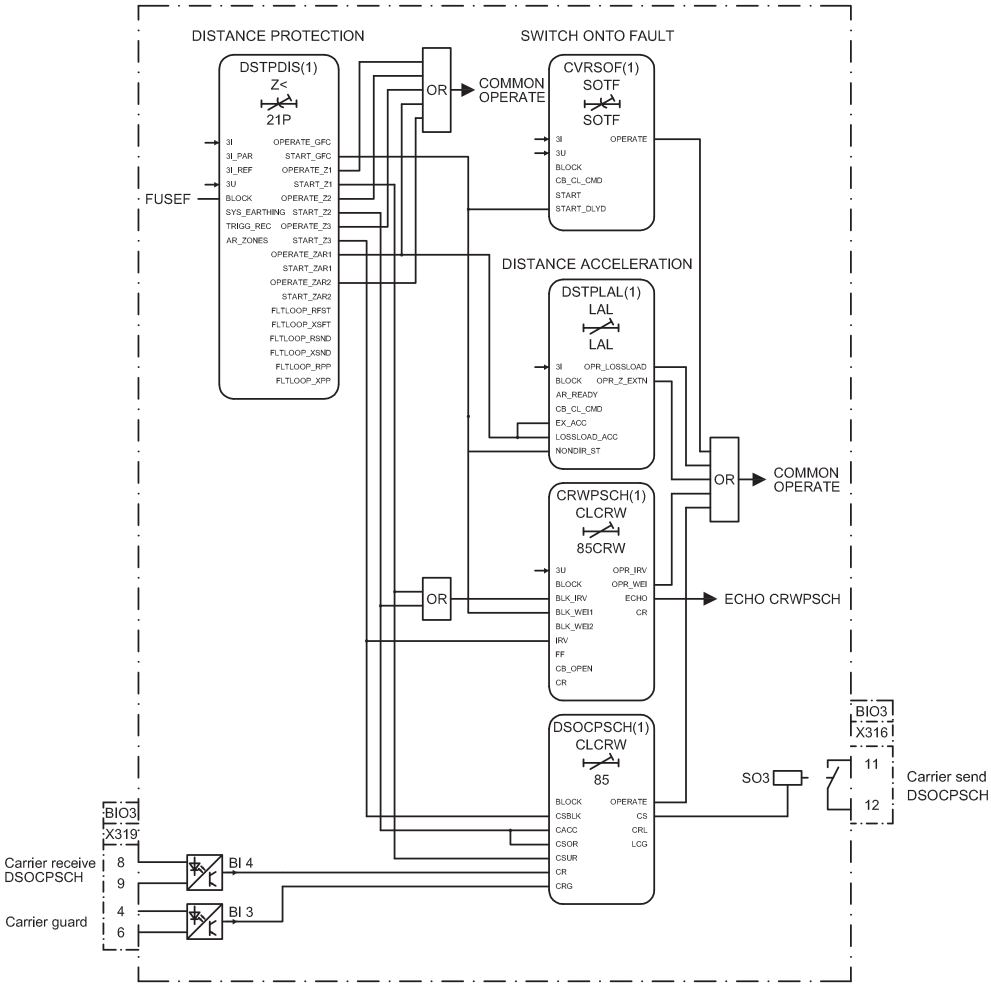


Figure 32: Distance protection

3.4.6.15 Scheme communication logic for residual overcurrent protection RESCPSCH

To achieve instantaneous fault clearing independent of the fault location on the protected feeder, a scheme communication logic RESCPSCH is provided.

There are different types of communication schemes available.

- Direct intertrip (DUTT)
- Permissive underreach (PUTT)
- Permissive overreach (POTT)
- Directional comparison blocking (DCB)

The directional comparison unblocking scheme (DCUB) can also be provided by complementing the permissive schemes by an additional logic called the unblocking function, which is also included in RESCPSCH.

If the permissive overreaching scheme is used, some power system conditions require additional special logic circuits, like current reversal logic and weak-end infeed logic (WEI) for residual overcurrent protection RCRWPSCH.

The BLK_CS input connected to the operate signal from current reversal logic is used to block the carrier send signal from the overreaching function. It is applicable in directional comparison blocking scheme (DCB) and in the permissive overreach schemes (POTT).

The CSBLK input connected to the START signal from a reverse looking residual overcurrent function is used in the directional comparison blocking scheme (DCB) in order to create a carrier send signal CS.

The CACC input connected to the START signal from an overreaching residual overcurrent function is used in the permissive underreach scheme (PUTT) and in the directional comparison blocking scheme (DCB).

The CSOR input connected to the START signal from an overreaching residual overcurrent function, is used in the permissive overreach scheme (POTT).

The CSUR input connected to the START signal from an underreaching residual overcurrent function, is used in the direct intertrip scheme (DUTT) and in the permissive underreach scheme (PUTT). It can also be used in the permissive overreach scheme (POTT).

The CR input is a carrier received signal from the IED available at the opposite end of the feeder via binary input BI0_3 BI2. Similarly, the CRG input is a carrier guard signal used in the directional comparison unblocking scheme (DCUB) is from IED available at opposite end of the feeder via binary input BI0_3 BI3.

The CS output is the carrier send signal, send to the IED available at the opposite end of the feeder and send via binary output BI0_3 SO1.

The operate signal, OPERATE along with carrier guard received, RESCPSCH carrier received and RESCPSCH carrier send signal available at binary input BI0_3 BI3, BI0_3 BI4 and binary output BI0_3 SO3 are connected to disturbance recorder.

The OPERATE output along with other operate signals from the distance support functions are connected to an OR-block to form a combined operate signal from the distance support functions.

3.4.6.16 Current reversal and scheme communication logic for residual overcurrent RCRWPSCH

Scheme communication logic for residual overcurrent protection (RESCPSCH) may require additional logics in order to operate correctly in all possible power system conditions. Such special logics include for example current reversal logic and weak-end infeed logic which are combined to the function block CRWPSCH.

The main purpose of the current reversal logic is to prevent unwanted operation of the distance protection. In parallel feeder applications, the direction of fault current on the healthy feeder can change when the circuit breaker on the faulty feeder opens to clear the fault. This can lead to unwanted operation of the distance protection on the healthy parallel feeder when scheme communication logic (RESCPSCH) with permissive overreach scheme is used.

Permissive communication schemes can operate only when the protection in the remote terminal can detect the fault. Detection requires a sufficient minimum fault current. If such current is not available due to too weak remote-end source, the weak-end infeed logic can be used to overcome the situation and to trip the remote-end breaker.

The set of three phase voltages, U3P, is connected to the inputs.

The BLK_IRV input connected to the START signal from a forward directional residual overcurrent function, is used to block the activation of the OPR_IRV output. The BLK_WEI1 input connected to the START signal from non-directional residual overcurrent function is used to block the operate signal from WEI logic. The IRV input is connected to the reverse looking residual overcurrent function to recognize that the fault is in the reverse direction, that is, in the parallel feeder. The CR input is connected to the carrier received signal. This is obtained from scheme communication logic from residual overcurrent protection (RESCPSCH). The CB_OPEN input is connected to the binary input COM_101 BI2.

The OPR_IRV output indicates current reversal detection and it is used in scheme communication logic from residual overcurrent protection (RESCPSCH) in order to block the sending of the carrier send signal (CS) and to block the activation of the OPERATE output of the communication logic.

OPR_WEI is connected to disturbance recorder and also connected to OR block to from a combine operate signal from distance support functions.

The output ECHO from CRWPSCH and RCRWPSCH are connected to an OR-block to form a carrier guard signal for the IED available at the opposite end of the feeder and send via binary output BI0_3 SO6.

3.4.6.17 Thermal overload protection T1PTTR

The three-phase thermal overload protection function is used for thermal protection of the three-phase power cables and overhead lines. It has adjustable temperature limits for tripping, alarm and reclose inhibit. The thermal model applied uses one time constant and the true RMS current measuring principle.

The operate signal from the thermal overload protection is further used to trigger the disturbance recorder. Both the operate and alarm signals provide a LED indication on the LHMI.

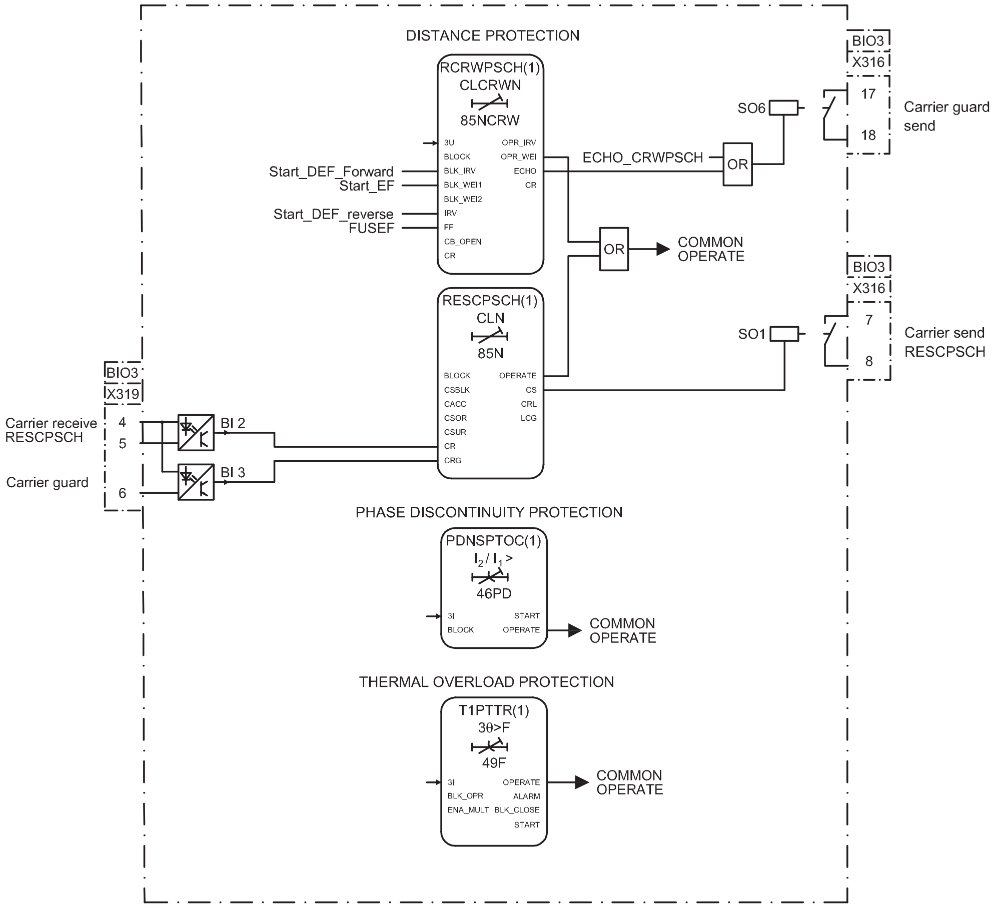


Figure 33: Current reversal and scheme communication logic (residual overcurrent), phase discontinuity and thermal overload protection

3.4.6.18 Circuit-breaker failure protection CCBRBRF

The function is activated by the common operate command from the protection functions. The breaker failure function issues a backup trip command to adjacent circuit breakers in case the main circuit breaker fails to trip for the protected component. The backup trip is connected at binary output BIO_3 PO3.

A failure of a circuit breaker is detected by measuring the current or by detecting the remaining trip signal. Function also provides retrip. Retrip is used along with the main trip, and is activated before the backup trip signal is generated in case the main breaker fails to open. Retrip is used to increase the operational reliability of the circuit breaker.

3.4.6.19 Tripping logic TRPPTRC

Tripping logic has been configured to provide tripping signal of required duration. The tripping circuit opens the circuit breaker on

- Receipt of operate signal from the protection function or
- Retrip signal from the circuit-breaker failure protection.

Two master tripping signals are available at binary output PSM PO1 and PSM PO3.

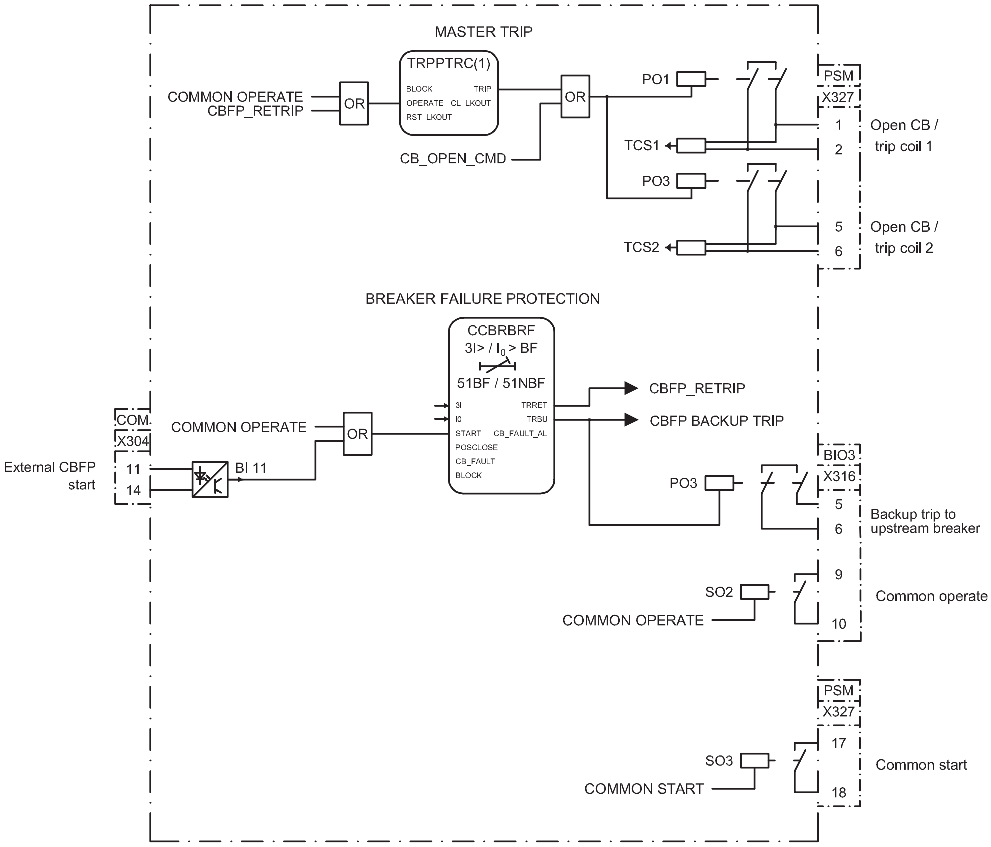


Figure 34: Tripping logic and breaker failure protection

3.4.6.20 Combined operate and start alarm signal

The operate outputs of all protection functions are combined in an OR-gate to get a common Operate output. This common operate signal is connected to a tripping logic. It is also available as an alarm binary output, BIO_3_SO2, with a settable minimum alarm delay of 80 ms. Also, a common Start output is derived from the start outputs of protection functions combined in an OR-gate. The output is available as an alarm binary output PSM SO3 with a settable minimum alarm delay of 80 ms.

3.4.6.21 Other output and alarm signals

- Combined alarm from circuit-breaker monitoring function available at binary output BIO_3 SO4
- Combined alarm from various supervision functions available at binary output BIO_3 SO5

3.4.7 Supervision functions

3.4.7.1 Trip circuit supervision TCSSCBR

Two instances of trip circuit supervision function are used for supervising Master trip 1 and Master trip 2. Function continuously supervises trip circuit and an alarm is issued in case of a failure of a trip circuit. The function does not perform the supervision itself but it is used as an aid for configuration.

Function gives an indication via a LED on the LHMI on detection of any of the trip circuit failure. To prevent unwanted alarms, the function is blocked when the circuit breaker is open, one of the protection function operate signals is active.

Apart from the previous two instances, another instance of trip circuit supervision is used to check the proper functioning of closing circuit of the circuit breaker. This function is blocked when the circuit breaker is in closed. A common trip alarm from all three instances of the trip circuit supervision is connected to an OR-gate to form a combined trip circuit supervision alarm which is used to trigger the disturbance recorder and to provide a LED indication on the LHMI.

3.4.7.2 Fuse failure and current circuit supervision SEQRFUF, CCRDIF

The fuse failure and current circuit supervision functions give an alarm in case of a failure in the secondary circuits between the voltage transformer or current transformer and the IED respectively. The set of three phase currents and voltages, I3P and U3P, are connected to the inputs.

An alarm is available on failure of the secondary circuits. Alarms are recorded by a disturbance recorder.

3.4.7.3 Circuit-breaker condition monitoring SSCBR

The circuit-breaker condition monitoring function checks for the health of the circuit breaker. The circuit breaker status is connected to the function via binary inputs. Function requires also pressure lockout input and spring charged input connected via binary input COM_101.BI12 and COM_101.BI13 respectively. Various alarm outputs from the function are combined in an OR-gate to create a master circuit-breaker monitoring alarm, which is available at binary output BIO_3 SO4.

All of the alarms are separately connected to the binary recorder and a combined alarm is available as an indication via a LED on the LHMI.

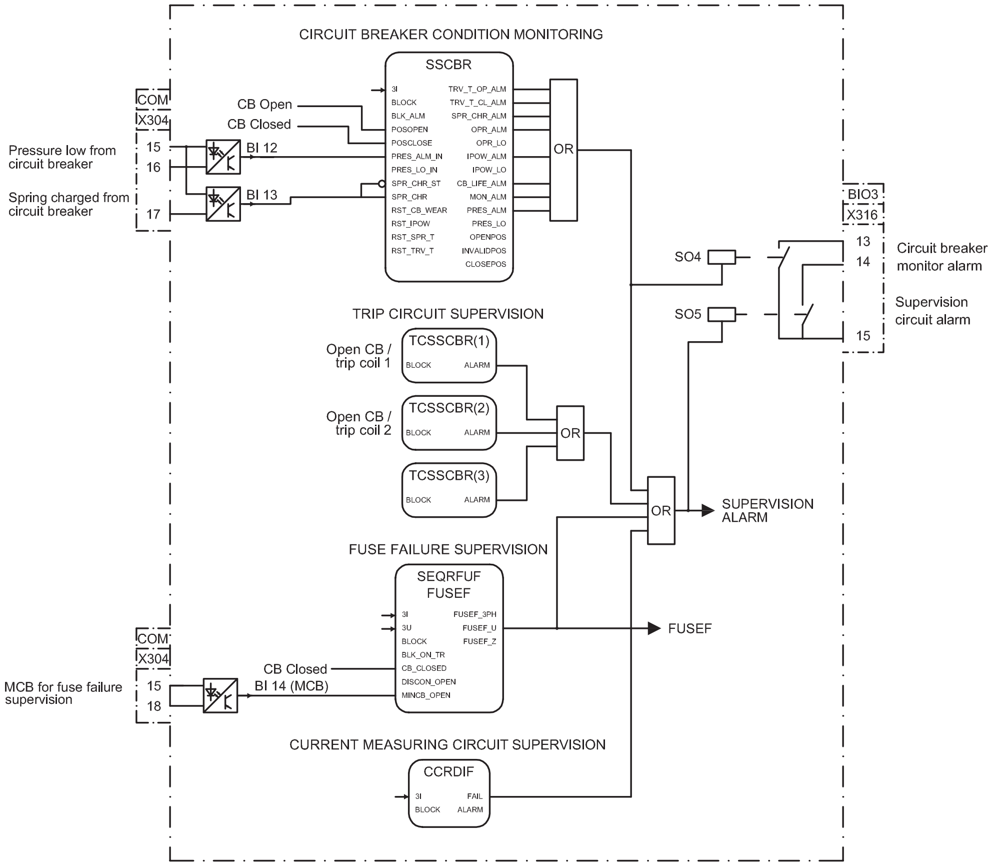


Figure 35: Circuit-breaker condition monitoring and trip-circuit, fuse failure and current measuring circuit supervision

3.4.8 Measurement and analog recording functions

The measured quantities in this configuration are:

- Sequence current
- Sequence voltage
- Residual voltage
- Residual current
- Energy
- Phase current
- Phase voltage
- Line voltage
- Power with frequency

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 21: Signals connected to the analog recorder A1RADR

Channel ID	Description
Channel 1	Phase A current
Channel 2	Phase B current
Channel 3	Phase C current
Channel 4	Neutral current
Channel 5	Phase A voltage
Channel 6	Phase B voltage
Channel 7	Phase C voltage
Channel 8	Neutral voltage

Data connected to analog channels contain 20 samples per cycle.

Table 22: Signals connected to the analog recorder A4RADR

Channel ID	Description
Channel 31	Real part of p-p/3p impedance from zone 1
Channel 32	Imaginary part of p-p/3p impedance from zone 1
Channel 33	Real part of first p-e loop impedance from zone 1
Channel 34	Imaginary part of first p-e loop impedance from zone 1
Channel 35	Real part of second p-e loop impedance from zone 1
Channel 36	Imaginary part of second p-e loop impedance from zone 1

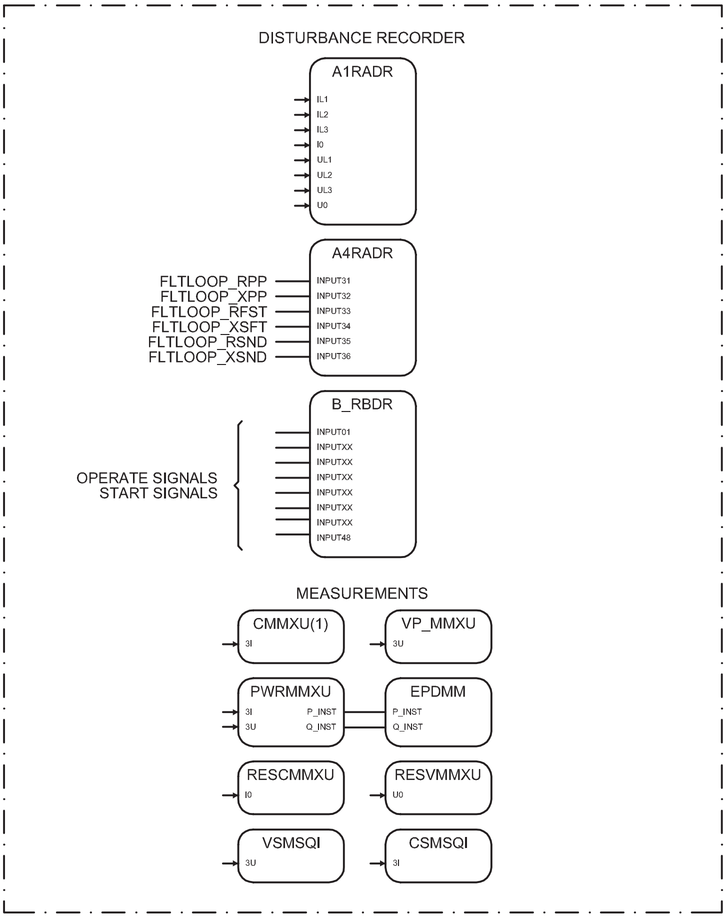


Figure 36: Measurement and analog recording

3.4.9 Binary recording and LED configuration

All of 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 which in turn will record all the signals connected to the recorder.

Table 23: Signals connected to the binary recorder

Channel ID	Description
Channel 1	Block by inrush protection
Channel 2	Start of overcurrent high stage 1
Channel 3	Operate of overcurrent high stage 1
Channel 4	Start of overcurrent high stage 2
Channel 5	Operate of overcurrent high stage 2
Channel 6	Start of instantaneous overcurrent stage
Table continues on next page	

Channel ID	Description
Channel 7	Operate of instantaneous overcurrent stage
Channel 8	Start of overcurrent low stage
Channel 9	Operate of overcurrent low stage
Channel 10	Start of directional earth fault high stage
Channel 11	Operate of directional earth fault high stage
Channel 12	Start of directional earth fault low stage 1
Channel 13	Operate of directional earth fault low stage 1
Channel 14	Start of directional earth fault low stage 2
Channel 15	Operate of directional earth fault low stage 2
Channel 16	Operate of thermal overload
Channel 17	Start of negative-sequence overcurrent stage 1
Channel 18	Operate of negative-sequence overcurrent stage 1
Channel 19	Start of negative-sequence overcurrent stage 2
Channel 20	Operate of negative-sequence overcurrent stage 2
Channel 21	Start of earth fault high stage
Channel 22	Operate of earth fault high stage
Channel 23	Start of directional earth fault low stage 3
Channel 24	Operate of directional earth fault low stage 3
Channel 25	Start of phase discontinuity protection
Channel 26	Operate of phase discontinuity protection
Channel 27	Combined start of phase overvoltage protection
Channel 28	Combined operate of phase overvoltage protection
Channel 29	Combined start of phase undervoltage protection
Channel 30	Combined operate of phase undervoltage protection
Channel 31	Combined start of residual overvoltage protection
Channel 32	Combined operate of residual overvoltage protection
Channel 33	Circuit breaker closed
Channel 34	Circuit breaker is open
Channel 35	Unsuccessful autoreclosing
Channel 36	Autoreclosing function locked out
Channel 37	Reclose by autoreclosing
Channel 38	Backup trip from circuit-breaker failure protection
Channel 39	Retrip from circuit-breaker failure protection
Channel 40	Combined trip circuit alarm
Channel 41	Current circuit failure
Channel 42	Fuse failure
Channel 43	Start from zone 1 of distance protection
Channel 44	Operate from zone 1 of distance protection
Channel 45	Start from zone 2 of distance protection

Table continues on next page

Channel ID	Description
Channel 46	Operate from zone 2 of distance protection
Channel 47	Start from zone 3 of distance protection
Channel 48	Operate from zone 3 of distance protection
Channel 49	Start from AR zone 1 of distance protection
Channel 50	Operate from AR zone 1 of distance protection
Channel 51	Start from AR zone 2 of distance protection
Channel 52	Operate from AR zone 2 of distance protection
Channel 53	Start from GFC of distance protection
Channel 54	Operate from GFC of distance protection
Channel 55	Operate from switch on to fault protection
Channel 56	Operate by zone extension
Channel 57	Operate from DSOCPSCH
Channel 58	Operate from RESCPSCH
Channel 59	Operate from WEI logic of CRWPSCH
Channel 60	Operate from WEI logic of RCRWPSCH
Channel 61	Operate by loss of load
Channel 62	Carrier receive from remote IED - RESCPSCH
Channel 63	Carrier guard receive from remote IED
Channel 64	Carrier receive from remote IED – DSOCPSCH

The LEDs are configured for alarm indications.

Table 24: LEDs configured on LHMI alarm page 1

LED No	LED color	Description
LED 1	Yellow	Combined start from distance protection
LED 1	Red	Combined operate from distance protection
LED 2	Yellow	Combined start from OC
LED 2	Red	Combined operate from OC
LED 3	Yellow	Combined start from NSOC
LED 3	Red	Combined operate from NSOC
LED 4	Yellow	Combined start from DEF
LED 4	Red	Combined operate from DEF
LED 5	Yellow	Combined start from EF
LED 5	Red	Combined operate from EF
LED 6	Yellow	Start from phase discontinuity
LED 6	Red	Operate from phase discontinuity
LED 7	Yellow	Alarm from thermal overload
LED 7	Red	Operate from thermal overload
LED 8	Green	Autoreclosing ready
Table continues on next page		

LED No	LED color	Description
LED 8	Yellow	Autoreclosing in progress
LED 8	Red	Autoreclosing function locked out
LED 9	Red	Operate from switch on to fault logic
LED 10	Red	Operate from distance support function
LED 11	Yellow	Combined start from overvoltage
LED 11	Red	Combined operate from overvoltage
LED 12	Yellow	Combined start from undervoltage
LED 12	Red	Combined operate from undervoltage
LED 13	Yellow	Backup trip from circuit-breaker protection function
LED 13	Red	Retrip from circuit-breaker protection function
LED 14	Yellow	Fuse failure supervision
LED 14	Red	Current circuit failure
LED 15	Red	Combined supervision alarm

3.5 Preconfiguration D for bus sectionalizer

3.5.1 Application

The functionality of the IED is designed to be used for selective short-circuit, overcurrent and earth-fault protection in a bus sectionalizer on double busbar systems with a truck circuit breaker.

The object controlled by the IED is the circuit breaker with truck. The open, close and undefined states of the circuit breaker are indicated on the LHMI.

Required interlocking is configured in the IED.

The preconfiguration includes:

- Control functions
- Current protection functions
- Supervision functions
- Disturbance recorders
- LEDs' configuration
- Measurement functions

3.5.2 Functions

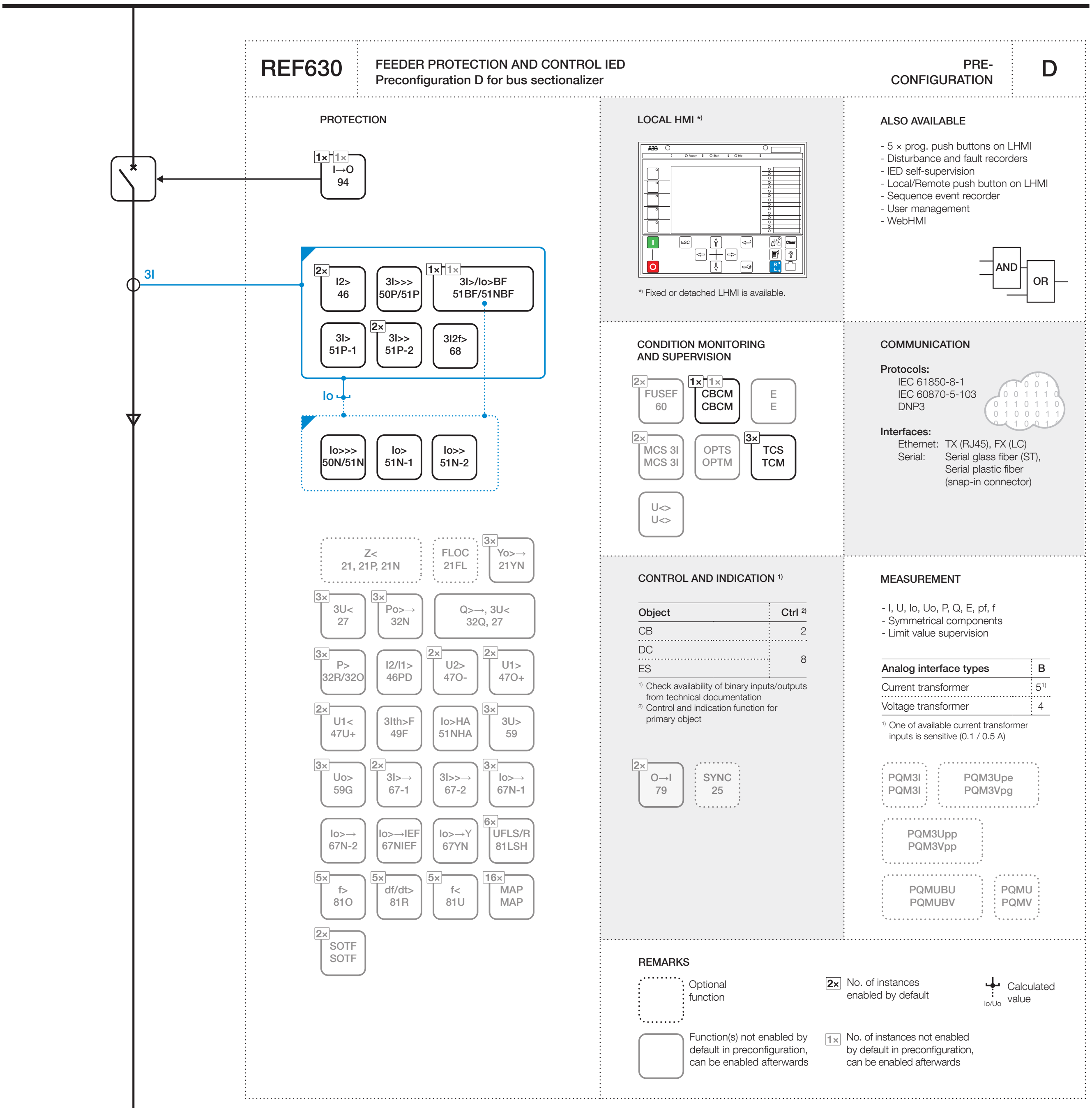


Figure 37: Functionality overview for preconfiguration D

3.5.3 Input/output signal interfaces

Table 25: Interface of binary inputs

Hardware module instance	Hardware channel	Description
COM	BI1	Circuit breaker closed
COM	BI2	Circuit breaker open
COM	BI3...BI8	Not connected
COM	BI9	Circuit breaker truck closed
COM	BI10	Circuit breaker truck open
COM	BI11	External start of circuit-breaker failure protection
COM	BI12	Pressure low from circuit breaker
COM	BI13	Spring charged from circuit breaker
COM	BI14	Not connected

The outputs of the IED are categorized as power outputs (POx) and signal outputs (SOx). The power outputs can be used for closing and tripping of circuit breakers and disconnector control. The signal outputs are not heavy-duty outputs. They are used for alarm or signaling purposes.

Table 26: Interface of binary outputs

Hardware module instance	Hardware channel	Description
PSM	BO1_PO	Master trip 1 (circuit breaker open)
PSM	BO2_PO	Master close (circuit breaker closed)
PSM	BO3_PO	Master trip 2 (circuit breaker open)
PSM	BO4_PO	Not connected
PSM	BO5_PO	Not connected
PSM	BO6_PO	Not connected
PSM	BO7_SO	OC operate alarm
PSM	BO8_SO	EF operate alarm
PSM	BO9_SO	Common start
BIO_3	BO1_PO	Not connected
BIO_3	BO2_PO	Not connected
BIO_3	BO3_PO	Backup trip
BIO_3	BO4_SO	Upstream OC block
BIO_3	BO5_SO	Common operate
BIO_3	BO6_SO	Not connected
BIO_3	BO7_SO	Circuit-breaker monitoring alarm
BIO_3	BO8_SO	Supervision circuit alarm
BIO_3	BO9_SO	Not connected

The IED measures the analog signals needed for protection and measuring functions via galvanically isolated matching transformers. The matching transformer input channels 1…3 are intended for current measuring and channels 7...9 for voltage measuring.

Table 27: Interface of analog inputs

Hardware module instance	Hardware channel	Description
AIM_2	CH1	Phase current IL1
AIM_2	CH2	Phase current IL2
AIM_2	CH3	Phase current IL3
AIM_2	CH4	Not connected
AIM_2	CH5	Not connected
AIM_2	CH6	Not available
AIM_2	CH10	Not connected
AIM_2	CH7	Phase voltage UL1
AIM_2	CH8	Phase voltage UL2
AIM_2	CH9	Phase voltage UL3

3.5.4 Preprocessing blocks and fixed signals

The analog current and voltage signals coming to the IED are processed by preprocessing blocks. There are two types of preprocessing blocks based on 20 samples per cycle and 80 samples per cycle. All function blocks functioning at 5 ms task time need 80 samples per cycle whereas all the rest need 20 samples per cycle.

A fixed signal block providing a logical TRUE and a logical FALSE output has been used. Outputs are connected internally to other functional blocks when needed.

Even if the *AnalogInputType* setting of a SMAI block is set to "Current", the *MinValFreqMeas* setting is still visible. This means that the minimum level for current amplitude is based on UBase. As an example, if UBase is 20 kV, the minimum amplitude for current is 20000 × 10% = 2000 A.

3.5.5 Control functions

3.5.5.1 Bay control QCCBAY

Bay control is used to handle the selection of the operator place per bay. It provides blocking functions that can be distributed to different apparatuses within the bay. Bay control sends information about the permitted source to operate (PSTO) and blocking conditions to other functions within the bay, for example switch control functions.

3.5.5.2 Apparatus control

Apparatus control initializes and supervises proper selection and switches on circuit breaker. The circuit breaker requires interlocking function, switch control function and apparatus functions.

Circuit-breaker control function

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

The position information of the circuit breaker and the truck are connected to DAXCBR. The interlocking logics for the circuit breaker have been programmed to open at any time, provided that the gas pressure inside the circuit breaker is above the lockout limit. Closing of the circuit breaker is always prevented if the gas pressure inside the circuit breaker is below the lockout limit or the truck is open or spring charge time is above the set limit.

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

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

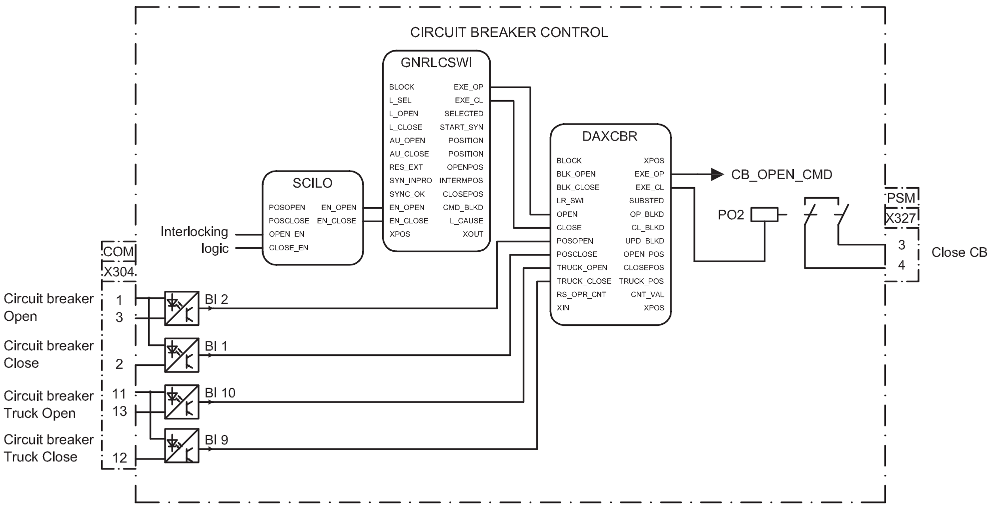


Figure 38: Apparatus control

3.5.6 Protection functions

3.5.6.1 Three-phase current inrush detection INRPHAR

The configuration includes a three-phase current inrush detection function. The function can be used for increasing, typically double, the set start value of the non-directional overcurrent stage (OC) during inrush condition. This is done by the ENA_MULT input and the *Start value mult* setting in the corresponding function blocks. The default multiplier setting is 1.0.

3.5.6.2 Non-directional overcurrent protection PHxPTOC

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

The configuration includes four variants of non-directional overcurrent functions: high 1, high 2, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs. The inrush function can increase the start value of each overcurrent function.

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

3.5.6.3 Negative-sequence overcurrent protection NSPTOC

Two instances of negative-sequence overcurrent detection are provided, for protection against single-phasing, unbalanced load or asymmetrical feeder voltage. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from both NSPTOC functions are connected to an OR-gate to form a combined negative-sequence overcurrent operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from the NSPTOC function is connected to the disturbance recorder.

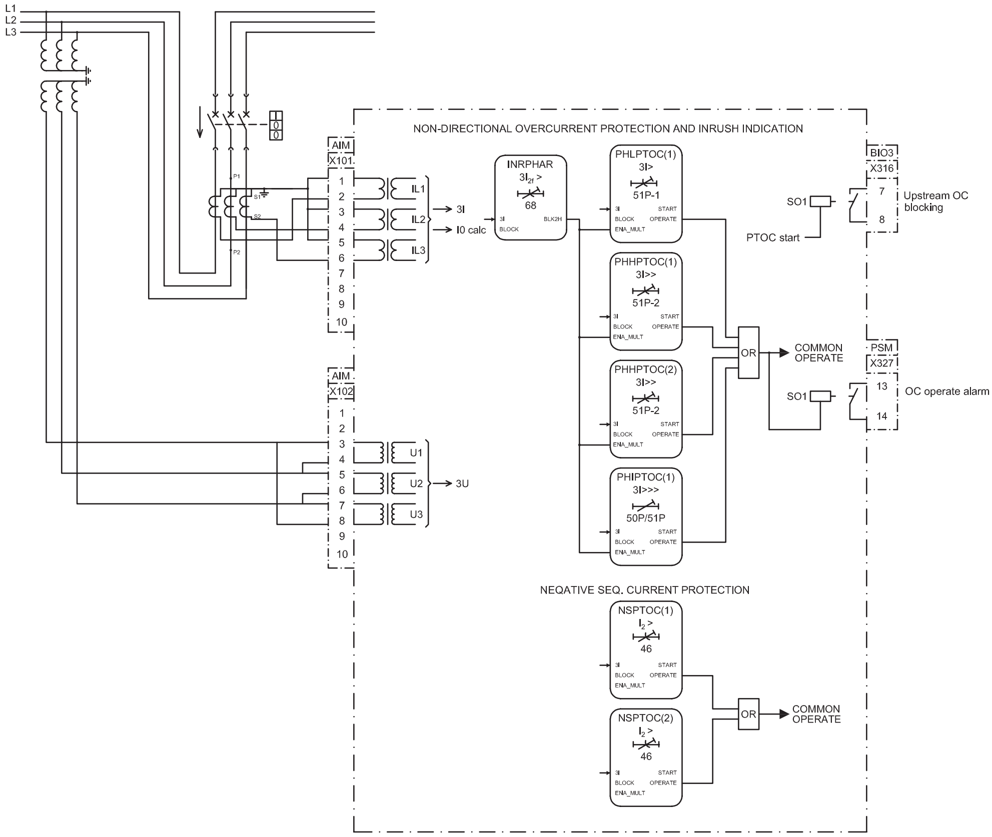


Figure 39: Non-directional overcurrent and negative-sequence overcurrent protection

3.5.6.4 Non-directional earth-fault protection EFxPTOC

The non-directional earth-fault protection functions are used for protection under earth fault conditions with definite-time (DT) or with inverse definite minimum time (IDMT) characteristic when appropriate.

The operation of the stage is based on three measuring principles: DFT, RMS or peak-to-peak values. The configuration includes three variants of non-directional earth-fault functions: high, low and instantaneous. The set of three phase currents, I3P, is connected to the inputs.

A common operate and start signal from all the three non-directional earth-fault functions are connected to an OR-block to form a combined non-directional earth-fault operate and start signal which is used to provide a LED indication on the LHMI. Also separate start and operate signals from all the three EF functions are connected to the disturbance recorder.

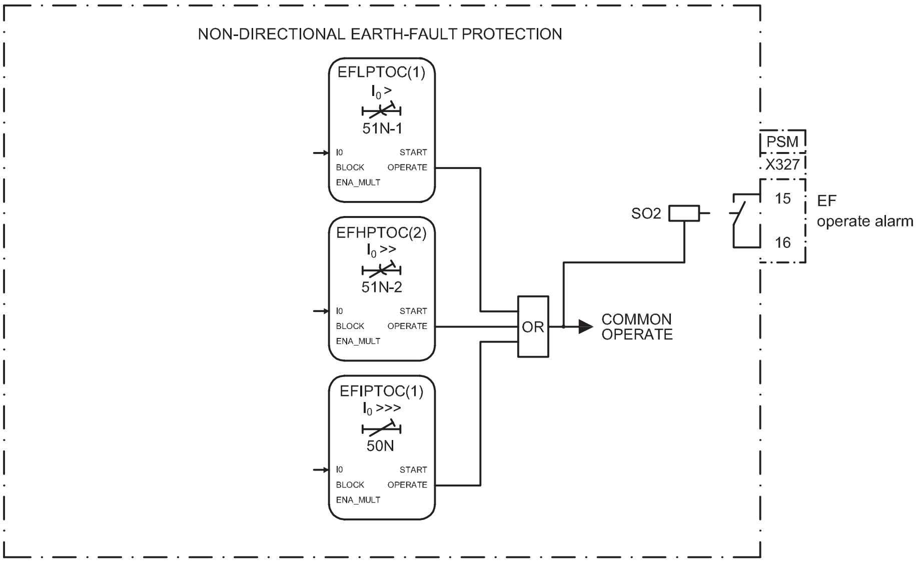


Figure 40: Non-directional earth-fault protection

3.5.6.5 Circuit-breaker failure protection CCBRBRF

The function is activated by the common operate command from the protection functions. The breaker failure function issues a backup trip command to adjacent circuit breakers in case the main circuit breaker fails to trip for the protected component. The backup trip is connected at binary output BIO_3 PO3.

A failure of a circuit breaker is detected by measuring the current or by detecting the remaining trip signal. Function also provides retrip. Retrip is used along with the main trip, and is activated before the backup trip signal is generated in case the main breaker fails to open. Retrip is used to increase the operational reliability of the circuit breaker.

3.5.6.6 Tripping logic TRPPTRC

Tripping logic has been configured to provide tripping signal of required duration. The tripping circuit opens the circuit breaker on

- Receipt of operate signal from the protection function or
- Retrip signal from the circuit-breaker failure protection.

Two master tripping signals are available at binary output PSM PO1 and PSM PO3.

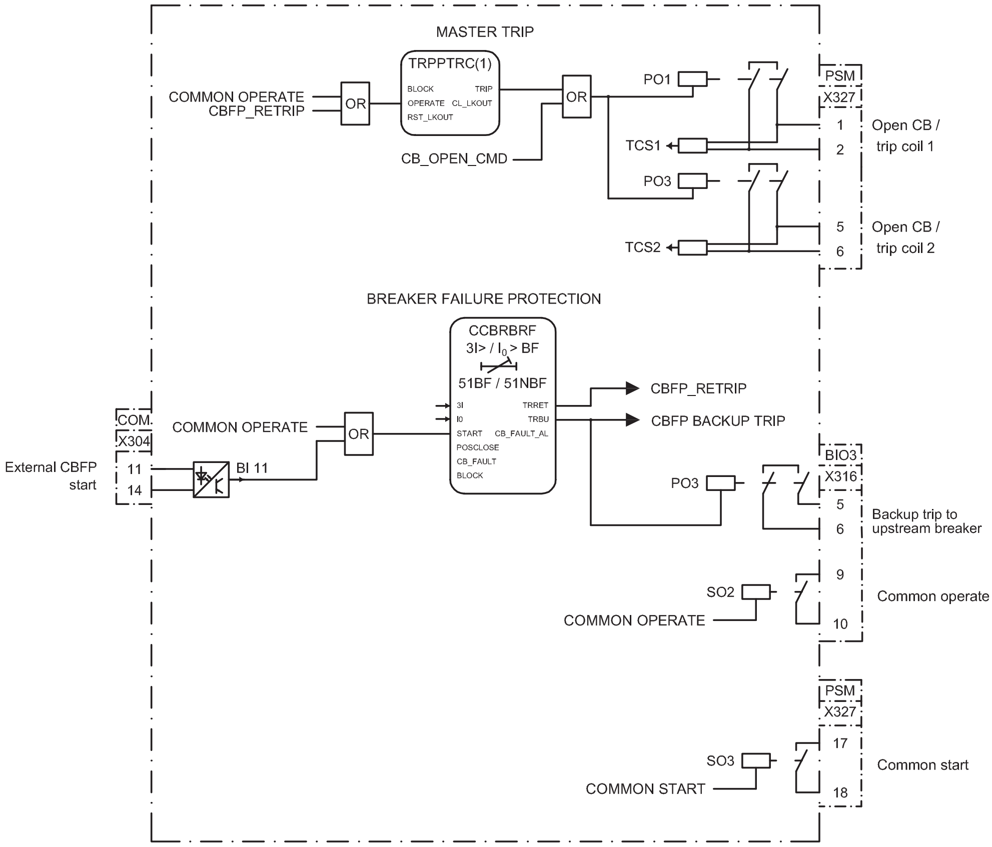


Figure 41: Tripping logic and breaker failure protection

3.5.6.7 Combined operate and start alarm signal

The operate outputs of all protection functions are combined in an OR-gate to get a common Operate output. This common operate signal is connected to a tripping logic. It is also available as an alarm binary output, BIO_3_SO2, with a settable minimum alarm delay of 80 ms. Also, a common Start output is derived from the start outputs of protection functions combined in an OR-gate. The output is available as an alarm binary output PSM SO3 with a settable minimum alarm delay of 80 ms.

3.5.6.8 Other output and alarm signals

- Combined overcurrent (OC) operate signal available at binary output PSM SO1
- Combined earth fault (EF) operate signal available at binary output PSM SO2
- Combined alarm signal from circuit-breaker monitoring function available at binary output BIO_3 SO4
- Combined alarm signal from various supervision functions available at binary output BIO_3 SO5
- Upstream overcurrent (OC) blocking signal available at binary output BIO_3 SO1

3.5.7 Supervision functions

3.5.7.1 Trip circuit supervision TCSSCBR

Two instances of trip circuit supervision function are used for supervising Master trip 1 and Master trip 2. Function continuously supervises the trip circuit and an alarm is issued in case of a failure of a trip circuit. The function does not perform the supervision itself but it is used as an aid for configuration. An additional instance is used to check the proper functioning of the closing circuit of the circuit breaker.

Function gives an indication via a LED on the LHMI on detection of any of the trip circuit failure. To prevent unwanted alarms, the function is blocked when the circuit breaker is open, one of the protection function operate signals is active.

An instance of trip circuit supervision is used to check the proper functioning of closing circuit of the circuit breaker. This function is blocked when the circuit breaker is in closed position to prevent unwanted alarms.

3.5.7.2 Circuit-breaker condition monitoring SSCBR

The circuit-breaker condition monitoring function checks for the health of the circuit breaker. The circuit breaker status is connected to the function via binary inputs. Function requires also pressure lockout input and spring charged input connected via binary input COM_101.BI12 and COM_101.BI13 respectively. Various alarm outputs from the function are combined in an OR-gate to create a master circuit-breaker monitoring alarm, which is available at binary output BIO_3 SO4.

All of the alarms are separately connected to the binary recorder and a combined alarm is available as an indication via a LED on the LHMI.

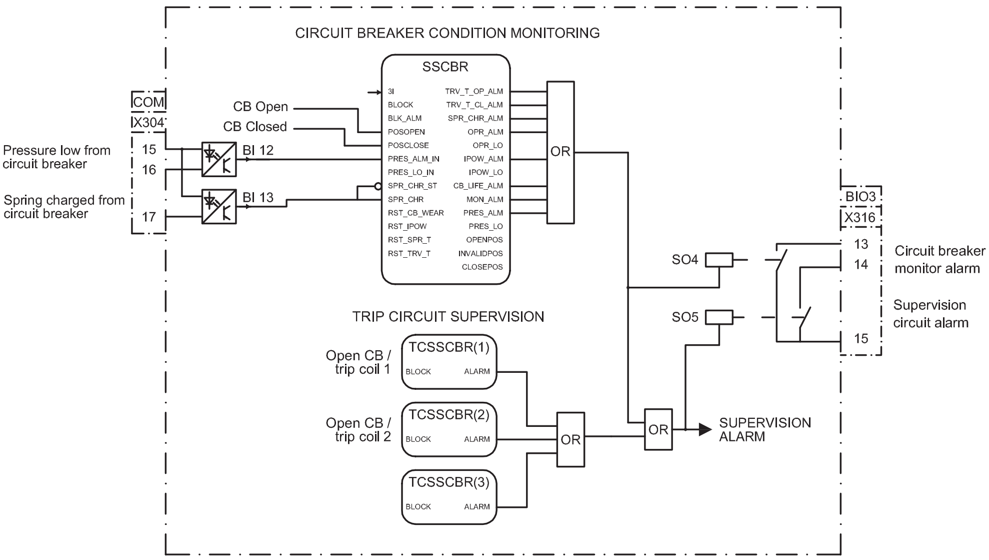


Figure 42: Circuit-breaker condition monitoring and trip circuit supervision

3.5.8 Measurement and analog recording functions

The measured quantities in this configuration are:

- Sequence current
- Sequence voltage
- Residual voltage
- Residual current
- Energy
- Phase current
- Phase voltage
- Line voltage
- Power with frequency

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 28: Signals connected to the analog recorder

Channel ID	Description
Channel 1	Phase A current
Channel 2	Phase B current
Channel 3	Phase C current
Channel 4	Calculated neutral current
Channel 5	Phase A voltage
Channel 6	Phase B voltage
Channel 7	Phase C voltage
Channel 8	Calculated neutral voltage

Data connected to analog channels contain 20 samples per cycle.

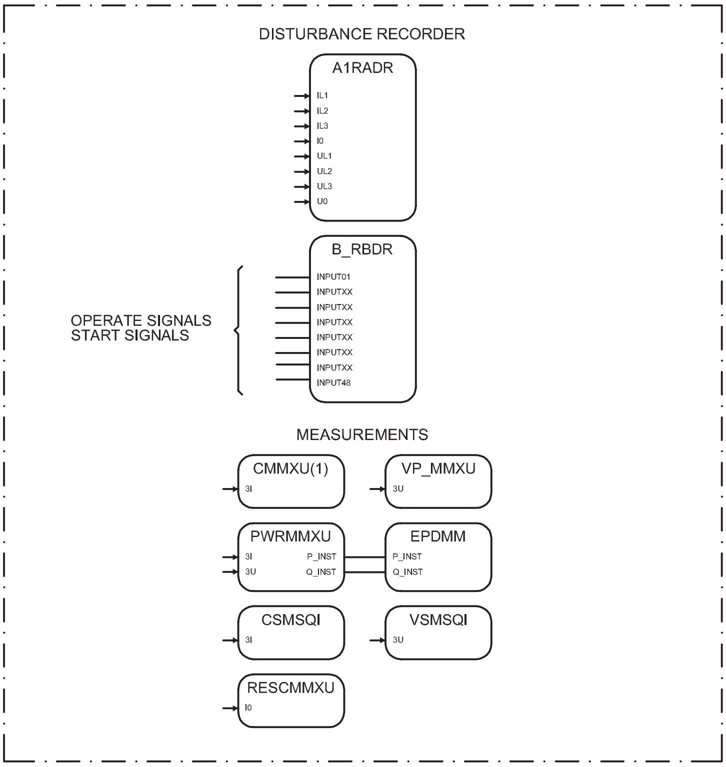


Figure 43: Measurement and analog recording

3.5.9 Binary recording and LED configurations

All of 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 which in turn will record all the signals connected to the recorder.

Table 29: Signals connected to the binary recorder

Channel ID	Description
Channel 1	Block by inrush protection
Channel 2	Start of overcurrent high stage 1
Channel 3	Operate of overcurrent high stage 1
Channel 4	Start of overcurrent high stage 2
Channel 5	Operate of overcurrent high stage 2
Channel 6	Start of instantaneous overcurrent stage
Channel 7	Operate of instantaneous overcurrent stage
Channel 8	Start of overcurrent low stage
Channel 9	Operate of overcurrent low stage
Channel 10	Start of instantaneous earth fault
Table continues on next page	

Channel ID	Description
Channel 11	Operate of instantaneous earth fault stage
Channel 12	Start of earth fault high stage
Channel 13	Operate of earth fault high stage
Channel 14	Start of earth fault low stage
Channel 15	Operate of earth fault low stage
Channel 16	Pressure in circuit breaker below lockout limit
Channel 17	Start of negative sequence overcurrent stage 1
Channel 18	Operate of negative-sequence overcurrent stage 1
Channel 19	Start of negative-sequence overcurrent stage 2
Channel 20	Operate of negative-sequence overcurrent stage 2
Channel 21	Backup trip from circuit-breaker failure protection
Channel 22	Retrip from circuit-breaker failure protection
Channel 23	Circuit breaker closed
Channel 24	Circuit breaker is open
Channel 25	Trip circuit alarm 1 (supervising master trip 1)
Channel 26	Trip circuit alarm 2 (supervising master trip 2)
Channel 27	Trip circuit alarm 3 (supervising closing circuit)
Channel 28	Closing time of circuit breaker exceeded the limit
Channel 29	Opening time of circuit breaker exceeded the limit
Channel 30	Spring charge time of circuit breaker exceeded the limit
Channel 31	Number of circuit breaker operation exceeded the set limit
Channel 32	Circuit breaker maintenance alarm: number of operations exceeds the set limit
Channel 33	Circuit breaker maintenance alarm: accumulated energy exceeds the set limit
Channel 34	Circuit breaker not operated since long

The LEDs are configured for alarm indications.

Table 30: LEDs configured on LHMI alarm page 1

LED No	LED color	Description
LED 1	Yellow	Combine start from OC
LED 1	Red	Combine operate from OC
LED 2	Yellow	Combine start from NSOC
LED 2	Red	Combine operate from NSOC
LED 3	Yellow	Combine start from EF
LED 3	Red	Combine operate from EF
LED 4	Red	Backup trip from circuit-breaker protection function
LED 5	Red	Retrip from circuit-breaker protection function
LED 6	Red	Alarm from circuit-breaker monitoring function
Table continues on next page		

LED No	LED color	Description
LED 7	Red	Trip circuit supervision alarm 1
LED 8	Red	Trip circuit supervision alarm 2
LED 9	Red	Closing circuit supervision alarm

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 31: 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.

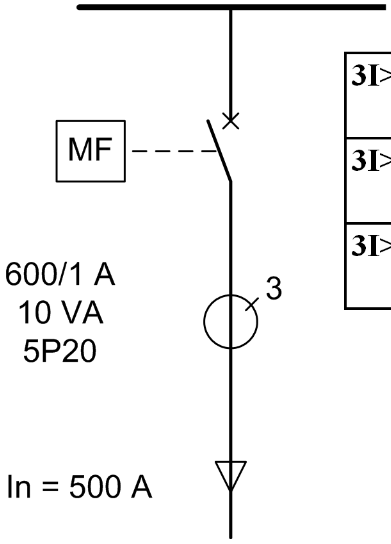
With inverse time mode of operation and when the high-set stages are not used, the AC component of the fault current should not saturate the CT less than 20 times the starting current. Otherwise, the inverse operation time can be further prolonged. Therefore, the accuracy limit factor F_a should be chosen 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** **0.75 s**	**2.00 x I_{2n}** **0.75 s**
3I>>	**1800A** **0.50 s**	**3.00 x I_{2n}** **0.50 s**
3I>>>	**3500 A** **0.20 s**	**5.83 x I_{2n}** **0.20 s**

Figure 44: 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 44). 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 44.

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
AR	Autoreclosing
BI/O	Binary input/output
BIO	Binary input and output
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
DCB	Directional comparison blocking scheme
DCUB	Directional comparison unblocking scheme
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
DUTT	Direct underreach transfer trip
EF	Earth fault
EMC	Electromagnetic compatibility
Ethernet	A standard for connecting a family of frame-based computer networking technologies into a LAN
GFC	General fault criteria
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
OC	Overcurrent
PCM600	Protection and Control IED Manager
POTT	Permissive overreach transfer trip
PUTT	Permissive underreach transfer trip
REF630	Feeder protection and control relay
RJ-45	Galvanic connector type
RMS	Root-mean-square (value)
RTD	Resistance temperature detector
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
VT	Voltage transformer
WAN	Wide area network
WEI	Weak-end infeed logic
WHMI	Web human-machine interface

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