Relion® Protection and Control

Feeder Protection and Control
REF615R
Application Manual

Power and productivity
for a better world™

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This product complies with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive 2004/108/EC) and concerning electrical equipment for use within specified voltage limits (Low-voltage directive 2006/95/EC). This conformity is the result of tests conducted by ABB in accordance with the product standards EN 50263 and EN 60255-26 for the EMC directive, and with the product standards EN 60255-6 and EN 60255-27 for the low voltage directive. The protection relay is designed in accordance with the international standards of the IEC 60255 series and ANSI C37.90. This protection relay complies with the UL 508 certification.

Table of Contents

Section 1 Introduction

1.1 This manual

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

1.2 Intended audience

This manual addresses the protection and control engineer responsible for planning, pre-engineering and engineering.

The protection and control engineer must be experienced in electrical power engineering and have knowledge of related technology, such as communication and protocols.

1.3 Product documentation

1.3.1 Product documentation set

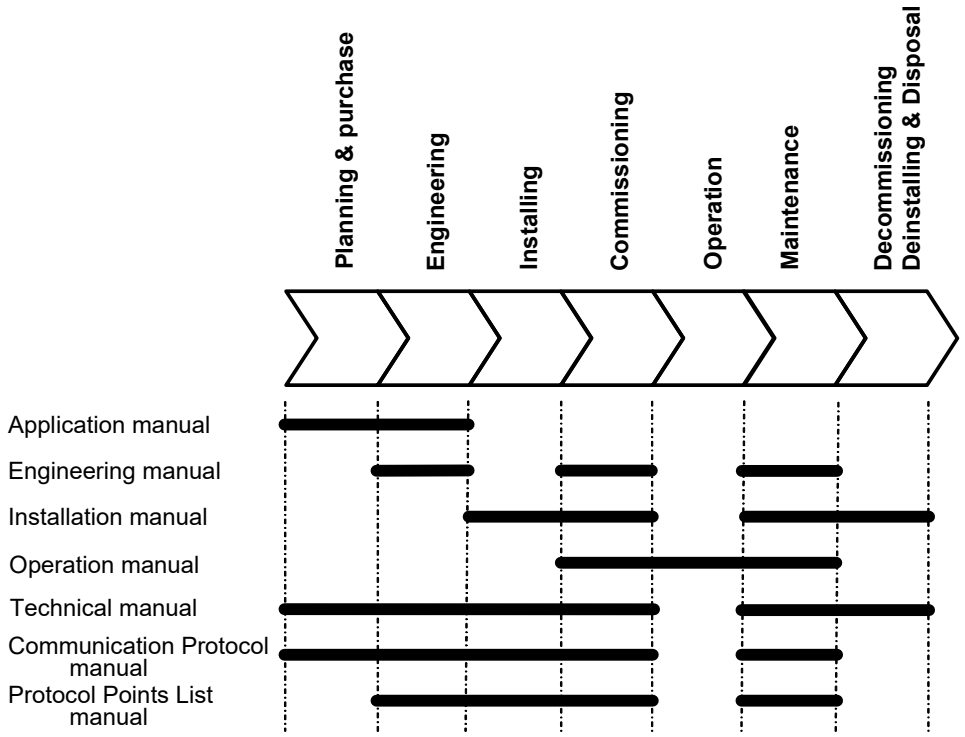


Figure 1: The intended use of manuals in different life cycles

The engineering manual contains instructions on how to engineer the protection relays using the different tools in PCM600. The manual provides instructions on how to set up a PCM600 project and insert protection relays to the project structure. The manual also recommends a sequence for engineering of protection and control functions, LHMI functions as well as communication engineering for IEC 61850 and other supported protocols. Consult the REF615R's Technical Manual to confirm the minimum PCM600 tool version that is required for use.

The installation manual contains instructions on how to install the protection relay. The manual provides procedures for mechanical and electrical installation. The chapters are organized in chronological order in which the protection relay should be installed.

The operation manual contains instructions on how to operate the protection relay once it has been commissioned. The manual provides instructions for monitoring, controlling and setting the protection relay. The manual also describes how to identify disturbances and how to view calculated and measured power grid data to determine the cause of a fault.

The application manual contains application descriptions and setting guidelines sorted per function. The manual can be used to find out when and for what purpose a typical protection function can be used. The manual can also be used when calculating settings.

The technical manual contains application and functionality descriptions and lists function blocks, logic diagrams, input and output signals, setting parameters and technical data

sorted per function. The manual can be used as a technical reference during the engineering phase, installation and commissioning phase, and during normal service.

The communication protocol manual describes a communication protocol supported by the protection relay. The manual concentrates on vendor-specific implementations. The point list manual describes the outlook and properties of the data points specific to the protection relay. The manual should be used in conjunction with the corresponding communication protocol manual.

1.3.2 Document revision history

Document revision/date	Product version	History
A/11/22/2013	4.0	First release
B/09/23/2016	4.1	Content update

Download the latest documents from the ABB website http://www.abb.com/substationautomation.

1.3.3 Related documentation

Name of the document	Document ID
Modbus Communication Protocol Manual	1MRS240047-IB
DNP3 Communication Protocol Manual	1MRS240048-IB
IEC 61850 Engineering Guide	1MRS240045-IB
Installation Manual	1MRS240046-IB
Operation Manual	1MRS240049-IB
Technical Manual	1MRS240050-IB

1.4 Symbols and conventions

1.4.1 Safety indication 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 to 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 should be understood that operation of damaged equipment could, under certain operational conditions, result in degraded process performance leading to personal injury or death. Therefore, comply fully with all warning and caution notices.

1.4.2 Manual conventions

Conventions used in protection relay manuals. A particular convention may not be used in this manual.

- Abbreviations and acronyms in this manual are spelled out in the glossary. The glossary also contains definitions of important terms.
- pushbutton navigation in the LHMI menu structure is presented by using the pushbutton icons, for example:
  To navigate between the options, use  and  .
- HMI menu paths are presented in bold, for example:
  Select **Main menu > Settings**.
- LHMI messages are shown in Courier font, for example:
  To save the changes in non-volatile memory, select `Yes` and press  .
- Parameter names are shown in italics, for example:
  The function can be enabled and disabled with the *Operation* setting.
- Parameter values are indicated with quotation marks, for example:
  The corresponding parameter values are "Enabled" and "Disabled".
- Protection relay input/output messages and monitored data names are shown in Courier font, for example:
  When the function picks up, the `PICKUP` output is set to TRUE.
- Dimensions are provided both in inches and mm. If it is not specifically mentioned then the dimension is in mm.

1.4.3 Functions, codes and symbols

All available functions are listed in the table. All of them may not be applicable to all products.

Table 1: Functions included in standard configurations, REF615R

Function	IEC61850	ANSI/C37.2 -2008	IEC60617
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	51P-1	3I> (1)
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	50P-1	3I>> (1)
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	50P-2	3I>> (2)
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	50P-3	3I>>> (1)
Three-phase non-directional long time overcurrent protection, low stage, instance 1	PHLTPTOC1	51LT	3I> (3)
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	67/51P	3I> -> (1)
Three-phase directional overcurrent protection, high stage, instance 1	DPHHPDOC1	67/50P-1	3I>> -> (1)
Three-phase directional overcurrent protection, high stage, instance 2	DPHHPDOC2	67/50P-2	3I>> -> (2)
Non-directional ground-fault protection, low stage, instance 1	EFLPTOC1	51G	Io> (1)
Non-directional ground-fault protection, low stage, instance 2	EFLPTOC2	51N-1	Io> (2)
Non-directional ground-fault protection, low stage, instance 4	EFLPTOC4	50SEF	Io> (4)
Non-directional ground-fault protection, high stage, instance 1	EFHPTOC1	50G-1	Io>> (1)
Non-directional ground-fault protection, high stage, instance 2	EFHPTOC2	50G-2	Io>> (2)
Non-directional ground-fault protection, high stage, instance 3	EFHPTOC3	50N-1	Io>> (3)
Non-directional ground-fault protection, high stage, instance 4	EFHPTOC4	50N-2	Io>> (4)
Non-directional ground-fault protection, instantaneous stage, instance 1	EFIPTOC1	50G-3	Io>>> (1)
Non-directional ground-fault protection, instantaneous stage, instance 2	EFIPTOC2	50N-3	Io>>> (2)
Directional ground-fault protection, low stage, instance 1	DEFLPDEF1	67/51N	Io> -> (1)
Directional ground-fault protection, high stage, instance 1	DEFHPDEF1	67/50N-1	Io>> -> (1)
Directional ground-fault protection, high stage, instance 2	DEFHPDEF2	67/50N-2	Io>> -> (2)
Three phase directional power protection, instance 1	DPSRDIR1	32P-1	I1-> (1)
Ground directional power protection, instance 1	DNZSRDIR1	32N-1	I2 ->, Io-> (1)
Negative-sequence overcurrent protection, instance 1	NSPTOC1	46-1	I2> (1)
Negative-sequence overcurrent protection, instance 2	NSPTOC2	46-2	I2> (2)
Phase discontinuity protection	PDNSPTOC1	46PD	I2/I1>

Function	IEC61850	ANSI/C37.2 -2008	IEC60617
Residual overvoltage protection, instance 1	ROVPTOV1	59G	Uo> (1)
Residual overvoltage protection, instance 2	ROVPTOV2	59N-1	Uo> (2)
Three-phase undervoltage protection, instance 1	PHPTUV1	27-1	3U< (1)
Three-phase undervoltage protection, instance 2	PHPTUV2	27-2	3U< (2)
Three-phase overvoltage protection, instance 1	PHPTOV1	59-1	3U> (1)
Three-phase overvoltage protection, instance 2	PHPTOV2	59-2	3U> (2)
Negative-sequence overvoltage protection, instance 1	NSPTOV1	47-1	U2> (1)
Negative-sequence overvoltage protection, instance 2	NSPTOV2	47-2	U2> (2)
Frequency protection, instance 1	FRPFRQ1	81-1	f>/f<,df/dt (1)
Frequency protection, instance 2	FRPFRQ2	81-2	f>/f<,df/dt (2)
Voltage per hertz protection, instance 1	OEPVPH1	24	U/f> (1)
Three-phase thermal protection for feeders, cables and distribution transformers, Instance 1	T1PTTR1	49F-1	3Ith>F (1)
Numerical stabilized low impedance restricted ground-fault protection	LREFPNDF1	87LOZREF	dIoLo>
Circuit breaker failure protection, instance 1	CCBRBRF1	50BF-1	3I>/Io>BF (1)
Three-phase inrush detector, instance 1	INRPHAR1	INR-1	3I2f> (1)
Master trip, instance 1	TRPPTRC1	86/94-1	Master Trip (1)
Master trip, instance 2	TRPPTRC2	86/94-2	Master Trip (2)
Arc protection, instance 1	ARCSARC1	AFD-1	ARC (1)
Arc protection, instance 2	ARCSARC2	AFD-2	ARC (2)
Arc protection, instance 3	ARCSARC3	AFD-3	ARC (3)
High impedance fault detection	PHIZ1	HIZ	PHIZ1
Load shedding and restoration, instance 1	LSHDPFRQ1	81LSH-1	UFLS/R (1)
Load shedding and restoration, instance 2	LSHDPFRQ2	81LSH-2	UFLS/R (2)
Loss of phase, instance 1	PHPTUC1	37-1	3I< (1)
Control			
Circuit-breaker control, instance 1	CBXCBR1	52-1	I <-> O CB (1)
Auto-reclosing	DARREC1	79	O -> I
Synchronism and energizing check	SECRSYN1	25	SYNC
Condition Monitoring			
Circuit-breaker condition monitoring, instance 1	SSCBR1	52CM-1	CBCM (1)
Current circuit supervision	CCRDIF1	CCM	MCS 3I
Fuse failure supervision, instance 1	SEQRFUF1	60-1	FUSEF (1)
Cable fault detection	RCFD1	CFD	CFD
Measurement			
Three-phase current measurement, instance 1	CMMXU1	IA, IB, IC	3I
Sequence current measurement, instance 1	CSMSQI1	I1, I2, I0	I1, I2, I0
Residual current measurement, instance 1	RESCMMXU1	IG	Io
Three-phase voltage measurement, instance 1	VMMXU1	VA, VB, VC	3U
Residual voltage measurement, instance 1	RESVMMXU1	VG	Uo

Function	IEC61850	ANSI/C37.2 -2008	IEC60617
Sequence voltage measurement, instance 1	VSMSQI1	V1, V2, V0	U1, U2, U0
Single-phase power and energy measurement, instance 1	SPEMMXU1	SP, SE-1	SP, SE
Three-phase power and energy measurement, instance 1	PEMMXU1	P, E-1	P, E
Current total demand distortion, instance 1	CMHAI1	PQI-1	PQM3I
Voltage total harmonic distortion, instance 1	VMHAI1	PQVPH-1	PQM3U(1)
Voltage variation, instance 1	PHQVVR1	PQSS-1	PQ 3U<>(1)
Voltage unbalance, instance 1	VSQVUB1	PQVUB-1	PQMUBU(1)
Load profile	LDPMSTA1	LoadProf	LoadProf
Frequency measurement, instance 1	FMMXU1	f	f
Logging Function			
Disturbance recorder	RDRE1	DFR	DR
Fault recorder	FLTMSTA1	FR	FR
Sequence event recorder	SER	SER	SER
Fault location	DRFLO	FLO	DRFLO
Other Functions			
Minimum pulse timer (2 pcs), instance 1	TPGAPC1	TP (1)	TP (1)
Minimum pulse timer (2 pcs), instance 2	TPGAPC2	TP (2)	TP (2)
Minimum pulse timer (2 pcs), instance 3	TPGAPC3	TP (3)	TP (3)
Minimum pulse timer (2 pcs), instance 4	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution), instance 1	TPSGAPC1	62CLD-1	TPS (1)
Minimum pulse timer (2 pcs, minute resolution), instance 1	TPMGAPC1	62CLD-2	TPM (1)
Pulse timer (8 pcs), instance 1	PTGAPC1	PT-1	PT (1)
Pulse timer (8 pcs), instance 2	PTGAPC2	PT-2	PT (2)
Time delay off (8 pcs), instance 1	TOFGAPC1	TOF-1	TOF (1)
Time delay off (8 pcs), instance 2	TOFGAPC2	TOF-2	TOF (2)
Time delay on (8 pcs), instance 1	TONGAPC1	TON-1	TON (1)
Time delay on (8 pcs), instance 2	TONGAPC2	TON-2	TON (2)
Set reset (8 pcs), instance 1	SRGAPC1	SR-1	SR (1)
Set reset (8 pcs), instance 2	SRGAPC2	SR-2	SR (2)
Set reset (8 pcs), instance 3	SRGAPC3	SR-3	SR (3)
Set reset (8 pcs), instance 4	SRGAPC4	SR-4	SR (4)
Move (8 pcs), instance 1	MVGAPC1	MV-1	MV (1)
Move (8 pcs), instance 2	MVGAPC2	MV-2	MV (2)
Move (8 pcs), instance 3	MVGAPC3	MV-3	MV (3)
Move (8 pcs), instance 4	MVGAPC4	MV-4	MV (4)
Move (8 pcs), instance 5	MVGAPC5	MV-5	MV (5)
Move (8 pcs), instance 6	MVGAPC6	MV-6	MV (6)
Move (8 pcs), instance 7	MVGAPC7	MV-7	MV (7)
Move (8 pcs), instance 8	MVGAPC8	MV-8	MV (8)
Generic control points, instance 1	SPCGGIO1	CNTRL-1	SPC(1)

Function	IEC61850	ANSI/C37.2 -2008	IEC60617
Generic control points, instance 2	SPCGGIO2	CNTRL-2	SPC(2)
Generic control points, instance 3	SPCGGIO3	CNTRL-3	SPC(3)
Remote Generic control points, instance 1	SPCRGGIO1	RCNTRL-1	SPCR(1)
Local Generic control points, instance 1	SPCLGGIO1	LCNTRL-1	SPCL(1)
Programmable buttons (16 buttons), instance 1	FKEYGGIO1	FKEY	FKEY
Generic Up-Down Counters, instance 1	UDFCNT1	CTR-1	CTR(1)
Generic Up-Down Counters, instance 2	UDFCNT2	CTR-2	CTR(2)
Generic Up-Down Counters, instance 3	UDFCNT3	CTR-3	CTR(3)
Shift register, instance 1	SHFTGAPC1	SHFT-1	SHFT(1)
Shift register, instance 2	SHFTGAPC2	SHFT-2	SHFT(2)
Shift register, instance 3	SHFTGAPC3	SHFT-3	SHFT(3)

Section 2 REF615R overview

2.1 Overview

REF615R is a dedicated feeder protection relay (intelligent electronic device) designed for the protection, control, measurement and supervision of utility substations and industrial power systems. REF615R is a member of ABB's Relion® product family. The 615R series protection relays are characterized by their versatility of 19" rack mounting and withdrawable design.

Re-engineered from the ground up, the REF615R has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices.

The protection relay provides main protection for overhead lines and cable feeders in distribution networks. The protection relay is also used as back-up protection in applications, where an independent and redundant protection system is required.

Depending on the chosen standard configuration, the protection relay is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance grounded, compensated and solidly grounded networks. Once the standard configuration protection relay has been given the application-specific settings, it can directly be put into service.

REF615R supports a range of communication protocols including IEC 61850 with GOOSE messaging, Modbus® and DNP3.

REF615R is designed to be a wire-alike replacement of an existing DPU2000R installation. It is designed to match existing DPU2000R cutout and external wiring except communication cable connections.

2.1.1 Product version history

Product version	Product history
4.0	Product released
4.1	Content update

2.1.2 PCM600 and protection relay connectivity package version

- Protection and Control protection relay Manager PCM600 Ver. 2.5 or later
- Protection relay Connectivity Package REF615R Ver 4.0 or later
  - Parameter Setting
  - Application Configuration
  - Firmware Update
  - Disturbance Handling
  - Signal Monitoring
  - Lifecycle Traceability
  - Signal Matrix
  - Communication Management
  - Configuration Wizard
  - Label Printing
  - Protection Relay User Management
  - Protection Relay Users

Download connectivity packages from the ABB website
http://www.abb.com/substationautomation

2.2 Physical hardware

The protection relay consists of two main parts: "Inner Chassis" and "Outer Case". The contents of the units depend on the ordered functionality.

The protection relay can be ordered together as a unit comprising of both the "Inner Chassis" and "Outer Case". It is possible to order the "Inner Chassis" and "Outer Case" separately based on the ordering code, as detailed in the product guide as spares.

The unit as a whole is a one-to-one replacement for an existing DPU2000R installation and will match cutout and external wiring except communication cable connections. This aids quicker upgrading of the older DPU2000R units with minimum shutdown for the associated feeder.

Before removing and / or replacing units make sure associated feeder protected by the unit is shutdown and grounded. Apply necessary safety precautions on secondary circuits including shorting/isolation/grounding of appropriate connections associated with CT, PT, DC, trip circuits.

It is possible to do hot swapping of the inner chassis with the outer case inputs energized by the respective CT, PT, DC inputs. Use this method for emergency replacement of the inner chassis on suspected failures of front display, power supply, binary input and output cards. Note that while swapping, CT secondary circuit remains unaffected, so long as outer case connections remain undisturbed.

Before swapping the inner chassis, make sure the order code of the case and the inner chassis are compatible and the inner chassis is set with all necessary pre-determined settings applicable for the feeder being serviced.

Figure 2: Front view of REF615R

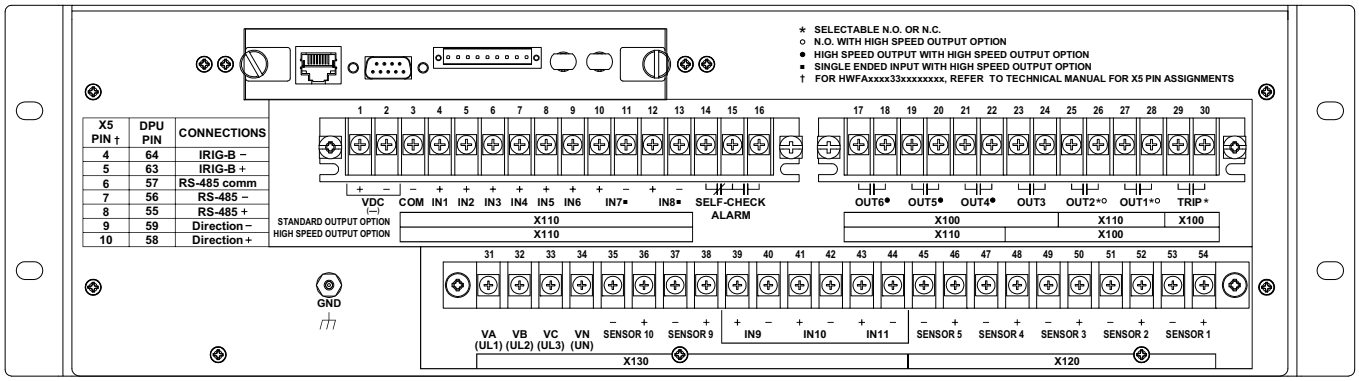


Figure 3: Rear view of REF615R

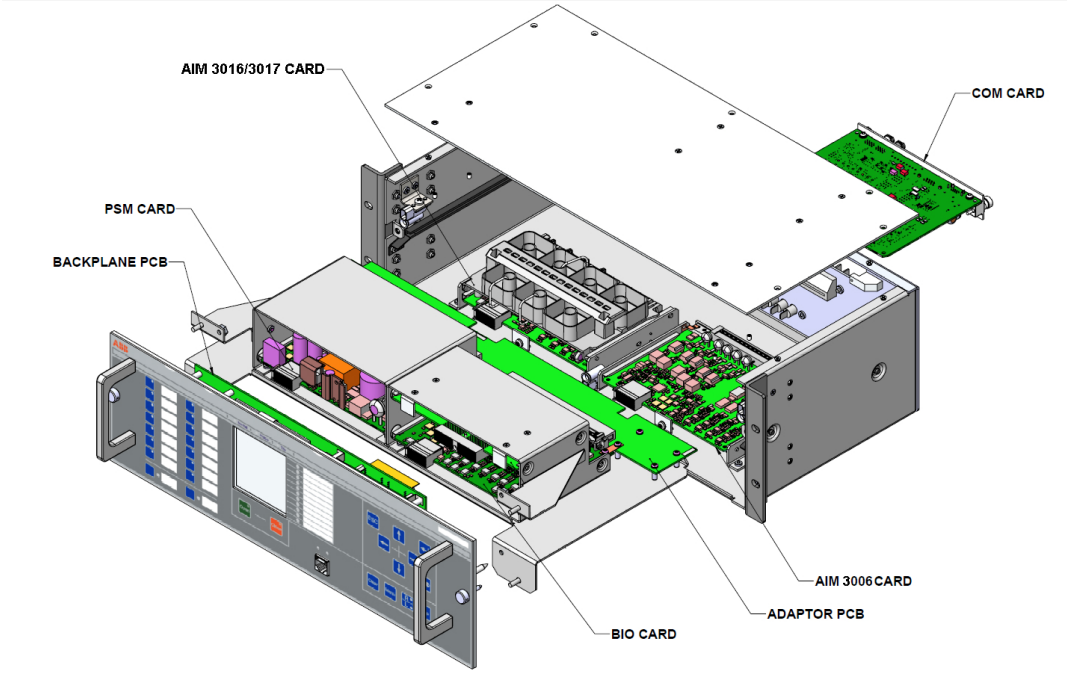


Figure 4: *View of REF615R indicating type of cards*

Table 2:

Main unit	Module ID	Content options	
Inner chassis	DIS0008	HMI	128/128 LCD large display with text and graphics
	PSM0004 Or PSM0003	Auxiliary power/BO module	48-250V DC/ 80-240V AC; or 24-60V DC
	BIO0005	BI/O module	Equipped as default minimum;
	BIO0007		May be alternatively equipped with high-speed BIO card
Case	AIM3016	AI/BI module	With Configuration **A**A 3 phase current Inputs (1/5A) 1 phase current input (1/5A)
	AIM3017		With Configuration **A**B 3 phase current Inputs (1/5A) 1 phase current input (0.2/1A)
	AIM3006	AI/BI Module (Voltage sensor)	With Configuration **A**A and **A**B 5 Voltage Inputs
		Optional communication module	See technical manual for details about different type of communication modules. IEC61850 DNP3 Modbus

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

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

See the installation manual for more information about the case and the inner chassis.

2.3 Local HMI

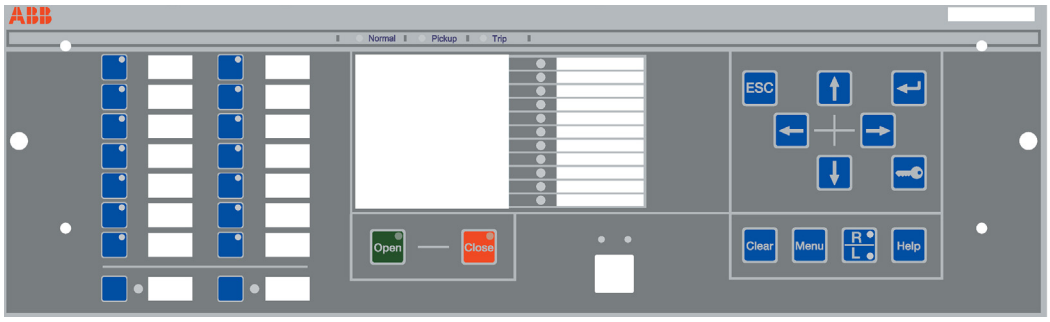


Figure 5a: LHMI REF615R (ANSI)

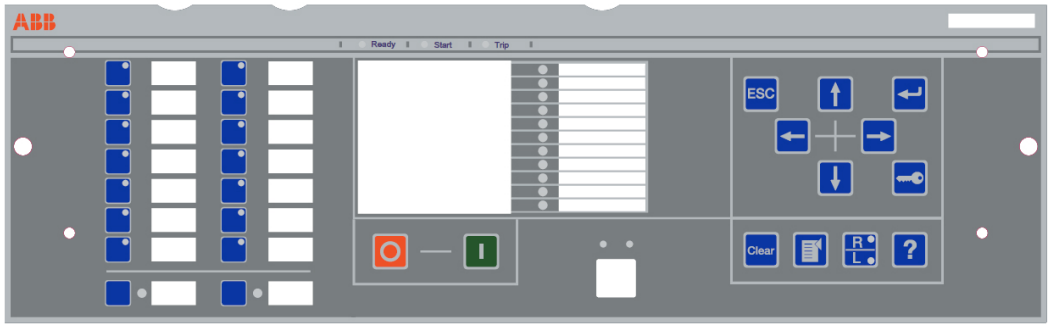


Figure 5b LHMI REF615R (IEC)

The LHMI of the protection relay contains the following elements:

- Display
- Buttons
- LED indicators
- Communication port

The LHMI is used for setting, monitoring and controlling.

2.3.1 LCD

The LHMI includes a graphical LCD that supports two character sizes. The character size depends on the selected language.

Table 3: Characters and rows on the view

Character size	Rows in view	Characters on row
Large, variable width (13x14 pixels)	10 rows 8 rows with large screen	min 8

The display view is divided into four basic areas.

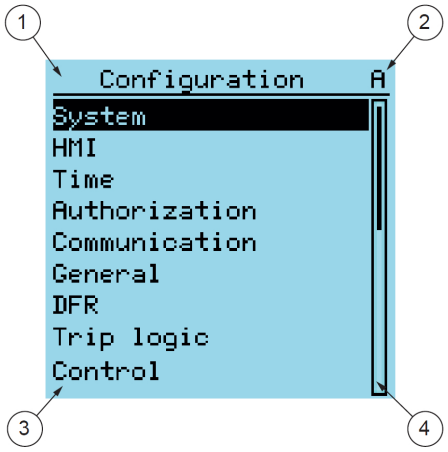


Figure 6: Display layout

1. Header
2. Icon
3. Content
4. Scroll bar (displayed when needed)

2.3.2 LEDs

The LHMI includes three protection indicators above the display: Normal, Pickup and Trip for ANSI LHMI and Ready, Start and Trip for IEC LHMI..

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

In ANSI LHMI models, there are two additional LEDs which are embedded into the control buttons 

and . 

. They represent the status of the circuit breaker.

In IEC LHMI, there are no status LEDs available on the control pushbuttons  and .  . The status is ascertained by the LCD display of the LHMI.

2.3.3 Keypad

The LHMI keypad contains pushbuttons which are used to navigate in different views or menus. With the pushbuttons you can give open or close commands to one primary object, for example, a circuit breaker, disconnector or switch. The pushbuttons are also used to acknowledge alarms, reset indications, provide help and switch between local and remote control mode.

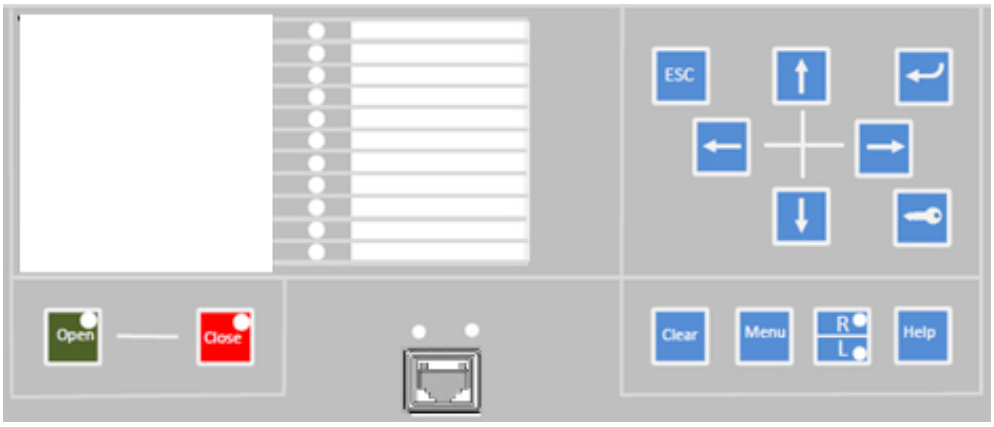


Figure 7a: *LHMI (ANSI) keypad with object control, navigation,* display, LEDs *and command pushbuttons and RJ-45 communication port*

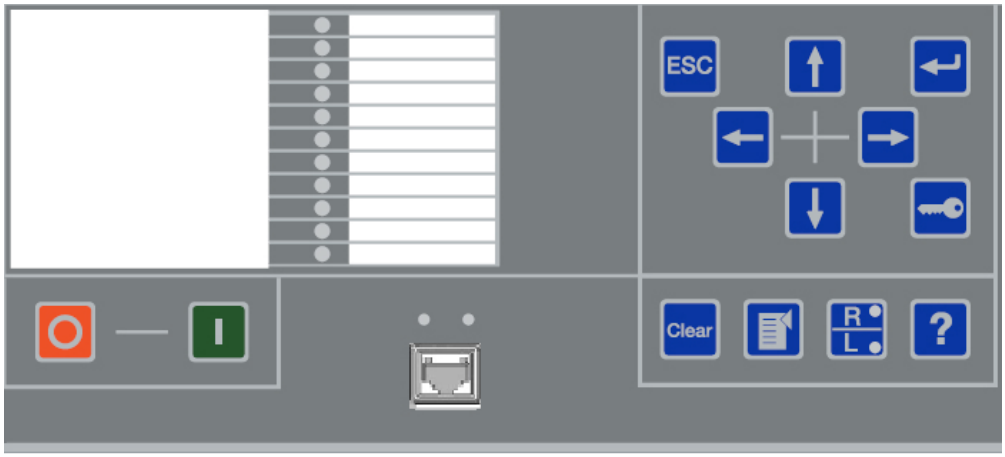


Figure 7b: *LHMI (IEC) keypad with object control, navigation, display, LEDs and command pushbuttons and RJ-45 communication port*

2.3.4 Programmable pushbuttons and LEDs

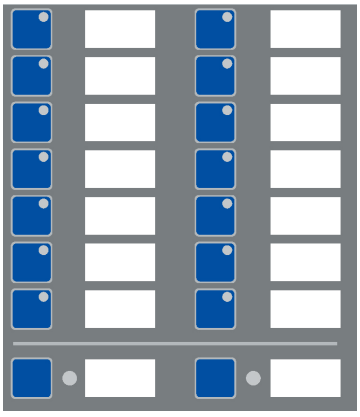


Figure 8: *Programmable pushbuttons with LEDs*

On the left portion of the protection relay, the LHMI keypad has sixteen programmable pushbuttons with 'Red' LEDs. Two of these pushbuttons, located at the bottom portion, have the LEDs located on the right side of the buttons, while the remaining fourteen buttons have the LEDs embedded on top right corners within the pushbuttons.

These pushbuttons are enabled and connected in the internal logics when the unit is ordered with "Enhanced OCI" option "B" and "D". When the unit is ordered with " Standard OCI" (options "A" and "C") the pushbuttons and lamps are disconnected. However, the user can connect them for use if desired by making necessary connections in the logics..

The pushbuttons and the LEDs are freely programmable and can be configured to not only select an operation but also get acknowledgement back from the internal logic that the action has been executed through the LEDs associated with the pushbuttons. The combination is very useful, typically for quickly selecting or changing setting groups, selection and operation of equipment, indicating field contact status, indication and acknowledging of individual alarms etc. Independent of the pushbuttons, the LEDs may also be independently configured for general indication or important alarms to draw operator's attention

The bottom two buttons with LEDs are typically used for Hotline Tag and emergency operation of the circuit which is controlled by the protection relay.

The space to the right side of the buttons is meant for providing a description of the functionality of each button. One can insert a sheet of paper with appropriate text behind a transparent film provided on the LHMI for this purpose.

The function block FKEYGGIO is the function interface associated with these sixteen pushbuttons and LEDs as indicated in figure below:

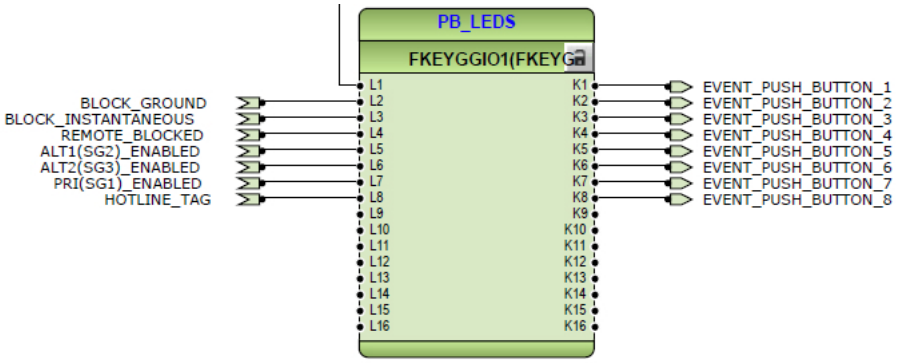


Figure 9: *Typical connections to and from FKEYGGIO function block in ACT logic of REF615R*

The outputs K1, K2 etc. are the signal outputs from the keys in the front of the panel. They can be connected to internal ACT scheme for various logical functionalities. The inputs L1, L2, etc. are the signal inputs that are wired to illuminate the lamps in the front panel.

The pushbutton controls are associated with the function block SPCGGIO . SPC offers the capability to activate its outputs through a local or remote control. The local control is

provided through the buttons in the front panel and the remote control is provided through communications. In mode 1(Local), Local control through front panel is provided. In mode 2 (Local and Remote), Local control is augmented with remote communication.

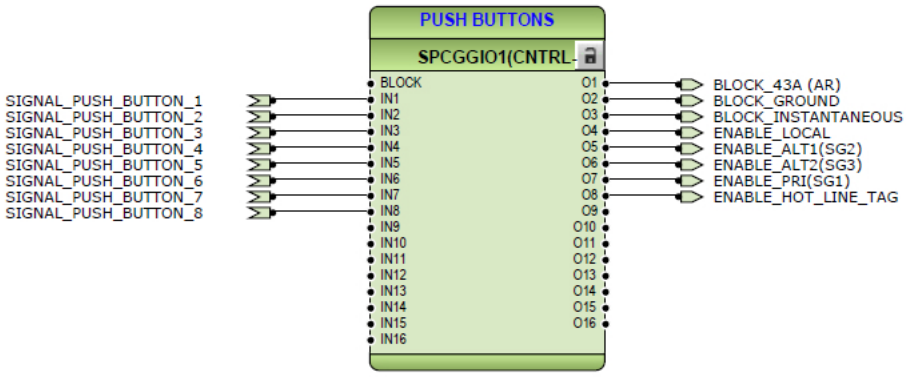


Figure 10: *Typical connections of SPCGGIO in ACT logic of REF615R*

Each point in SPC, has the Operation mode, Pulse length and Description settings available to control the output. The Operation mode can be set to Off, Pulse or Toggle mode. For more details on the above function blocks, please refer to the technical manual.

The Off, Pulse and Toggle modes of SPCGGIO are identical to the way the earlier DPU2000R (V5.42) with enhanced OCI had pushbutton settings selectable as Disable, Momentary or Maintained.

2.4 Web HMI

The WHMI enables the user to access the protection relay via a web browser. The supported web browser version is Internet Explorer IE7, IE8 and IE9.

WHMI is enabled by default.

WHMI offers several functions.

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

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

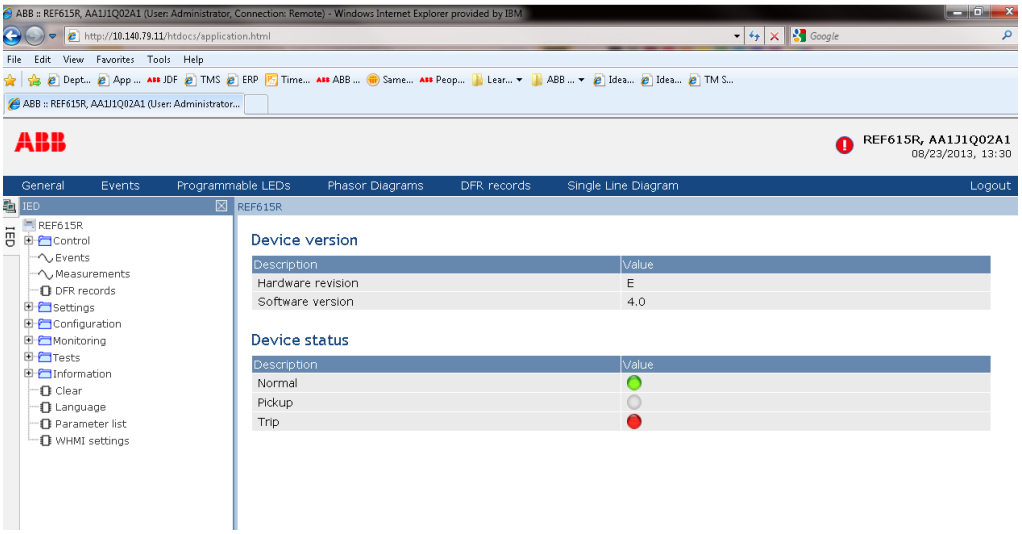


Figure 11: Example view of the WHMI

The WHMI can be accessed locally and remotely.

- Locally by connecting your laptop to the protection relay via the front communication port.
- Remotely over LAN/WAN.

2.5 Authorization

The user categories have been predefined for the LHMI and the WHMI, each with different rights and default passwords.

The default passwords can be changed with Administrator user rights.

User authorization is disabled by default but WHMI always uses authorization.

Table 4: Predefined user categories

User name	User rights
VIEWER	Read only access
OPERATOR	• Selecting remote or local state with  (only locally) • Changing setting groups • Controlling • Clearing alarm and indication LEDs and textual indications
ENGINEER	• Changing settings • Clearing event list • Clearing DFRs • Changing system settings such as IP address, serial baud rate or DFR settings • Setting the protection relay to test mode • Selecting language
ADMINISTRATOR	• All listed above • Changing password • Factory default activation

For user authorization for PCM600, see PCM600 documentation.

2.6 Communication

The protection relay supports different communication protocols: IEC 61850, Modbus® and DNP 3.0 Level 2 - all using TCP/IP. DNP3 and Modbus also support serial communication. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal peer-to-peer communication between the protection relays and parameters setting, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 communication implementation supports all monitoring and control functions. Additionally, parameter setting and DFR records can be accessed using the IEC 61850 protocol. Oscillographic files are available to any Ethernet-based application in the standard COMTRADE format. Further, the protection relay can send and receive binary signals from other protection relays (so called horizontal communication) using the IEC61850-8-1 GOOSE profile, where the highest performance class with a total transmission time of 3 ms is supported. Also, the protection relay supports sending and receiving of analog values using GOOSE messaging. The protection relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the 61850 standard. The protection relay can simultaneously report events to five different clients on the station bus.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The protection relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100BASE-TX) or the fiber-optic LC connector (100BASE-FX). An optional serial interface is available for RS-232/RS-485 communication.

Details of communication card options and configuration details are available in Technical Manual and Product Guide.

Section 3 REF615R configurations

3.1 REF615R variant list

REF615R is intended for protection and control mainly in distribution and sub-transmission feeder applications. The product has standard configurations covering a wide range of primary circuit configurations in such networks based on different system grounding methods.

Some of the functions included in the protection relay's standard configurations are optional at the time of placing the order. The description of standard configurations covers the full functionality including options, presenting the functionality, flexibility and external connections of REF615R with a specific configuration as delivered from the factory.

3.2 Presentation of standard configurations

Functional diagrams

The functional diagrams describe the protection relay's functionality from the protection, measuring, condition monitoring, recording, control and interlocking perspective. Wherever possible, the graphic symbols and connections as used in the standard configuration in Application Configuration Tool (ACT) of PCM600 have been used. A simplified logic diagram is also included to provide a overview of main protection functions in the protection relay and how their output signals are routed. The external connections to primary devices are also shown, stating the default connections to measuring transformers. The positive measuring direction is towards the outgoing feeder, away from the bus bar.

The functional diagrams are divided into sections with each section constituting 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 ANSI function number/acronym, but the IEC based symbol and the IEC 61850 names are also included. Some function blocks are used several times in the configuration. To separate the blocks from each other, the IEC 61850 name and ANSI function number are appended with a running number, that is an instance number, from one upwards. The protection relay's internal functionality and the external connections are separated with a dashed line presenting the protection relay's physical casing.

Signal Matrix and Application Configuration Tool (ACT)

With Signal Matrix and ACT in PCM600 the user can modify the standard configuration according to the actual needs. The protection relay is delivered from the factory with default connections described in the functional diagrams for BI's, BO's, function to function connections and alarm LEDs. Signal Matrix has a number of different page views, designated as follows:

- Binary input
- Binary output
- Functions

There are six protection relay variant-specific setting groups. Parameters can be set independently for each setting group.

The active setting group (1...6) can be changed with a parameter. The active setting group can also be changed via a binary input if the binary input is enabled for this. To enable the change of the active setting group via a binary input, connect a free binary input with PCM600 to the BI_SG_x input of the Protection block.

Table 5: Binary input states and corresponding active setting groups

BI state	Active setting group
OFF	1
ON	2

The active setting group defined by a parameter is overridden when a binary input is enabled for changing the active setting group.

REF615R can be programmed to use three pushbuttons in the front of the LHMI and use them to select three setting groups. By default, when enhanced OCI is ordered in REF615R, pushbuttons 5, 6 and 7 are configured for Group2(ALT1), Group3(ALT2) and Group 1(Primary) respectively, emulating DPU2000R group selection. The logic is realized using a number of function blocks and is described further.

Referring to Figure 12 below, SPCGGIO1 is the interface to connect the pushbutton signal to the rest of the ACT logic.

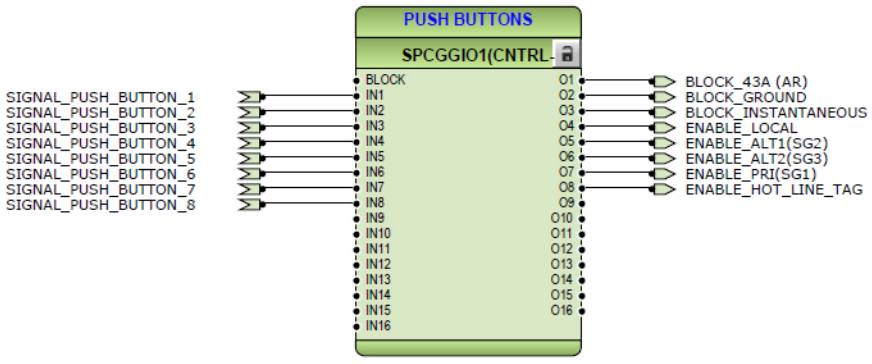


Figure 12: Pushbuttons 4,5 and 6 as selection buttons for three setting groups

The signal outputs from SPCGGIO are used in the following logic to set the PROTECTION function block with the selected setting group. Note once again that the SRGAPC1 block has two registers to hold on to either Group2(ALT1) and Group3(ALT2) selected groups and are given as outputs Q1 and Q2 respectively. Resetting of both the registers will make both Q1 and Q2 low, de-energizing both the inputs of PROTECTION function block enabling the Group1 (PRIMARY) protection group to be set.

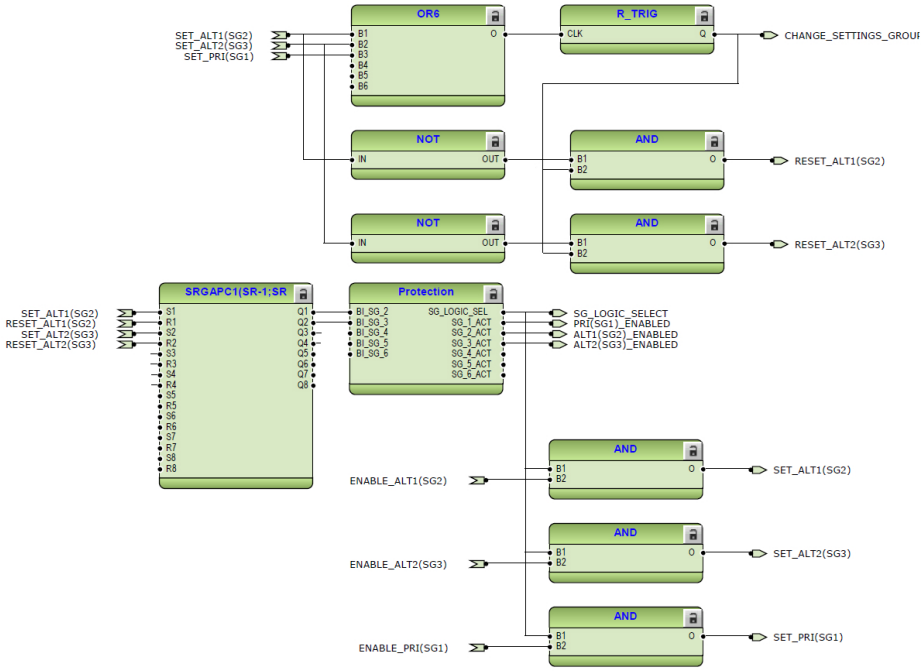


Figure 13: Setting group selection logic for three setting groups with three input pushbuttons (Applicable when embedded pushbutton logic is used)

It is also possible to arrange to change the setting groups in a sequence using one of the shift register function blocks SHFT in REF615R (Figure 14 below). The function SHFT has 8 outputs. It has three inputs; SHFT, HOLD and RESET which are explained in detail in technical manual. In discussions below, we will be using mainly the SHIFT input of the block.

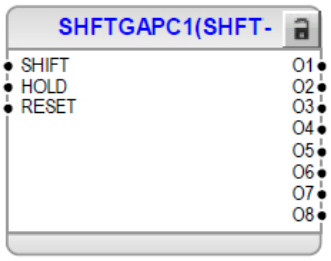


Figure 14: Shift register

The following sketch is a simplified electrical scheme of how the shift register works as implemented in REF615R.

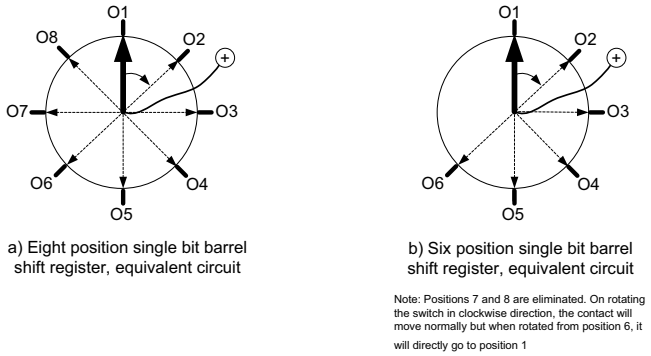


Figure 15: Electrical equivalent of barrel shift register execution with 8 outputs, alternatively 6 outputs

Figure 15a indicates a typical 8 position selector switch with output terminals O1 to O8 and with a facility to connect a positive voltage at the pivot of the switch (shown with a connection + in the sketch). The figure shows the selector switch resting in position O1. A positive voltage injected at the pivot of the switch makes the output O1 go high. On giving a manual impulse to rotate, the switch is arranged to make a single notch progress in clockwise direction. For example, if an impulse is given to the switch in the position shown, the switch moves to position O2, making the output O2 high. Output at O1 resets. Thus on every impulse given to rotate the switch, the output goes starting from O1 to O8 in a sequence and so on back to O1 etc., in an unending cyclic fashion.

It is possible to eliminate any individual position while configuring the function SHFT. Figure 15 b indicates a situation when positions O7 and O8 have been eliminated, making it a six position switch. Note that if the switch is on position O6, an impulse to the switch would move it to position O1 directly.

The six position shifter output signals can be wired to the 'PROTECTION' function block in REF615R to select one of the six setting groups available in the protection relay, as indicated in the sketch below. The function SHFT is programmed such that positions O7 and O8 are disabled. One of the pushbutton on the front panel can be configured as an input to the SHIFT and multiple presses will make the outputs of the Shifter to go high in a sequence O1, O2, O3, O4, O5, O6 and back to O1 in a cyclic fashion. Note the PROTECTION function has five inputs, excitation of any one input sets the corresponding setting group. (Ex. Energizing BI_SG_4 sets Group 4 in the protection relay and sets the output line SG_4_ACT goes high). Note that if none of the inputs are energized, Group 1 is set by default. Hence output O1 of SHFT function is not connected to 'PROTECTION' function block.

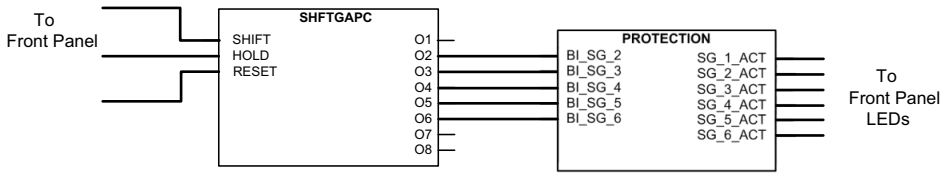


Figure 16: Connection of SHFT function block to PROTECTION function.

The above scheme lends itself to be quickly adopted when migrating from DPU2000R V5.42 or above to REF615R. Note that DPU2000R has three setting groups, viz., Primary, Alternative1 and Alternative2. Thus it is necessary to keep only three ouptut O1 to O3 (Corresponding to Prim, ALT1 and ALT2 of DPU2000R) in the shift register and eliminate positions O4 to O8. Here is a typical setting group change logic implemented in REF615R when embedded pushbutton logic is used:

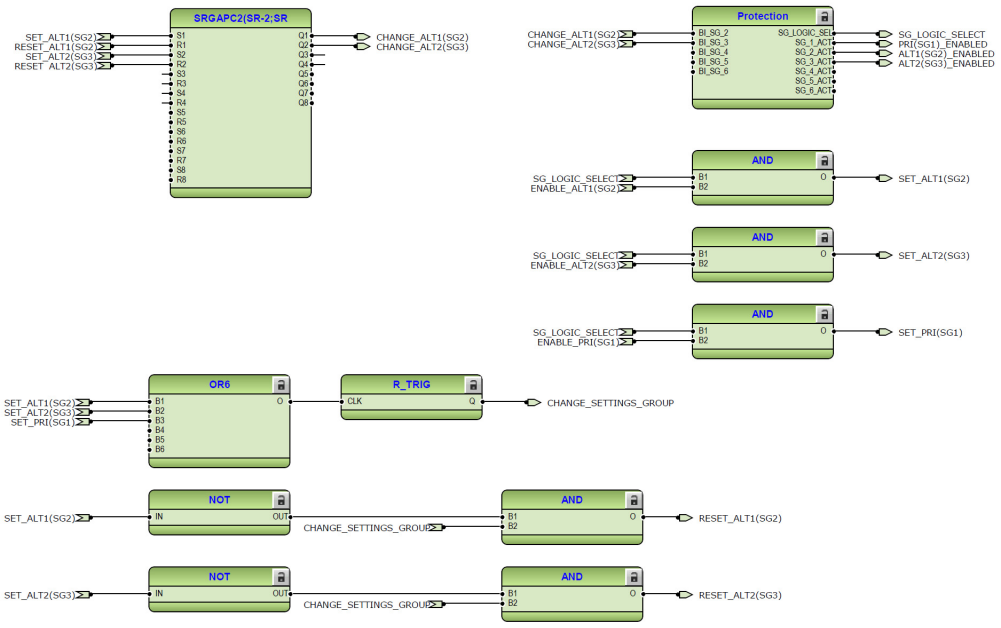


Figure 17: Setting Group Change Logic in REF615R when embedded pushbutton logic is used

3.2.1 Standard configurations

The feeder protection protection relay REF615R is available with one configuration as standard. Standard configuration is available with IG input with selectable 1/5A. If better sensitivity is required, the protection relay can be ordered with Sensitive Earth Fault (SEF) input, which can configured for 0.2 / 1A.configurations.

Table 6: Standard configurations (REF615R)

Description	Functional application configuration
Directional phase and ground over-current, voltage, frequency protection and power system metering for one breaker	A

Table 7: Supported functions (REF615R)

Standard Configuration Functionality	Std config A		ANSI/C37.2 - 2008
Function	AA	AB	REF615R
Protection			
Three-phase non-directional overcurrent protection, low stage, instance 1	●	●	51P-1
Three-phase non-directional overcurrent protection, high stage, instance 1	●	●	50P-1
Three-phase non-directional overcurrent protection, high stage, instance 2	●	●	50P-2
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	●	●	50P-3
Three-phase non-directional long time overcurrent protection, low stage, instance 1	●	●	51LT
Three-phase directional overcurrent protection, low stage, instance 1	●	●	67/51P
Three-phase directional overcurrent protection, high stage, instance 1	●	●	67/50P-1
Three-phase directional overcurrent protection, high stage, instance 2	●	●	67/50P-2
Non-directional ground-fault protection, low stage, instance 1	●	-	51G
Non-directional ground-fault protection, low stage, instance 2	●	●	51N-1
Non-directional ground-fault protection, low stage, instance 4	-	●	50SEF
Non-directional ground-fault protection, high stage, instance 1	●	-	50G-1
Non-directional ground-fault protection, high stage, instance 2	●	-	50G-2
Non-directional ground-fault protection, high stage, instance 3	●	●	50N-1
Non-directional ground-fault protection, high stage, instance 4	●	●	50N-2
Non-directional ground-fault protection, instantaneous stage, instance 1	●	-	50G-3
Non-directional ground-fault protection, instantaneous stage, instance 2	●	●	50N-3
Directional ground-fault protection, low stage, instance 1	●	●	67/51N
Directional ground-fault protection, high stage, instance 1	●	●	67/50N-1
Directional ground-fault protection, high stage, instance 2	●	●	67/50N-2
Three phase directional power protection, instance 1	●	●	32P-1
Ground directional power protection, instance 1	●	●	32N-1
Negative-sequence overcurrent protection, instance 1	●	●	46-1
Negative-sequence overcurrent protection, instance 2	●	●	46-2
Phase discontinuity protection	●	●	46PD
Residual overvoltage protection, instance 1	●	●	59G
Residual overvoltage protection, instance 2	●	●	59N-1
Three-phase undervoltage protection, instance 1	●	●	27-1
Three-phase undervoltage protection, instance 2	●	●	27-2
Three-phase overvoltage protection, instance 1	●	●	59-1

Standard Configuration Functionality	Std config A		ANSI/C37.2 - 2008
Function	AA	AB	REF615R
Three-phase overvoltage protection, instance 2	●	●	59-2
Negative-sequence overvoltage protection, instance 1	●	●	47-1
Negative-sequence overvoltage protection, instance 2	●	●	47-2
Frequency protection, instance 1	●	●	81-1
Frequency protection, instance 2	●	●	81-2
Voltage per hertz protection, instance 1	●	●	24
Three-phase thermal protection for feeders, cables and distribution transformers, Instance 1	●	●	49F-1
Numerical stabilized low impedance restricted ground-fault protection	●	-	87LOZREF
Circuit breaker failure protection, instance 1	●	●	50BF-1
Three-phase inrush detector, instance 1	●	●	INR-1
Master trip, instance 1	●	●	86/94-1
Master trip, instance 2	●	●	86/94-2
Arc protection, instance 1	●	●	AFD-1
Arc protection, instance 2	●	●	AFD-2
Arc protection, instance 3	●	●	AFD-3
High impedance fault detection	-	●	HIZ
Load shedding and restoration, instance 1	●	●	81LSH-1
Load shedding and restoration, instance 2	●	●	81LSH-2
Loss of phase, instance 1	●	●	37-1
Control			
Circuit-breaker control, instance 1	●	●	52-1
Auto-reclosing	●	●	79
Synchronism and energizing check	●	●	25
Condition Monitoring			
Circuit-breaker condition monitoring, instance 1	●	●	52CM-1
Current circuit supervision	●	●	CCM
Fuse failure supervision, instance 1	●	●	60-1
Cable fault detection	●	●	CFD
Measurement			
Three-phase current measurement, instance 1	●	●	IA, IB, IC
Sequence current measurement, instance 1	●	●	I1, I2, I0
Residual current measurement, instance 1	●	●	IG
Three-phase voltage measurement, instance 1	●	●	VA, VB, VC

Standard Configuration Functionality	Std config A		ANSI/C37.2 - 2008
Function	AA	AB	REF615R
Residual voltage measurement, instance 1	•	•	VG
Sequence voltage measurement, instance 1	•	•	V1, V2, V0
Single-phase power and energy measurement, instance 1	•	•	SP, SE-1
Three-phase power and energy measurement, instance 1	•	•	P, E-1
Current total demand distortion, instance 1	•	•	PQI-1
Voltage total harmonic distortion, instance 1	•	•	PQVPH-1
Voltage variation, instance 1	•	•	PQSS-1
Voltage unbalance, instance 1	•	•	PQVUB-1
Load profile	•	•	LoadProf
Frequency measurement, instance 1	•	•	f
Other functions			
Minimum pulse timer (2 pcs), instance 1	•	•	TP (1)
Minimum pulse timer (2 pcs), instance 2	•	•	TP (2)
Minimum pulse timer (2 pcs), instance 3	•	•	TP (3)
Minimum pulse timer (2 pcs), instance 4	•	•	TP (4)
Minimum pulse timer (2 pcs, second resolution), instance 1	•	•	62CLD-1
Minimum pulse timer (2 pcs, minute resolution), instance 1	•	•	62CLD-2
Pulse timer (8 pcs), instance 1	•	•	PT-1
Pulse timer (8 pcs), instance 2	•	•	PT-2
Time delay off (8 pcs), instance 1	•	•	TOF-1
Time delay off (8 pcs), instance 2	•	•	TOF-2
Time delay on (8 pcs), instance 1	•	•	TON-1
Time delay on (8 pcs), instance 2	•	•	TON-2
Set reset (8 pcs), instance 1	•	•	SR-1
Set reset (8 pcs), instance 2	•	•	SR-2
Set reset (8 pcs), instance 3	•	•	SR-3
Set reset (8 pcs), instance 4	•	•	SR-4
Move (8 pcs), instance 1	•	•	MV-1
Move (8 pcs), instance 2	•	•	MV-2
Move (8 pcs), instance 3	•	•	MV-3
Move (8 pcs), instance 4	•	•	MV-4
Move (8 pcs), instance 5	•	•	MV-5
Move (8 pcs), instance 6	•	•	MV-6

Standard Configuration Functionality	Std config A		ANSI/C37.2 - 2008
Function	AA	AB	REF615R
Move (8 pcs), instance 7	●	●	MV-7
Move (8 pcs), instance 8	●	●	MV-8
Generic control points, instance 1	●	●	CNTRL-1
Generic control points, instance 2	●	●	CNTRL-2
Generic control points, instance 3	●	●	CNTRL-3
Remote Generic control points, instance 1	●	●	RCNTRL-1
Local Generic control points, instance 1	●	●	LCNTRL-1
Generic Up-Down Counters, instance 1	●	●	CTR-1
Generic Up-Down Counters, instance 2	●	●	CTR-2
Generic Up-Down Counters, instance 3	○	○	CTR-3
Programmable buttons(16 buttons), instance 1	●	●	FKEY1
Shift register, instance 1	●	●	SHFT-1
Shift register, instance 2	●	●	SHFT-2
Shift register, instance 3	●	●	SHFT-3
Logging functions			
Disturbance recorder	●	●	DFR
Fault recorder	●	●	FR
Sequence event recorder	●	●	SER
Fault location	●	●	FLO

○-Optional

Each of the configurations can be re-configured to suit individual applications. Typically optional IO and some of the functions may not be configured at delivery. Only key functions such as tripping, breaker status inputs etc. are connected through the signal matrix tool.

Typical connection diagram for the default configuration as delivered from the factory is available for each alternative configuration. The diagrams show how to connect the primary apparatus to the protection relay assuming control functionality is also included in the protection relay. The configurations are prepared to cover for the most common applications but not all possibilities.

The number of protection elements including directional and non-directional Phase and Ground OC protections, thermal overload, undervoltage / overvoltage functions, frequency functions etc., coupled with Auto-reclose and check synch functionalities allow the user to fulfill any application requirement in protection and control of MV feeders. The protection relay is also provided with full control and interlocking functionality including co-operation with the synchrocheck function to allow integration of the main or back-up control.

The advanced logic capability, where the user logic is prepared with a graphical tool, allows special applications including automatic opening, sequencing etc. The graphical configuration tool ensures simple and fast testing and commissioning.

Various modes of communication including optical connections ensure integration of the protection relay with the rest of the power system protection, control and automation.

The wide application flexibility makes this product an excellent choice for both new installations and the refurbishment of existing installations.

It is strongly suggested that reference to Engineering Manual be made at this stage for details on PCM600 and organizing a project with various protection relays, uploading settings to protection relay etc. It is recommended to familiarize oneself with the grouping of various functions under PCM600, protection relay to configure, change settings connected with various functions. A typical screen shot is given below for ready reference. The next few paragraphs highlight a few steps to verify some of the important things in connection with analog inputs. The next sections give some of the settings suggestions and configuration possibilities which the users may navigate and set them as suggested by themselves.

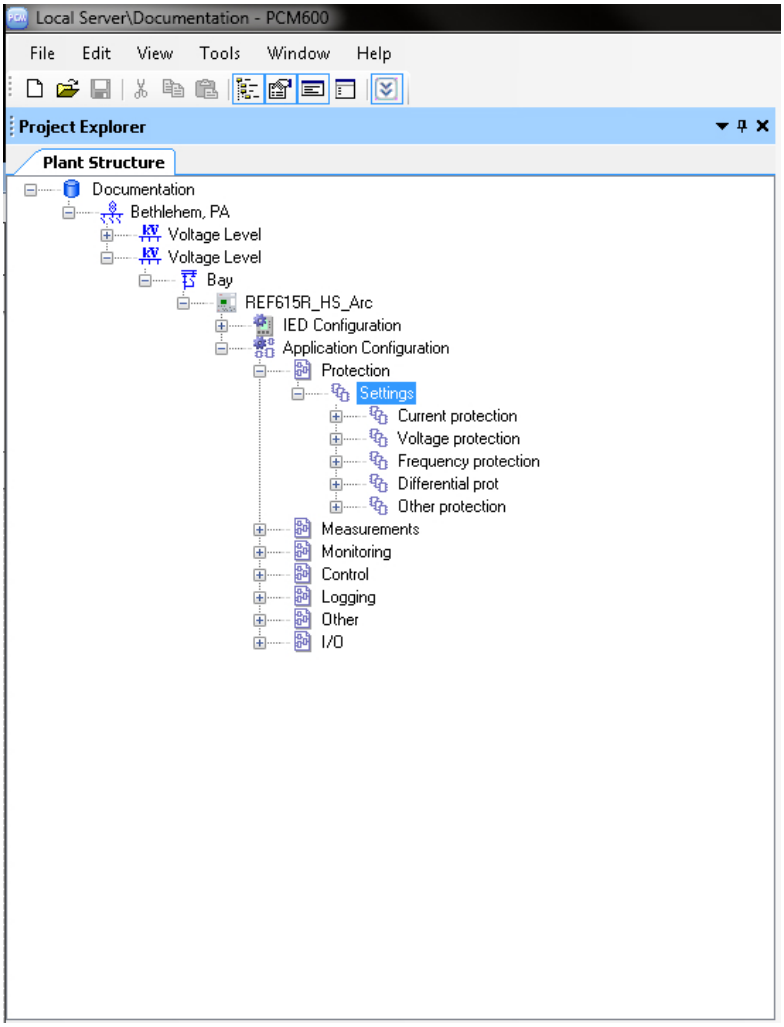


Figure 18: Example View of selecting settings under the plant structure of a protection relay in PCM600.

3.2.2 Verifying the order code and some of the most important configurations of protection relay in project tree:

Once the PCM600 project with the correct protection relay ordering code is up and running the protection relay details may be verified by right clicking on the protection relay name and selecting 'properties'.

Details of the ordering code, technical key etc. are displayed as follows:

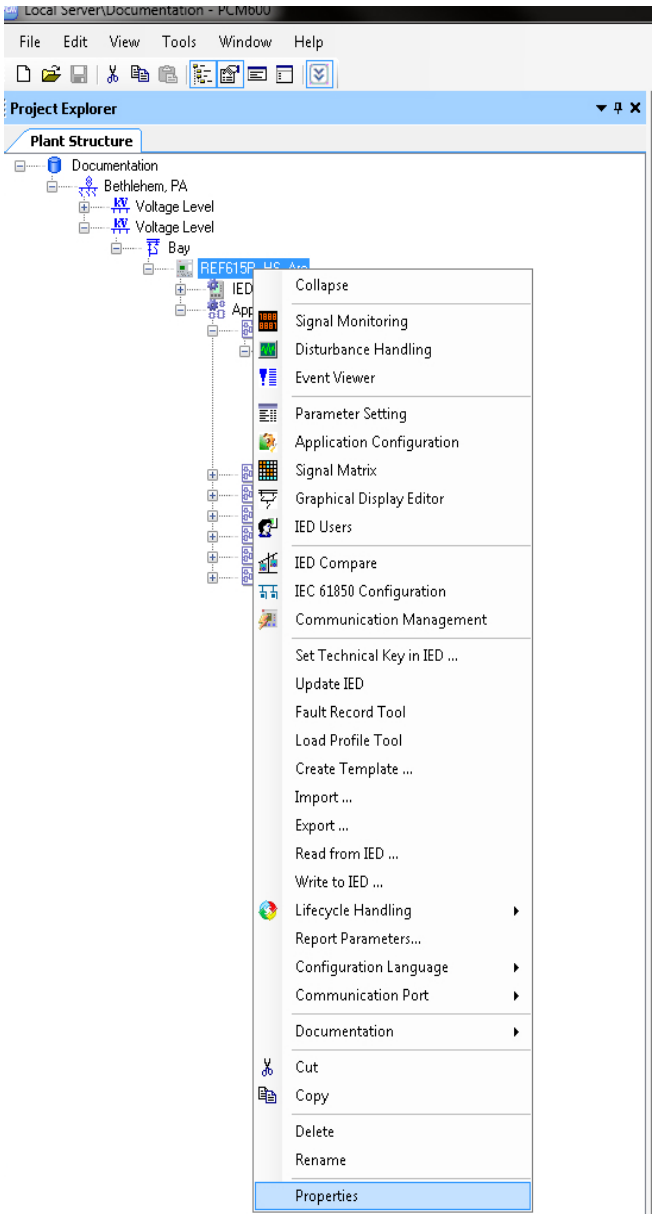


Figure 19: *PCM600 display with protection relay selected with a right click to display the menu and 'Properties' line of the menu just to be selected*

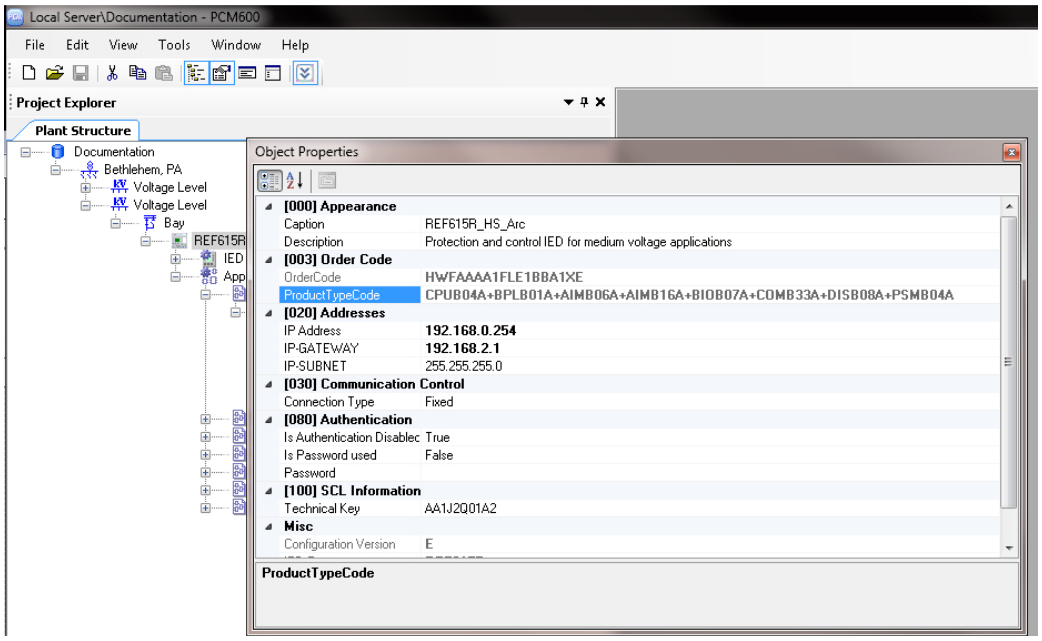


Figure 20: Display of product code when 'properties' of a protection relay is selected

It is also important that common system configurations such as frequency, phase sequence and group settings are also set properly and verified as shown in Figure 21 and Figure 22.

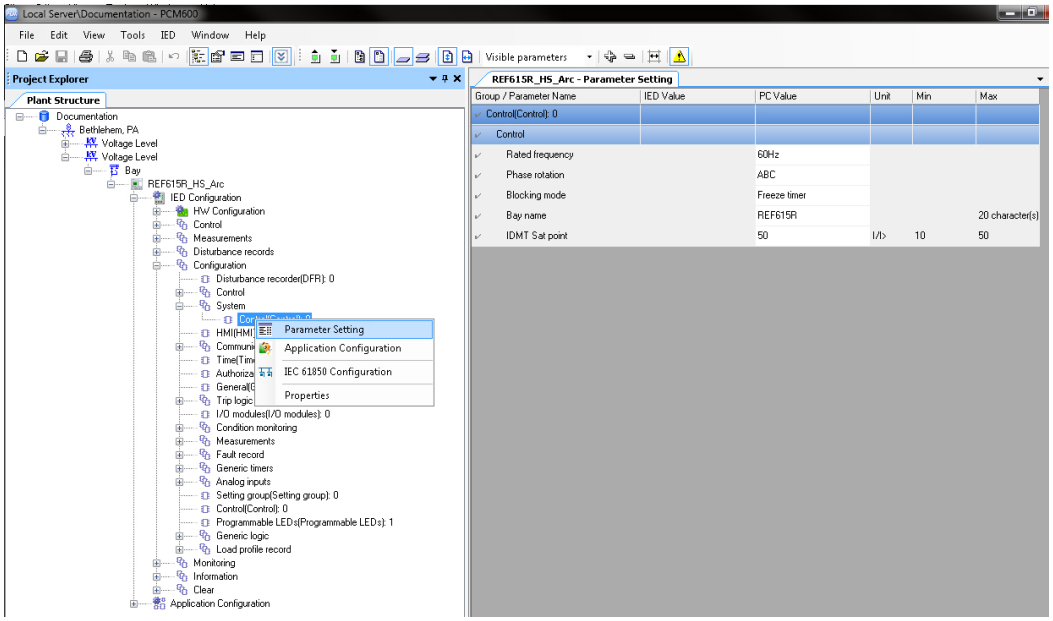


Figure 21: Display of common system configuration settings

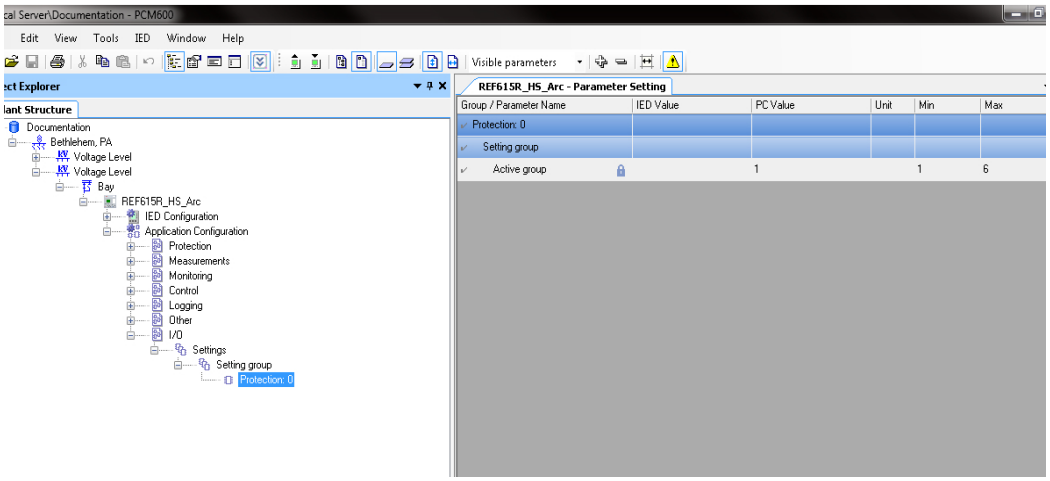


Figure 22: Display or setting of Setting Group

3.2.3 Analog inputs configuration

In order to get correct measurement results as well as correct protection operations, the analog input channels must be configured and / or wired, especially with respect to the polarity. The polarity shown in the suggested connection diagrams have to be strictly followed.

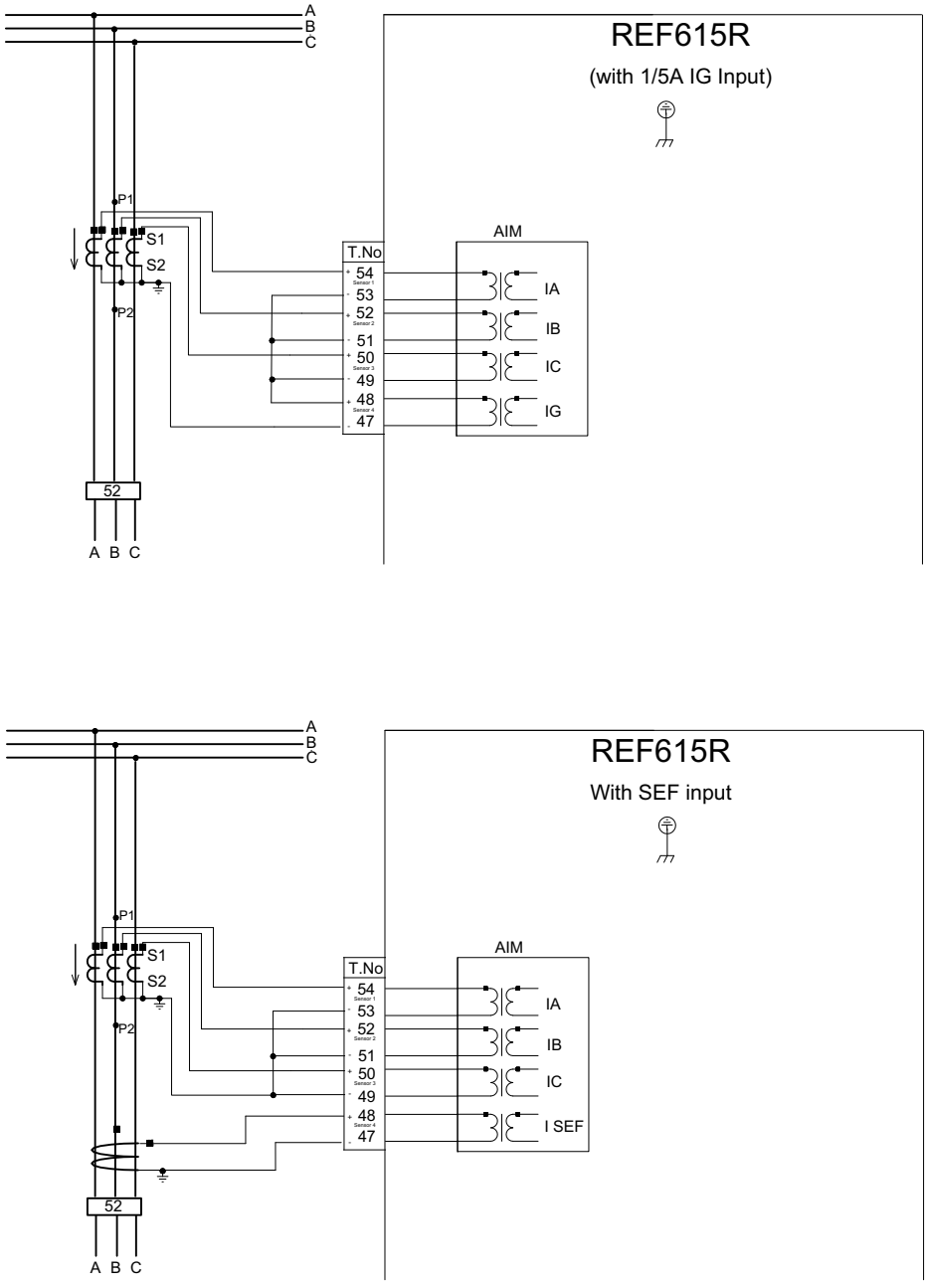


Figure 23: *REF615R Typical CT connection diagrams, marked with polarity*

Take for example, a fault in Phase A in a feeder, indicated in the picture above. The polarity of CT is arranged in Figure 23 in such a way that for a fault in the feeder in phase A, indicated by an arrow in the picture, a proportional current would flow into terminal 54 of the protection relay with the same phase angle. If the actual CT polarity is found reversed, it is best to correct it at the installation. Polarity of CT inputs is very important not only for directional protection but also for metering, differential and restricted earth fault protections.

In case it is not possible to change the connections in field installation, it is possible to reverse the connections say at terminals 54 and 53 at the relay end provided documentation is corrected for the whole installation. Alternatively it is possible to correct polarity error inside the relay using PCM600. Select the protection relay→protection relay Configuration→Configuration→ Analog inputs---> Current (3I,CT) as appropriate.

Then select the setting "Reverse Polarity" to "TRUE" as shown in Figure 24 below.

Changing polarity in the configuration of the protection relay would change all three phases together.

In the same window, one can input the rated primary current rating of the CT. The secondary rated current is 5A by default but can be changed to 1A if required.

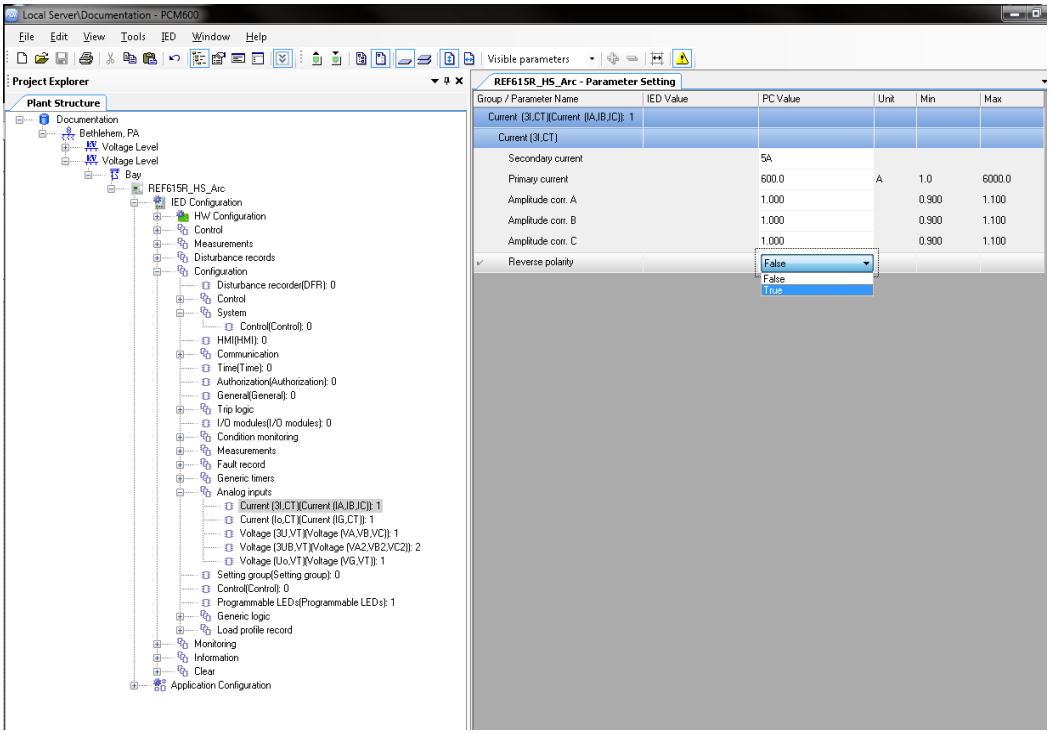


Figure 24: *Modifying Reverse Polarity setting of CT input to protection relay*

It may be noted that input current for ground fault protection, can be ordered with 5A/1A OR 1A/0.2A.

When ordered with 5A/1A option, IG input may be fed from either residual connection of the phase CTs or from Core Balance CT (CBCT / Window type CT). When CBCT or when incoming transformer WYE grounding CT is connected to this input, provision is made to set the primary and secondary input ratings independent of the phase CTs.

Whenever a sensitive ground fault protection is required or when the protected feeder is provided with a core-balance CT, (which is highly recommended with non-effectively grounded systems,) the protection relay can be ordered with more sensitive IG input rated

for 1A/0.2A. Instead of the functions 51G, 50G-1, 50G-2 and 50G-3, the protection relay is equipped with High Impedance Fault detection system HIZ and highly sensitive ground fault protection 50-SEF. While retrofitting DPU2000R units with SEF protection, note that there were separate inputs available in those units, Viz., IG input (sensor 4, terminals 48 &47) as well as SEF input (sensor5, terminals 46&45). However, REF615R has a single input to cater to both, available at the sensor 4 input terminals 48&47. The terminals 46 and 45 of REF615R are internally shorted as an abundant precaution to avoid CT open circuit should someone replace DPU2000R with REF615R.

The suggested scheme drawing without wiring modification to retrofit RER615R with SEF input to replace DPU2000R with SEF input is explained in Figure 25.

The internal ground directional function in protections such as 67/50N, 67/51N, 32N etc. , when selected with zero sequence operating current, look for the angle difference between Vo (alternatively V2) and -Io to arrive at the source impedance angle which is highly reactive for grounded systems. There are typically two options to select the Io input for the above. One is "Calculated Io" and the other "Measured Io". The Calculated Io is derived out of the phase currents and phase reversed before fed into above function internally.

Hence, with the connections and polarity indicated in this manual and with default polarity settings (setting "Reverse Polarity" set as "False"), the functions 67/51N, 67/50N, 32N would correctly operate for fault direction shown in diagrams with a "Characteristic angle" setting say -75 degrees for grounded system if "Io signal Sel" of the function is selected as "Calculated Io".

However, when the setting "Measured IG" is given as operating current, the polarity reversal of Io has to be accounted for by an external factor. In such a case, one needs to either set the Characteristic angle shifted by 180 degrees or set "Reverse Polarity" setting as "True".

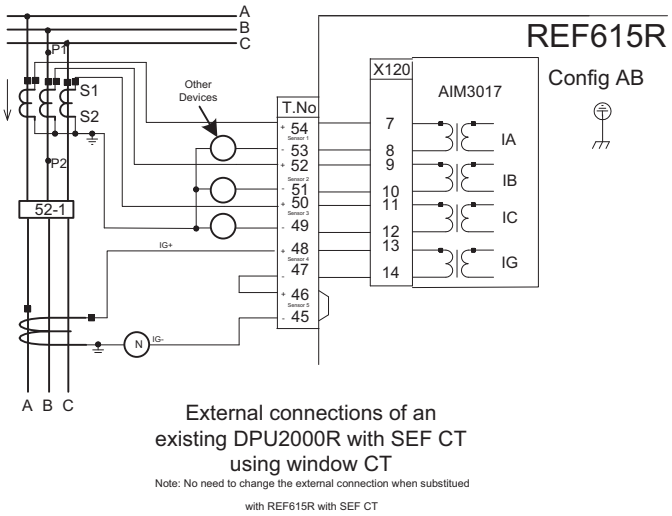


Figure 25: *Upgrading DPU2000R with (SEF input) with REF615R (with SEF input)*

Suggested connection diagrams when replacing DPU2000R with IG input with REF615R with 1/5A IG input is indicated in Figure 26.

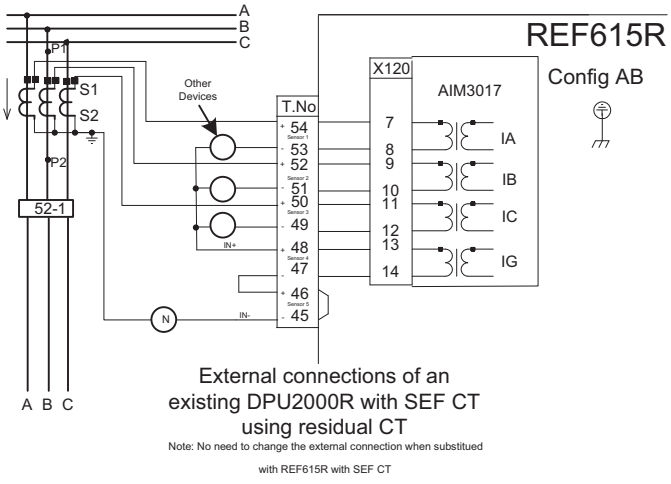


Figure 26: *Upgrading DPU2000R (with only IG input) with REF615R (with 1/5A IG input)*

When applied on LV side of a power transformer, the IG input can be connected to CT on the transformer neutral to provide standby ground fault protection or as input for Low Impedance Restricted Earth Fault protection.

The VT inputs are always wired as Wye in the internal analog input board. Three phase connection inputs as well as a neutral connection inputs are available in the unit which may be connected to a WYE connected VT.

If only two phase-phase connected VTs are available in the system (V Connection) the three phase connections may be brought to the protection relay. The neutral wire input connection may be ignored.

In the latter connection, the protection relay cannot calculate the system zero sequence voltage.

An additional VT input is available in case an external broken delta VT input is available for connection to the relay.

In any of the cases above, there is no need for changing any internal configuration of the protection relay. The VT connection configuration is always Wye/Delta as shown in Figure 27

The synchronizing voltage input may be connected Ph-Ph or Ph-Gnd. Select configuration of 3UB input as U12 (For A Ph- B Ph) and U1 for (A Ph-Gnd) as appropriate. This selection corresponds to external V connected or WYE connected main VT inputs as mentioned above.

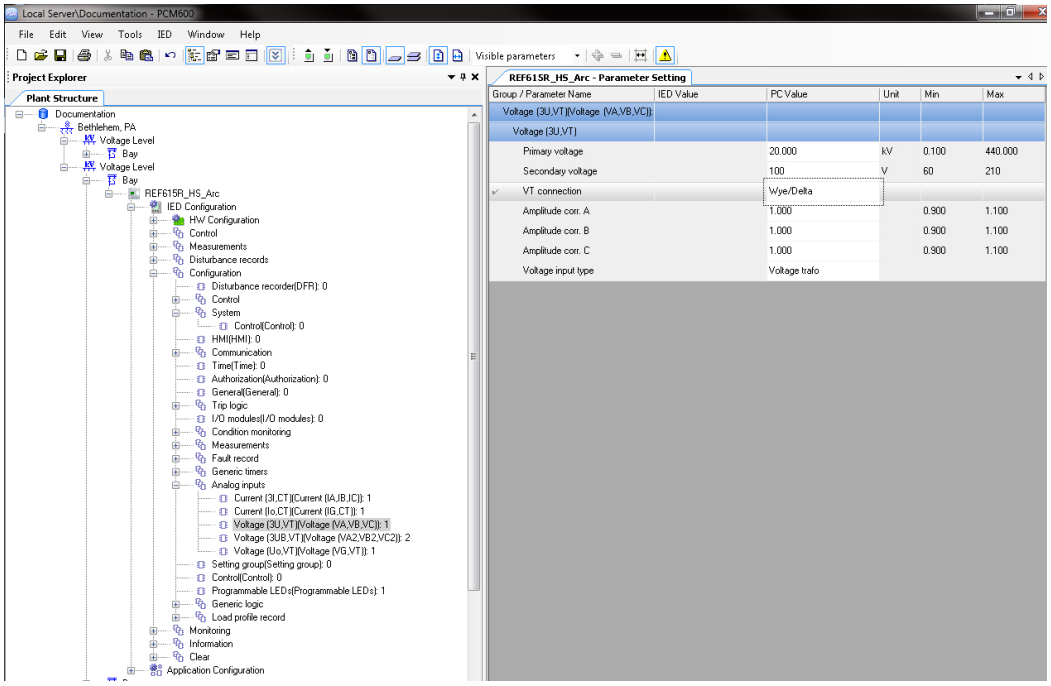
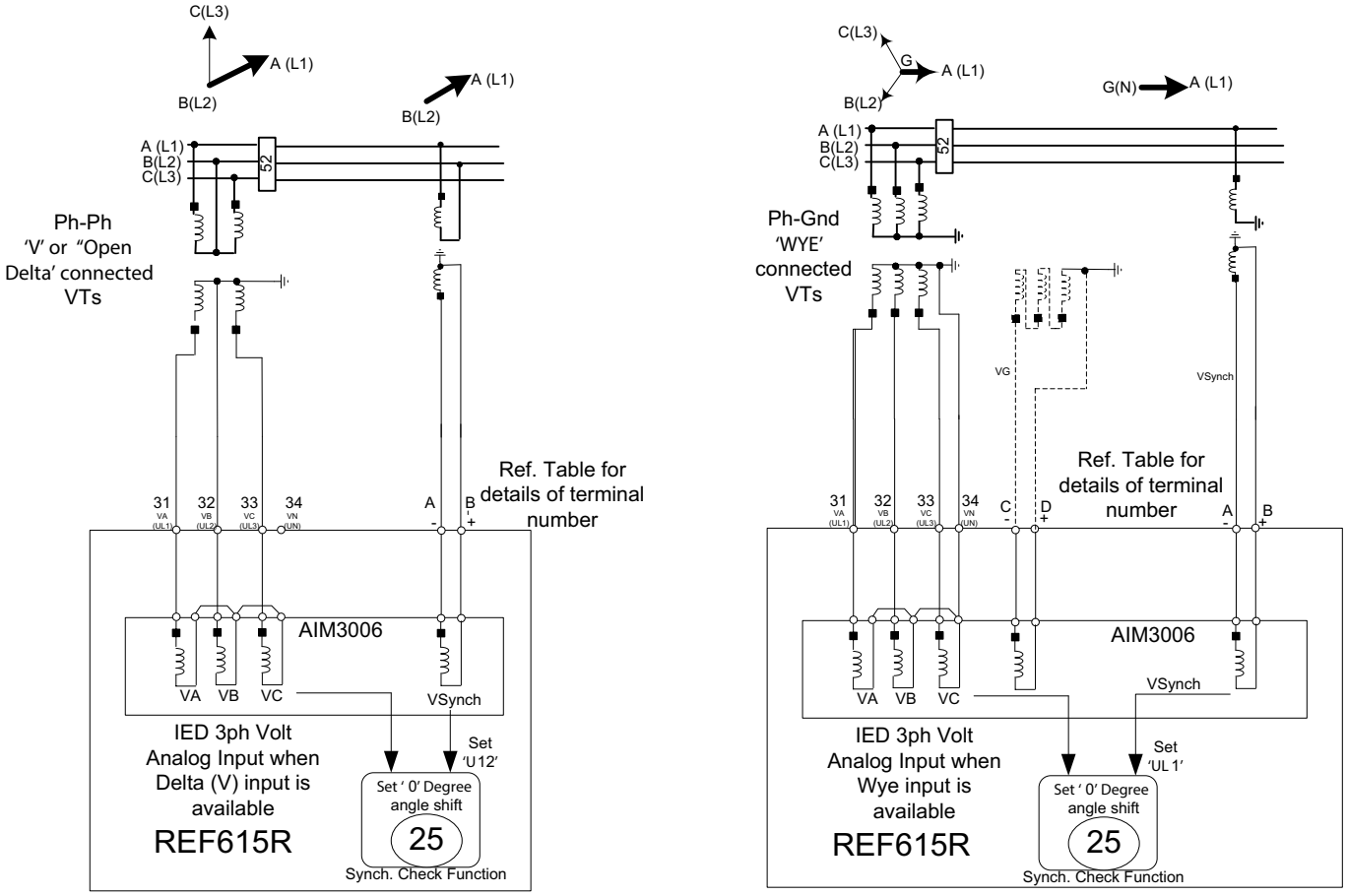


Figure 27: *Parameter setting verification of analog voltage input*

Different possibilities of connections of VTs are possible as detailed in Figure 28 below.



	Models with standard IG			Models with SEF		
Function	Code in Sketch	Terminal No. in REF615R	Sensor	Code in sketch	Terminal No. in REF615R	Sensor
Check Synch. Voltage input	A	36	Sensor 10	A	38	Sensor 9
	B	35		B	37	
Broken Delta voltage input	C	38	Sensor 9	C	36	Sensor 10
	D	37		D	35	

Figure 28: VT Inputs to REF615R

If the VT on the bus side is V(Delta), phase-phase connections are configured for the three phase VT inputs. It is expected that the feeder side of the breaker shall be similarly one ph-ph (Phases A and B) connected VT for synchronizing purposes.

Similarly when WYE connected VT is available (3no Ph-Gnd Connected VT) on the bus side, it is required to have Ph-Gnd connected VT on the feeder side in Ph A.

From synchronizing perspective, depending on application, three phase VTs on the feeder side with a single phase VT on the bus for synchronizing could be configured. Care shall be exercised while setting Dead Bus/ Dead Line setting with a clear understanding of which side is bus and line.

Depending on voltage selected for synchronizing voltage input, the phase shift setting under check synch function shall also be properly set, especially when voltage on one side of a transformer with a vector shift is used for synchronizing with a voltage on the other side of the transformer.

3.2.4 Application choice:

3.2.4.1 Configuration A:

This configuration is eminently suitable for most of the applications in MV systems involving single breaker control, protection and autoreclose fed off a single bus bar system.

From power system application perspective all REF615R models have Synchro check, directional or non-directional earth fault protection, fault recording, user programmable and special reclose curves as standard. Hence these requirements no longer influence the ordering particulars.

A few things one needs to check while ordering the REF615R to either replace an existing DPU2000R or from application perspective are:

1. System frequency:
   REF615R can be set for either 50 or 60Hz and hence need not be a concern while ordering the protection relay
2. Ground fault input:
   IG current input (5 or1A) or sensitive SEF input (1A or 0.2A). The former covers the setting range of 0.4-12A and the later 0.08-2.4A ranges available in DPU2000R.

   The latter may need to be ordered if the new unit is to replace the earlier units with Directional Sensitive Earth fault protection. Note that when the SEF input is ordered, High Impedance Fault detection function HIZ is also included in the REF615R.
3. Standard OCI or Enhanced OCI:
   In the new unit the front appearance of the ordered unit remains the same except that the additional pushbuttons with lamps on the left side of the unit are configured only when ordered with Enhanced OCI
4. ANSI or IEC type:
   This has to be decided before ordering the protection relay, please refer to the detailed ordering code in Product guide.
5. Auxiliary supply voltage:
   Note in REF615R one ordering code option covers 80-260 volts and another covers 24 to 60V.

The first would mostly cover the earlier range of products covered by models with input aux. supply source of 70-280V and the second would cover models with supply sources of either 38-58V or 19-29V.

The protection relay offers various communication options. For details please refer to the technical manual and product guide.

REF615R is not intended to replace vertical mounting models of earlier range of relays.

Configuration A with ground CT input is specially suitable for switchgear incoming breaker. The IG current input of the protection relay is set to measure the incoming WYE transformer neutral current. The low impedance restricted earth fault protection can be enabled to detect uncleared ground faults. The 51G function, operated off the IG input can be set to operate for all uncleared downstream fault as well as internal transformer ground faults on the MV system.

In the outgoing feeders with single breaker control, Configuration A with SEF/HIZ protection is eminently suitable for detecting very low ground faults as well detect high impedance ground faults in the feeders. A Core Balance CT (Window Type CT) is highly recommended for connection to this input, especially in non-effectively grounded system.

3.3 Standard configuration for order code functional application A

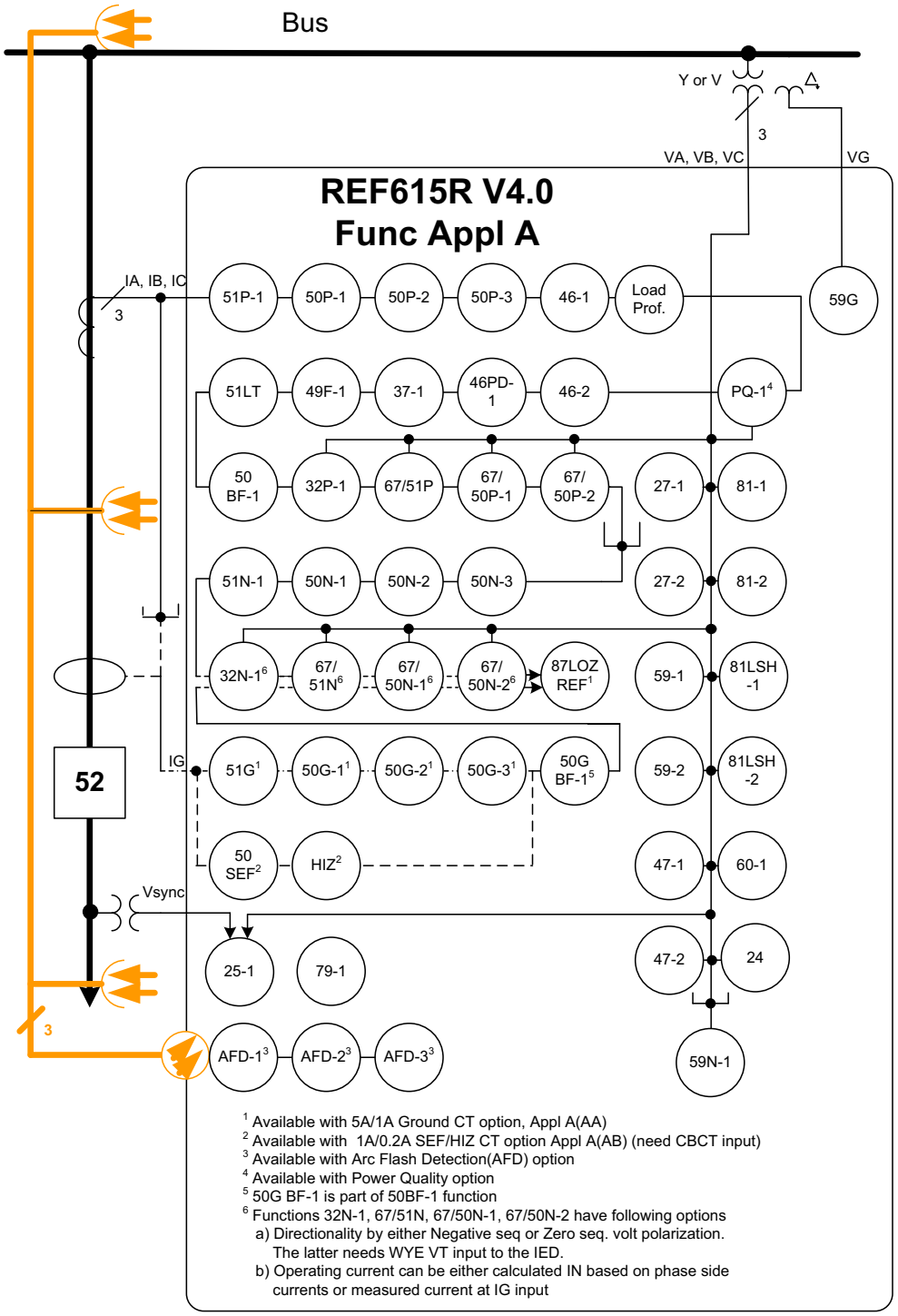


Figure 29: Functions included in REF615R, standard functional application A

3.3.1 Applications

This standard configuration is mainly intended for distribution feeders and a single breaker with power and energy metering provided as standard. This configuration includes non-directional and directional phase and ground overcurrent, phase distance, voltage and frequency protection. When ordered with the option of sensitive ground CT input, the protection relay is configured with High Impedance fault detection and sensitive earth fault protections.

The protection relay with this standard configuration is delivered from the factory with default settings and parameters. The end-user flexibility for incoming, outgoing and internal signal designation within the protection relay enable this configuration to be further adapted to different primary power system layouts and the related functionality needs by modifying the internal functionality using PCM600.

3.3.2 Functions

Table 8: Functions included in the REF615R standard configuration

Application configuration			A		
Function	**IEC 61850**	**ANSI C37.2-2008**	**IEC 60617**	**AA**	**AB**
Protection					
Three-phase non-directional overcurrent protection, low stage, instance 1	PHLPTOC1	51P	3I> (1)	●	●
Three-phase non-directional overcurrent protection, high stage, instance 1	PHHPTOC1	50P-1	3I>> (1)	●	●
Three-phase non-directional overcurrent protection, high stage, instance 2	PHHPTOC2	50P-2	3I>> (2)	●	●
Three-phase non-directional overcurrent protection, instantaneous stage, instance 1	PHIPTOC1	50P-3	3I>>> (1)	●	●
Three-phase non-directional long time overcurrent protection, low stage, instance 1	PHLTPTOC1	51LT	3I> (3)	●	●
Three-phase directional overcurrent protection, low stage, instance 1	DPHLPDOC1	67/51P	3I> -> (1)	●	●
Three-phase directional overcurrent protection, high stage, instance 1	DPHHPDOC1	67/50P-1	3I>> -> (1)	●	●
Three-phase directional overcurrent protection, high stage, instance 2	DPHHPDOC2	67/50P-2	3I>> -> (2)	●	●
Non-directional ground-fault protection, low stage, instance 1	EFLPTOC1	51G	Io> (1)	●	-
Non-directional ground-fault protection, low stage, instance 2	EFLPTOC2	51N-1	Io> (2)	●	●
Non-directional ground-fault protection, low stage, instance 4	EFLPTOC4	50SEF	Io> (4)	-	●
Non-directional ground-fault protection, high stage, instance 1	EFHPTOC1	50G-1	Io>> (1)	●	-
Non-directional ground-fault protection, high stage, instance 2	EFHPTOC2	50G-2	Io>> (2)	●	-
Non-directional ground-fault protection, high stage, instance 3	EFHPTOC3	50N-1	Io>> (3)	●	●
Non-directional ground-fault protection, high stage, instance 4	EFHPTOC4	50N-2	Io>> (4)	●	●
Non-directional ground-fault protection, instantaneous stage, instance 1	EFIPTOC1	50G-3	Io>>> (1)	●	-
Non-directional ground-fault protection, instantaneous stage, instance 2	EFIPTOC2	50N-3	Io>>> (2)	●	●
Directional ground-fault protection, low stage, instance 1	DEFLPDEF1	67/51N	Io> -> (1)	●	●
Directional ground-fault protection, high stage, instance 1	DEFHPDEF1	67/50N-1	Io>> -> (1)	●	●
Directional ground-fault protection, high stage, instance 2	DEFHPDEF2	67/50N-2	Io>> -> (2)	●	●
Three phase directional power protection, instance 1	DPSRDIR1	32P-1	I1-> (1)	●	●
Ground directional power protection, instance 1	DNZSRDIR1	32N-1	I2 ->, Io-> (1)	●	●

Application configuration			A		
Function	**IEC 61850**	**ANSI C37.2-2008**	**IEC 60617**	**AA**	**AB**
Negative-sequence overcurrent protection, instance 1	NSPTOC1	46-1	I2> (1)	●	●
Negative-sequence overcurrent protection, instance 2	NSPTOC2	46-2	I2> (2)	●	●
Phase discontinuity protection	PDNSPTOC1	46PD	I2/I1>	●	●
Residual overvoltage protection, instance 1	ROVPTOV1	59G	Uo> (1)	●	●
Residual overvoltage protection, instance 2	ROVPTOV2	59N-1	Uo> (2)	●	●
Three-phase undervoltage protection, instance 1	PHPTUV1	27-1	3U< (1)	●	●
Three-phase undervoltage protection, instance 2	PHPTUV2	27-2	3U< (2)	●	●
Three-phase overvoltage protection, instance 1	PHPTOV1	59-1(1)	3U> (1)	●	●
Three-phase overvoltage protection, instance 2	PHPTOV2	59-2(1)	3U> (2)	●	●
Negative-sequence overvoltage protection, instance 1	NSPTOV1	47-1	U2> (1)	●	●
Negative-sequence overvoltage protection, instance 2	NSPTOV2	47-2	U2> (2)	●	●
Frequency protection, instance 1	FRPFRQ1	81-1	f>/f<,df/dt (1)	●	●
Frequency protection, instance 2	FRPFRQ2	81-2	f>/f<,df/dt (2)	●	●
Voltage per hertz protection, instance 1	OEPVPH1	24	U/f> (1)	●	●
Three-phase thermal protection for feeders, cables and distribution transformers, Instance 1	T1PTTR1	49F-1	3Ith>F	●	●
Numerical stabilized low impedance restricted ground-fault protection	LREFPNDF1	87LOZREF	dIoLo>	●	-
Circuit breaker failure protection, instance 1	CCBRBRF1	50BF-1	3I>/Io>BF (1)	●	●
Three-phase inrush detector, instance 1	INRPHAR1	INR-1	3I2f> (1)	●	●
Master trip, instance 1	TRPPTRC1	86/94-1	Master Trip (1)	●	●
Master trip, instance 2	TRPPTRC2	86/94-2	Master Trip (2)	●	●
Arc protection, instance 1	ARCSARC1	AFD-1	ARC (1)	●	●
Arc protection, instance 2	ARCSARC2	AFD-2	ARC (2)	●	●
Arc protection, instance 3	ARCSARC3	AFD-3	ARC (3)	●	●
High impedance fault detection	PHIZ1	HIZ	PHIZ1	-	●
Load shedding and restoration, instance 1	LSHDPFRQ1	81LSH-1	UFLS/R (1)	●	●
Load shedding and restoration, instance 2	LSHDPFRQ2	81LSH-2	UFLS/R (2)	●	●
Loss of phase, instance 1	PHPTUC1	37-1	3I< (1)	●	●
Control					
Circuit-breaker control, instance 1	CBXCBR1	52-1	I <-> O CB (1)	●	●
Auto-reclosing	DARREC1	79	O -> I	●	●

Application configuration			A		
Function	**IEC 61850**	**ANSI C37.2-2008**	**IEC 60617**	**AA**	**AB**
Synchronism and energizing check	SECRSYN1	25	SYNC	●	●
Condition Monitoring					
Circuit-breaker condition monitoring, instance 1	SSCBR1	52CM-1	CBCM (1)	●	●
Current circuit supervision	CCRDIF1	CCM	MCS 3I	●	●
Fuse failure supervision, instance 1	SEQRFUF1	60-1	FUSEF (1)	●	●
Cable fault detection	RCFD1	CFD	CFD	●	●
Measurement					
Three-phase current measurement, instance 1	CMMXU1	IA, IB, IC	3I	●	●
Sequence current measurement, instance 1	CSMSQI1	I1, I2, I0	I1, I2, I0	●	●
Residual current measurement, instance 1	RESCMMXU1	IG	Io	●	●
Three-phase voltage measurement, instance 1	VMMXU1	VA, VB, VC	3U	●	●
Residual voltage measurement, instance 1	RESVMMXU1	VG	Uo	●	●
Sequence voltage measurement, instance 1	VSMSQI1	V1, V2, V0	U1, U2, U0	●	●
Single-phase power and energy measurement, instance 1	SPEMMXU1	SP, SE-1	SP, SE	●	●
Three-phase power and energy measurement, instance 1	PEMMXU1	P, E-1	P, E	●	●
Current total demand distortion, instance 1	CMHAI1	PQI-1	PQM3I	●	●
Voltage total harmonic distortion, instance 1	VMHAI1	PQVPH-1	PQM3U(1)	●	●
Voltage variation, instance 1	PHQVVR1	PQSS-1	PQ 3U<>(1)	●	●
Voltage unbalance, instance 1	VSQVUB1	PQVUB-1	PQMUBU(1)	●	●
Load profile	LDPMSTA1	LoadProf	LoadProf	●	●
Frequency measurement, instance 1	FMMXU1	f	f	●	●
Other Functions					
Minimum pulse timer (2 pcs), instance 1	TPGAPC1	TP (1)	TP (1)	●	●
Minimum pulse timer (2 pcs), instance 2	TPGAPC2	TP (2)	TP (2)	●	●
Minimum pulse timer (2 pcs), instance 3	TPGAPC3	TP (3)	TP (3)	●	●
Minimum pulse timer (2 pcs), instance 4	TPGAPC4	TP (4)	TP (4)	●	●
Minimum pulse timer (2 pcs, second resolution), instance 1	TPSGAPC1	62CLD-1	TPS (1)	●	●
Minimum pulse timer (2 pcs, minute resolution), instance 1	TPMGAPC1	62CLD-2	TPM (1)	●	●
Pulse timer (8 pcs), instance 1	PTGAPC1	PT-1	PT (1)	●	●
Pulse timer (8 pcs), instance 2	PTGAPC2	PT-2	PT (2)	●	●
Time delay off (8 pcs), instance 1	TOFGAPC1	TOF-1	TOF (1)	●	●
Time delay off (8 pcs), instance 2	TOFGAPC2	TOF-2	TOF (2)	●	●
Time delay on (8 pcs), instance 1	TONGAPC1	TON-1	TON (1)	●	●
Time delay on (8 pcs), instance 2	TONGAPC2	TON-2	TON (2)	●	●
Set reset (8 pcs), instance 1	SRGAPC1	SR-1	SR (1)	●	●

Application configuration			A		
Function	**IEC 61850**	**ANSI C37.2-2008**	**IEC 60617**	**AA**	**AB**
Set reset (8 pcs), instance 2	SRGAPC2	SR-2	SR (2)	●	●
Set reset (8 pcs), instance 3	SRGAPC3	SR-3	SR (3)	●	●
Set reset (8 pcs), instance 4	SRGAPC4	SR-4	SR (4)	●	●
Move (8 pcs), instance 1	MVGAPC1	MV-1	MV (1)	●	●
Move (8 pcs), instance 2	MVGAPC2	MV-2	MV (2)	●	●
Move (8 pcs), instance 3	MVGAPC3	MV-3	MV (3)	●	●
Move (8 pcs), instance 4	MVGAPC4	MV-4	MV (4)	●	●
Move (8 pcs), instance 5	MVGAPC5	MV-5	MV (5)	●	●
Move (8 pcs), instance 6	MVGAPC6	MV-6	MV (6)	●	●
Move (8 pcs), instance 7	MVGAPC7	MV-7	MV (7)	●	●
Move (8 pcs), instance 8	MVGAPC8	MV-8	MV (8)	●	●
Generic control points, instance 1	SPCGGIO1	CNTRL-1	SPC(1)	●	●
Generic control points, instance 2	SPCGGIO2	CNTRL-2	SPC(2)	●	●
Generic control points, instance 3	SPCGGIO3	CNTRL-3	SPC(3)	●	●
Remote Generic control points, instance 1	SPCRGGIO1	RCNTRL-1	SPCR(1)	●	●
Local Generic control points, instance 1	SPCLGGIO1	LCNTRL-1	SPCL(1)	●	●
Generic Up-Down Counters, instance 1	UDFCNT1	CTR-1	CTR(1)	●	●
Generic Up-Down Counters, instance 2	UDFCNT2	CTR-2	CTR(2)	●	●
Generic Up-Down Counters, instance 3	UDFCNT3	CTR-3	CTR(3)	○	○
Programmable buttons (16 buttons), instance 1	FKEYGGIO1	FKEY	FKEY	●	●
Shift register, instance 1	SHFTGAPC1	SHFT-1	SHFT(1)	●	●
Shift register, instance 2	SHFTGAPC2	SHFT-2	SHFT(2)	●	●
Shift register, instance 3	SHFTGAPC3	SHFT-3	SHFT(3)	●	●
Logging Functions					
Disturbance recorder	RDRE1	DFR	DFR	●	●
Fault recorder	FLMSTA1	FR	FR	●	●
Sequence event recorder	SER	SER	SER	●	●
Fault location	DRFLO1	FLO	FLO	●	●

○- Optional

3.3.3 Default input/output (I/O) assignments

Table 9: Default connections for analog inputs with IG CT input

Analog input	Default usage	Connector pins
IA	Phase A current	54-53
IB	Phase B current	52-51
IC	Phase C current	50-49
IG	Ground current	48-47
VA	Phase A voltage	VA-VN
VB	Phase B voltage	VB-VN
VC	Phase C voltage	VC-VN
VG	Broken Delta Voltage	38-37
VSync	Feeder Voltage	36-35

Table 10: Default connecion for analog inputs with SEF CT

Analog input	Default usage	Connector pins
IA	Phase A current	54-53
IB	Phase B current	52-51
IC	Phase C current	50-49
IG(SEF)	Ground current	48-45(46,47)
VA	Phase A voltage	VA-VN
VB	Phase B voltage	VB-VN
VC	Phase C voltage	VC-VN
VG	Broken Delta Voltage	36-35
VSync	Feeder Voltage	38-37

Note:
1. CT connections to 48-45 for SEF input typically while upgrading an existing DPU2000R. Note terminals 45 & 46 are internally shorted in REF615R. Ensure the external link between terminals 46&47 remains. Please also refer to connection diagram for more details.

Table 11: Default connections for binary inputs

Default usage	Connector pins
Circuit breaker closed position (52a)	4-3
Circuit breaker open position (52b)	5-3
Autoreclose blocking	6-3

Table 12: Default connections for binary outputs

Default usage	Connector pins
Close circuit breaker	27-28
Open circuit breaker / Master Trip -1	29-30

*Table 13: High speed binary output connections**

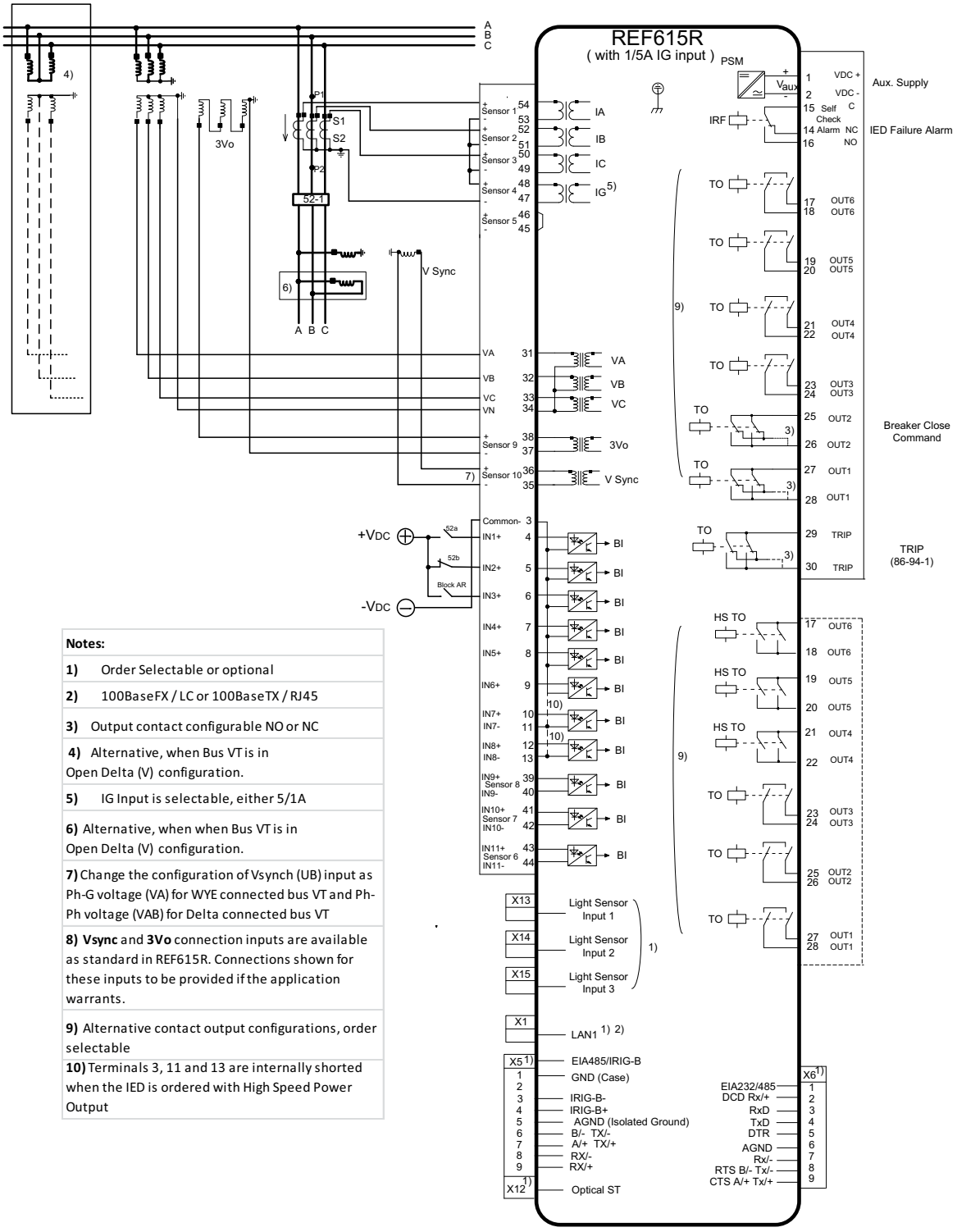
Default usage	Connector pins
Trip from ARC-1 protection	21(+) 22(-)
Trip from ARC-2 protection	19(+) 20(-)
Trip from ARC-3 protection	17(+) 18(-)
*Available only if protection relay has been ordered with High speed power output (HSO) card and ARC protection.	

Table 14: Default connections for LEDs

LED	LED label
LED 1	Phase A
LED 2	Phase B
LED 3	Phase C
LED 4	Neutral, Neutral / Ground, Neutral / SEF
LED 5	Time
LED 6	Instantaneous
LED 7	Frequency
LED 8	Negative Sequence
LED 9	Directional
LED 10	Voltage Protection
LED 11	Blown Fuse

Some of the alarm LED channel connections in the standard configuration depends on the optional functionality and are available according to order code.

3.3.4 Typical connection diagrams



Notes:
1) Order Selectable or optional
2) 100BaseFX / LC or 100BaseTX / RJ45
3) Output contact configurable NO or NC
4) Alternative, when Bus VT is in Open Delta (V) configuration.
5) IG Input is selectable, either 5/1A
6) Alternative, when when Bus VT is in Open Delta (V) configuration.
7) Change the configuration of Vsynch (UB) input as Ph-G voltage (VA) for WYE connected bus VT and Ph-Ph voltage (VAB) for Delta connected bus VT
8) **Vsync** and **3Vo** connection inputs are available as standard in REF615R. Connections shown for these inputs to be provided if the application warrants.
9) Alternative contact output configurations, order selectable
10) Terminals 3, 11 and 13 are internally shorted when the IED is ordered with High Speed Power Output

Figure 30: Typical connection diagram of REF615R with IG (5/1A) input

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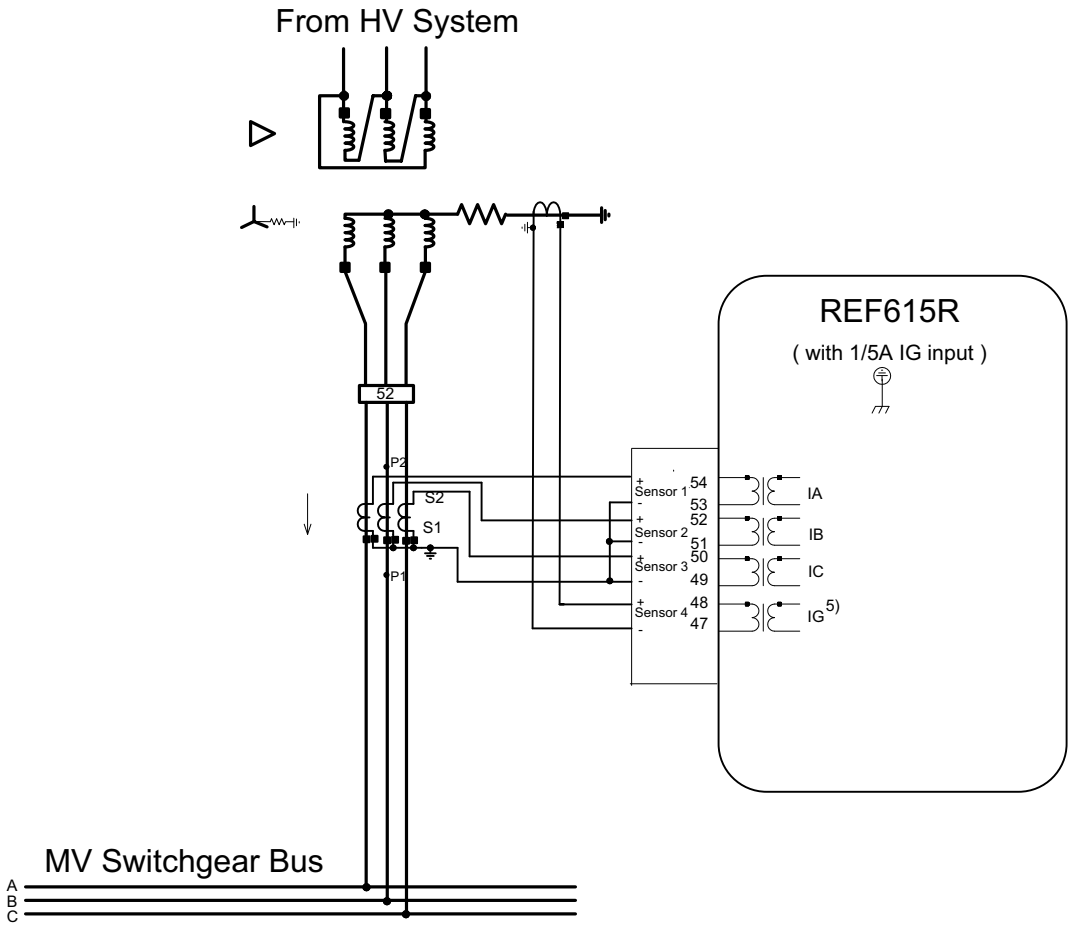
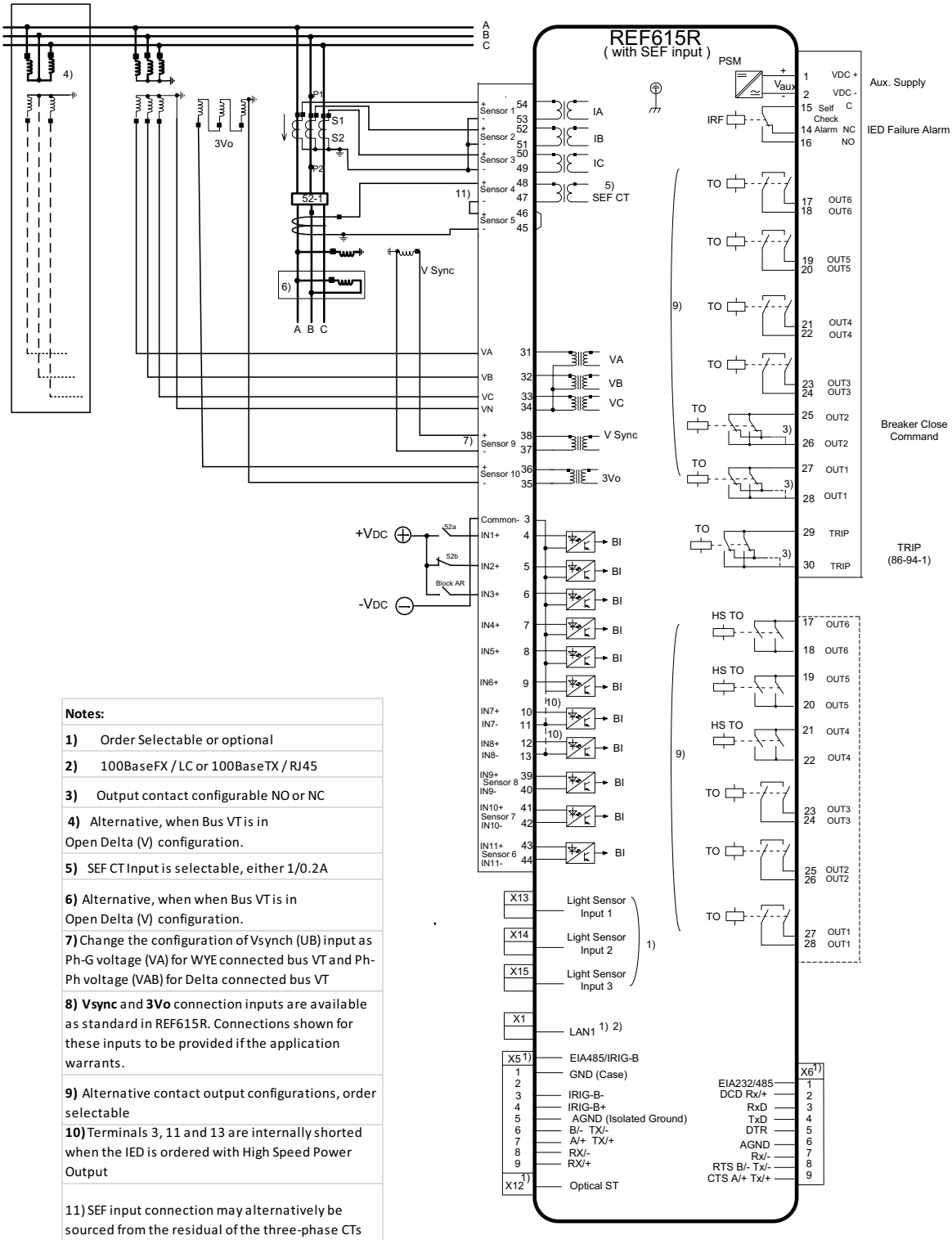


Figure 31: *Analog current inputs when REF615R with IG input (5/1A) is applied on a transformer feeder with Restricted Earth Fault protection*



Notes:
1) Order Selectable or optional
2) 100BaseFX / LC or 100BaseTX / RJ45
3) Output contact configurable NO or NC
4) Alternative, when Bus VT is in Open Delta (V) configuration.
5) SEF CT Input is selectable, either 1/0.2A
6) Alternative, when when Bus VT is in Open Delta (V) configuration.
7) Change the configuration of Vsynch (UB) input as Ph-G voltage (VA) for WYE connected bus VT and Ph-Ph voltage (VAB) for Delta connected bus VT
8) Vsync and **3Vo** connection inputs are available as standard in REF615R. Connections shown for these inputs to be provided if the application warrants.
9) Alternative contact output configurations, order selectable
10) Terminals 3, 11 and 13 are internally shorted when the IED is ordered with High Speed Power Output
11) SEF input connection may alternatively be sourced from the residual of the three-phase CTs

Figure 32: Typical connection diagram for REF615A with SEF (1/0.2A) input

The logics and routing of signals inside the protection relay with respect to protection and tripping are summarized in the next few sheets

.

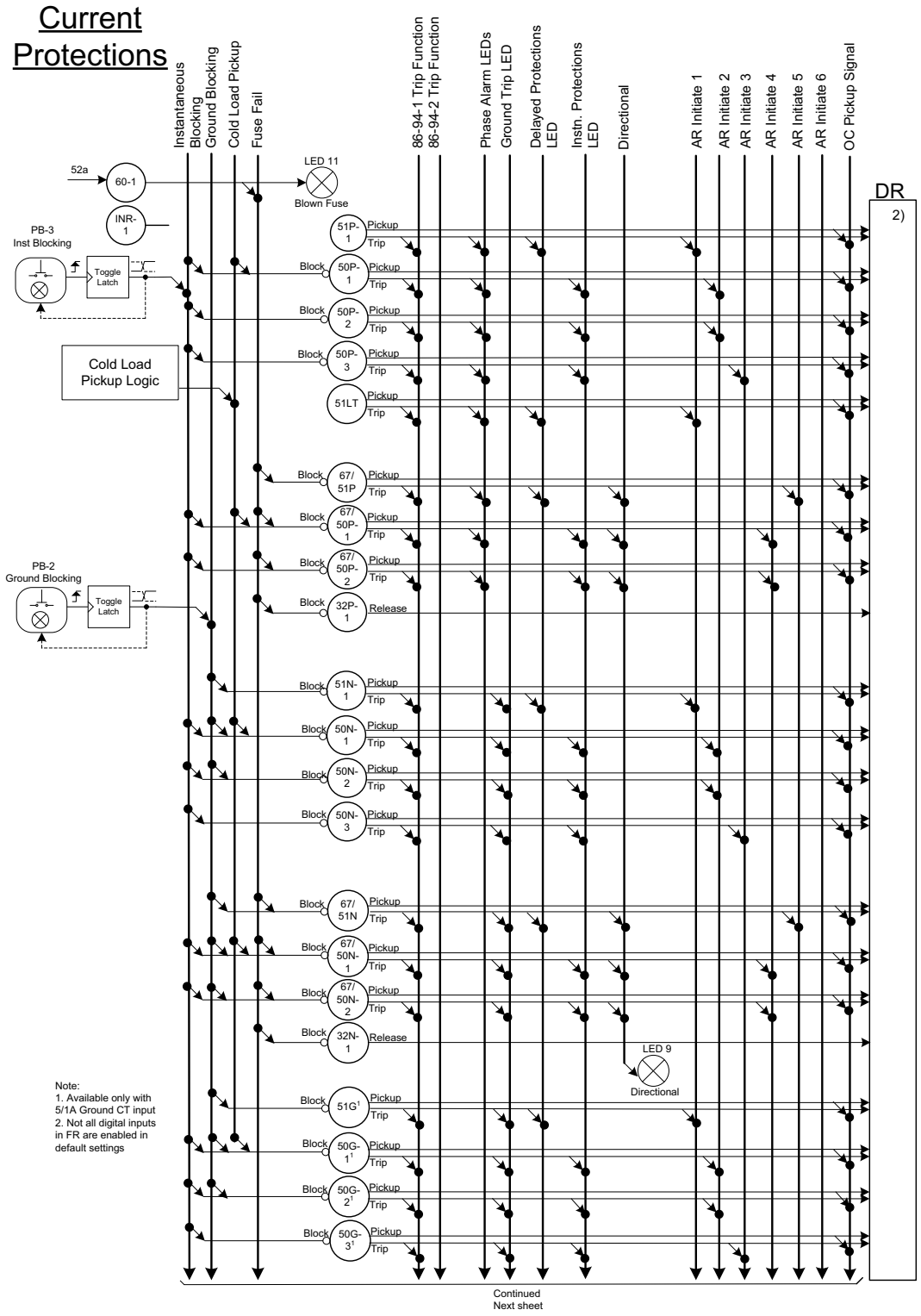


Figure 33: Simplified Logic Diagram for Current Protections, REF615R

Other Protections

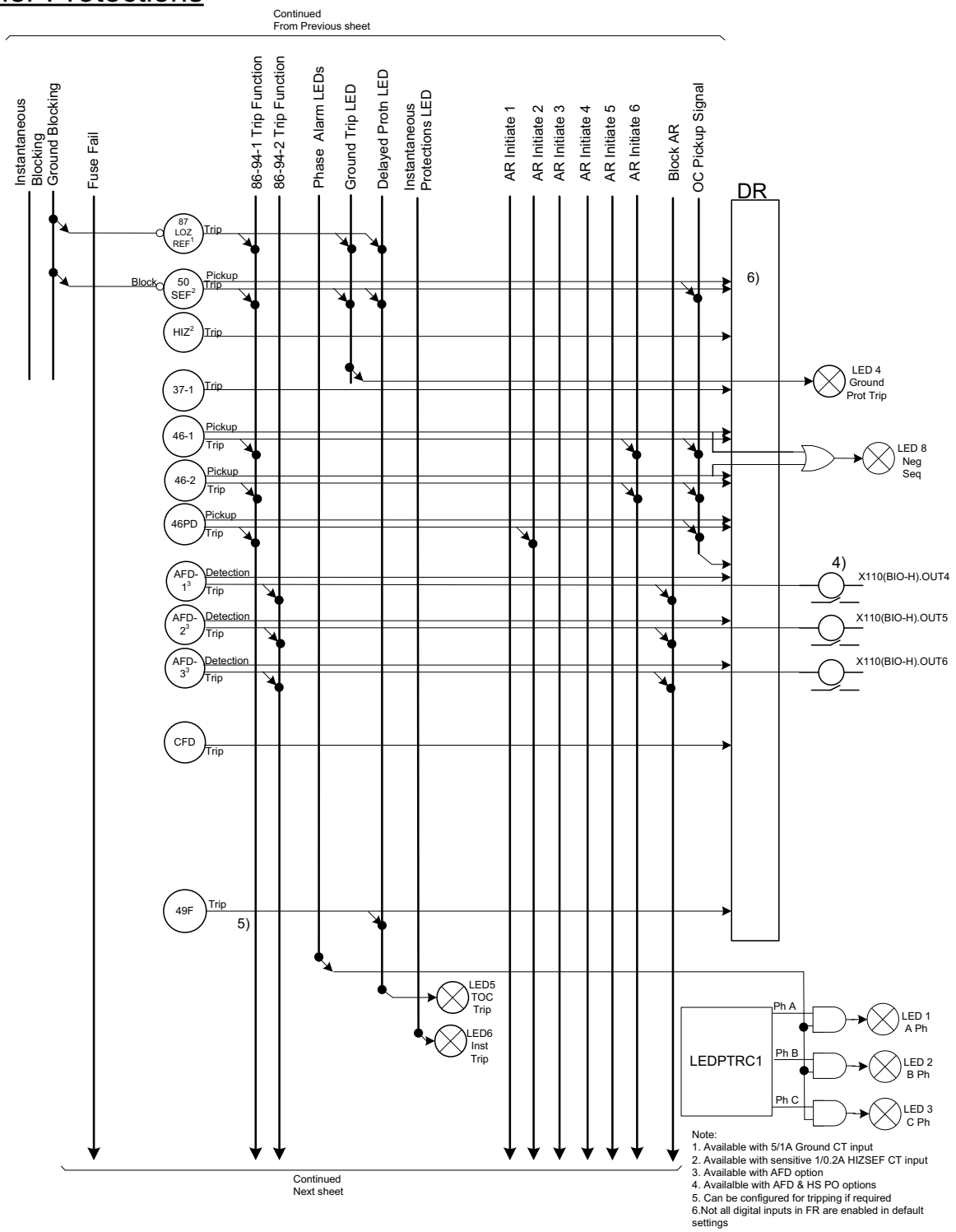


Figure 34: *Simplified Logic Diagram for Other Protections, REF615R*

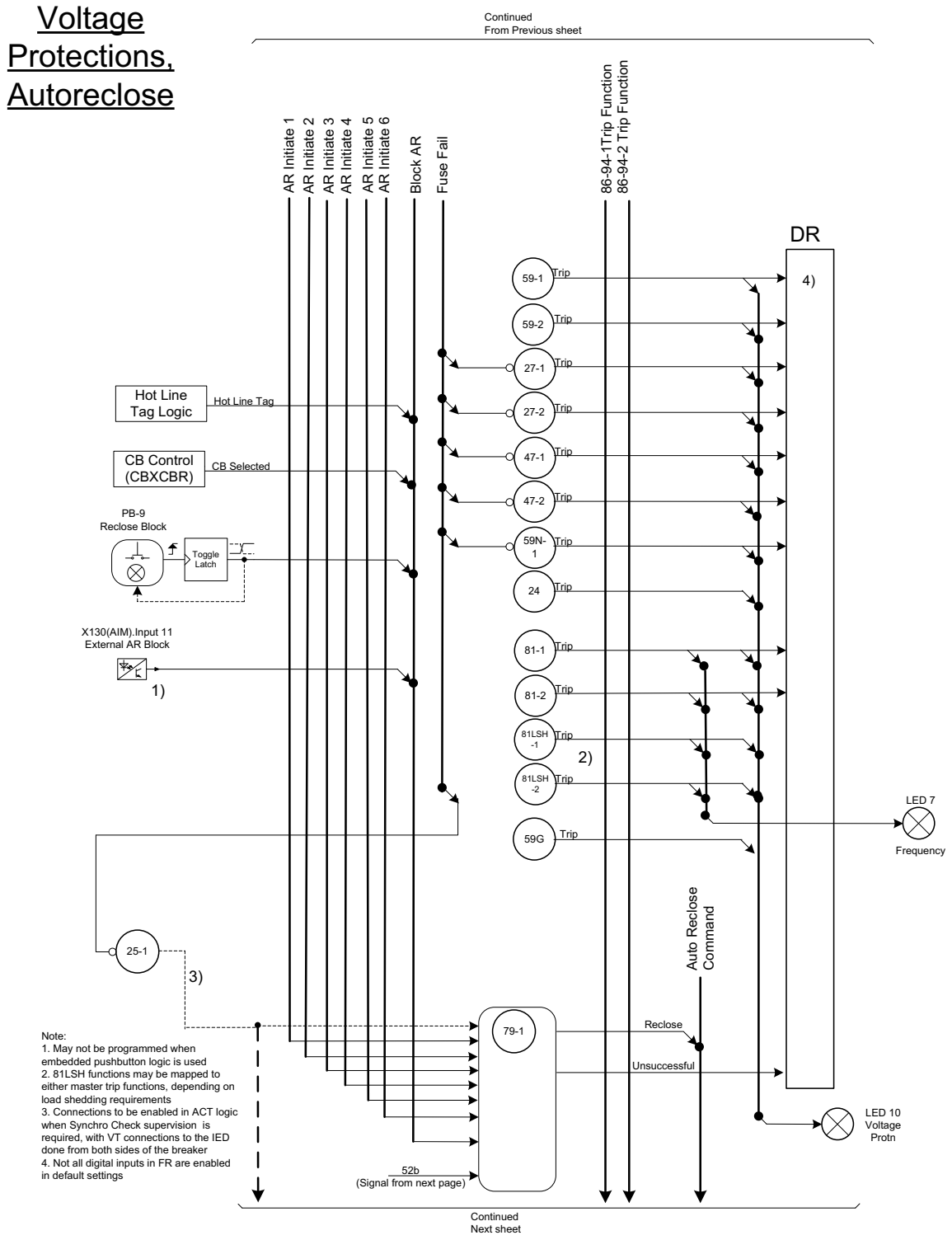


Figure 35: *Simplified Logic Diagram for Voltage Protections and Reclose, REF615R*

CB Control, Monitoring

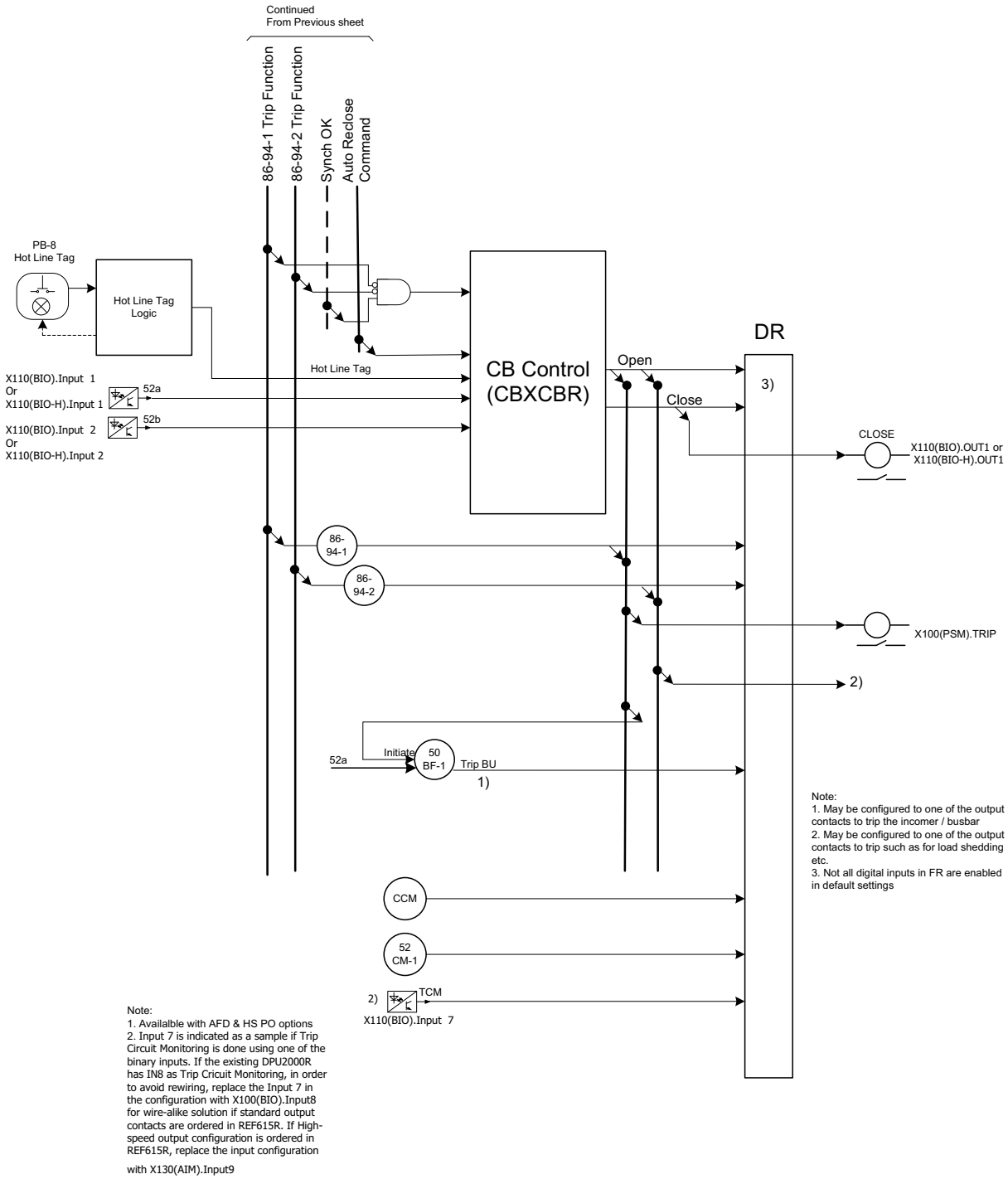


Figure 36: *Simplified Logic Diagram for CB Control and Monitoring, REF615R, Config A*

3.3.5 Functional diagrams

The functional diagrams describe the default input, output, alarm LED and function-to-function connections. The default connections can be viewed and changed with PCM 600 according to the application requirements, if necessary.

The analog channels, measurements from CTs and VTs, have fixed connections to the different function blocks inside the protection relay's standard configuration.

The signal marked with IA, IB and IC (IL1, IL2 and IL3) represents the three phase currents. The signal IG represents the measured ground current, fed from either residually connected CTs or an external Core Balance CT or neutral CT depending on the application.

The signal marked with VA, VB and VC (UL1, UL2 and UL3) represents the three phase system voltages on the bus. These inputs are connected in Delta, which are typically fed from open delta (V connected) VTs from the system. When WYE connected VT is available in the system, the VT inputs in the protection relay are WYE connected. In addition, the signal VG can be energized by the tertiary winding of the VTs, connected in broken delta.

When power system is provided with Open delta VT (V connected), since there is no way to measure or estimate the system zero sequence voltage, directional ground fault protection will have to be polarized by negative sequence voltage polarization method only. Select line quantities for all voltage-based protection and measurements.

The signal marked VSync is measured from the VT on the feeder side of the breaker. This signal is used for check synchronizing purposes. The input again is configured for Ph-Ph input from the system by default, but should be configured to take input from Ph-G voltage input when bus VT is WYE connected to have consistency in input voltage magnitudes in the internal synch. function. Care shall be taken in setting the synchrocheck function with correct phase angle correction, especially in applications such as voltages fed to synchrocheck across a transformer with vector shift.

REF 615R offers six different settings group which the user can set based on individual needs. Each group can then, be activated/ deactivated by using the programmable button offered in the front panel of the unit. In addition to this the programmable button, when ordered, can also be used for enabling/disabling switch mode, hot line tag, sensitive earth fault detection, etc. Figure 37 shows the default mapping for the available programmable buttons. Figure 38 shows the hot line tag logic. These logics are available as standard when the protection relay is ordered with Enhanced OCI. (LHMI "B" or "D" options). When the unit is ordered with "Standard OCI" (Options "A" and "C"), to match with an existing DPU2000R with standard OCI, the push buttons though available, are not connected to any internal logics. User, if desired, can refer the logics shown in the next few pages to connect the pushbuttons to other internal logics.

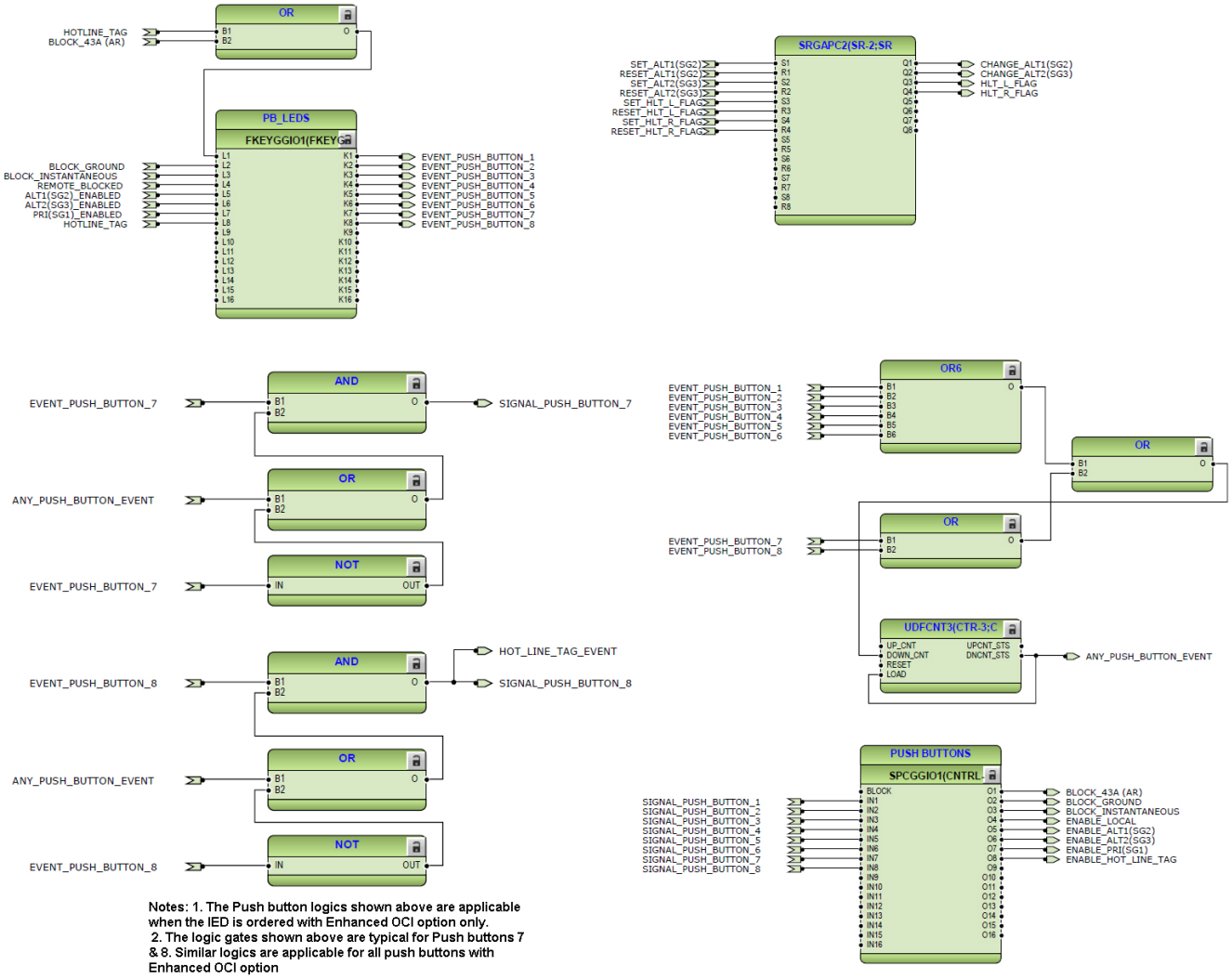


Figure 37: *Default mapping on programmable buttons (When the protection relay is ordered with Enhanced OCI)*

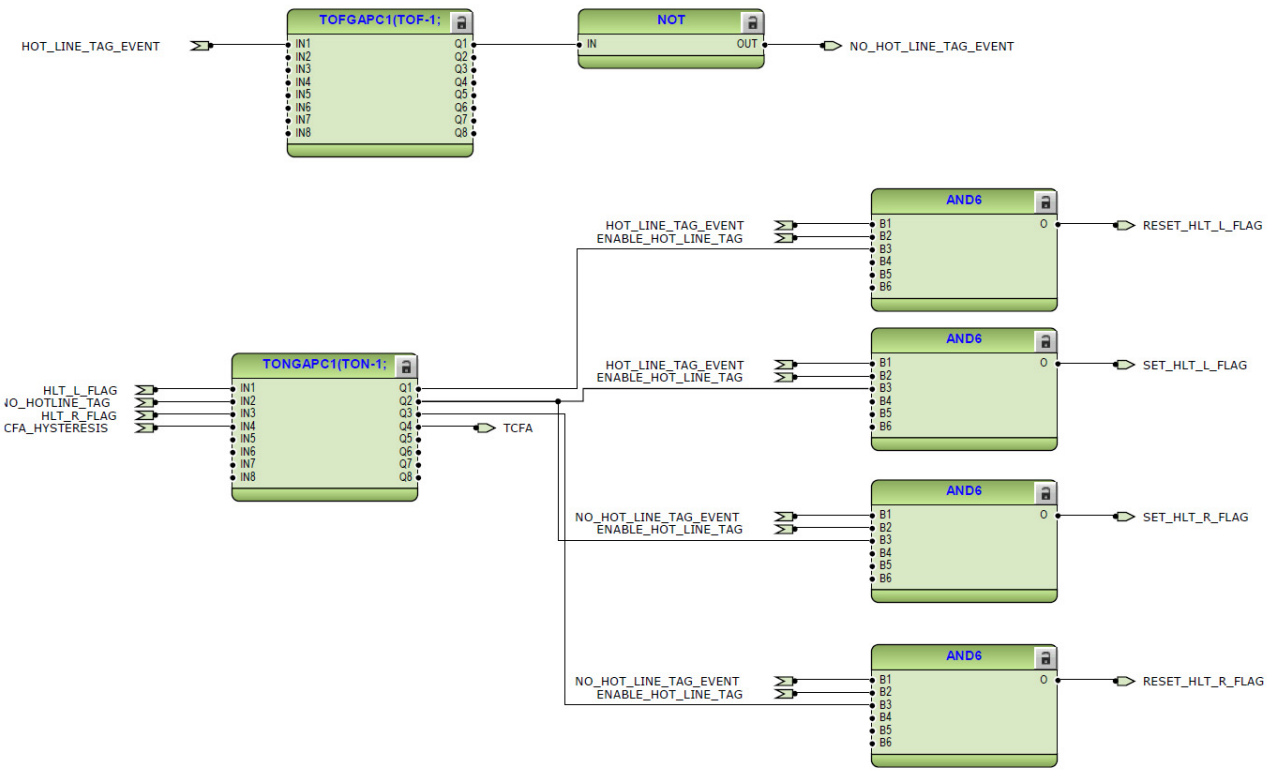


Figure 38: Hot line Tag logic (When the protection relay is ordered with Enhanced OCI)

3.3.6 Functional diagrams for protection

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

Eight overcurrent stages (51P, 50P-1, 50P-2, 50P-3, 51LT, 67/51P, 67/50P-1, 67/50P-2) are offered for overcurrent and short-circuit protection. Three include directional functionality. The non directional high stage (50P-1) and directional high stage (67/50P-1) will be blocked by cold load detection logic. The cold load detection logic starts from closing of the circuit breaker and is active during set time. The cold load detection logic's active time can be set in a resolution of minutes or seconds to the functions TPSGAPC and TPMGAPC.

The operation of 50P-1, 50P-2, 50P-3, 67/50P-1 and 67/50P-2 will be blocked if Instantaneous Blocking signal is active.

The directional overcurrent and short circuit protection will be blocked by default also if the fuse failure situation is detected.

The inrush detection block's (INR-1) output BLK2H offers the possibility to either block the function or multiply the active settings for any of the shown protection function blocks.

All trip signals are connected to the Master Trip and also to the alarm LEDs. Alarm LEDs 1, 2 and 3 are used for phase segregated information of faults. The alarm LED 5 is used to indicate time delayed trips and the alarm LED 6 instantaneous trips of the current based protection functions. The directional protections are arranged to energize the LED 9.

The pickup information of all overcurrent functions is collected to the variable OC_PICKUP_ALARM and connected to the disturbance recorder. This signal can be mapped to the signal outputs depending on the application needs.

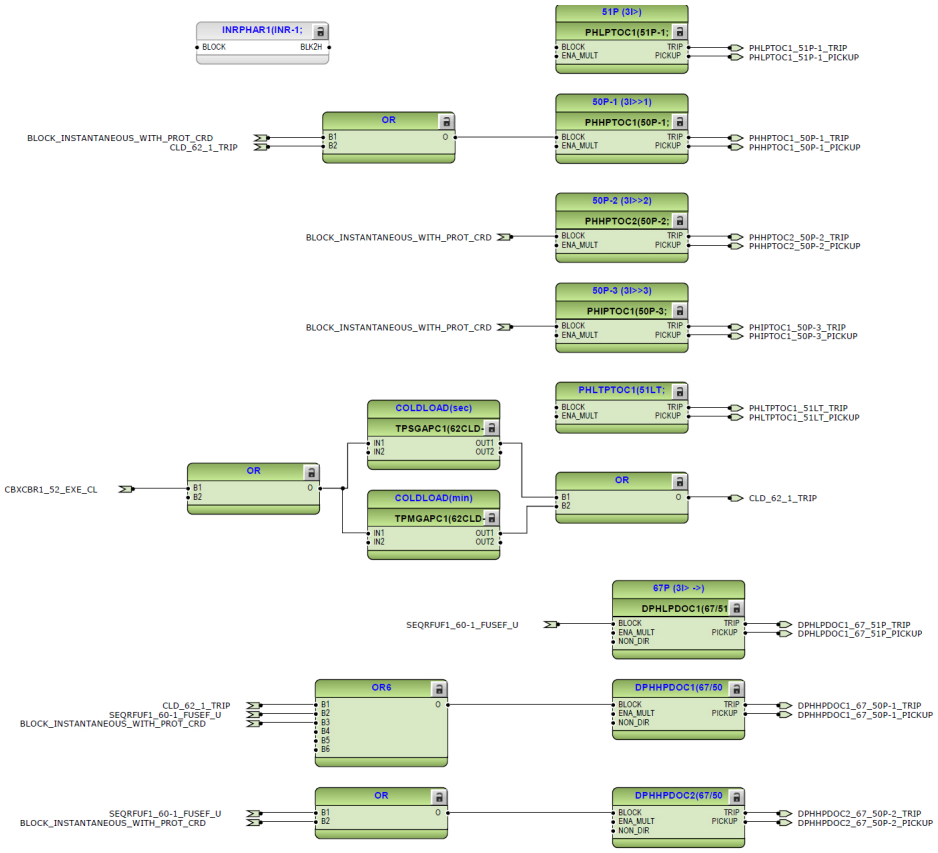


Figure 39: *Three phase overcurrent protection*

Four stages are provided to non-directional neutral overcurrent protection (51N-1, 50N-1, 50N-2, 50N-3). The neutral overcurrent protection uses calculated residual current component.

Four stages of ground overcurrent protections (51G, 50G-1, 50G-2 and 50G-3) are operated off standard IG input (rated 5/1A) when ordered. When sensitive ground input (1/0.2A) is ordered sensitive ground fault protection 50SEF is provided (instead of four ground overcurrent protections).

The operation of 51N-1, 50N-1, 50N-2 and 50SEF will be blocked if GROUND_BLOCKING is active. The 50N-1 will also be blocked if the cold load detection logic is activated. The operation of neutral overcurrent protection functions is connected to alarm LED 4.

The alarm LED 5 is used to indicate time delayed trips and the alarm LED 6 instantaneous trips of the current based protection functions.

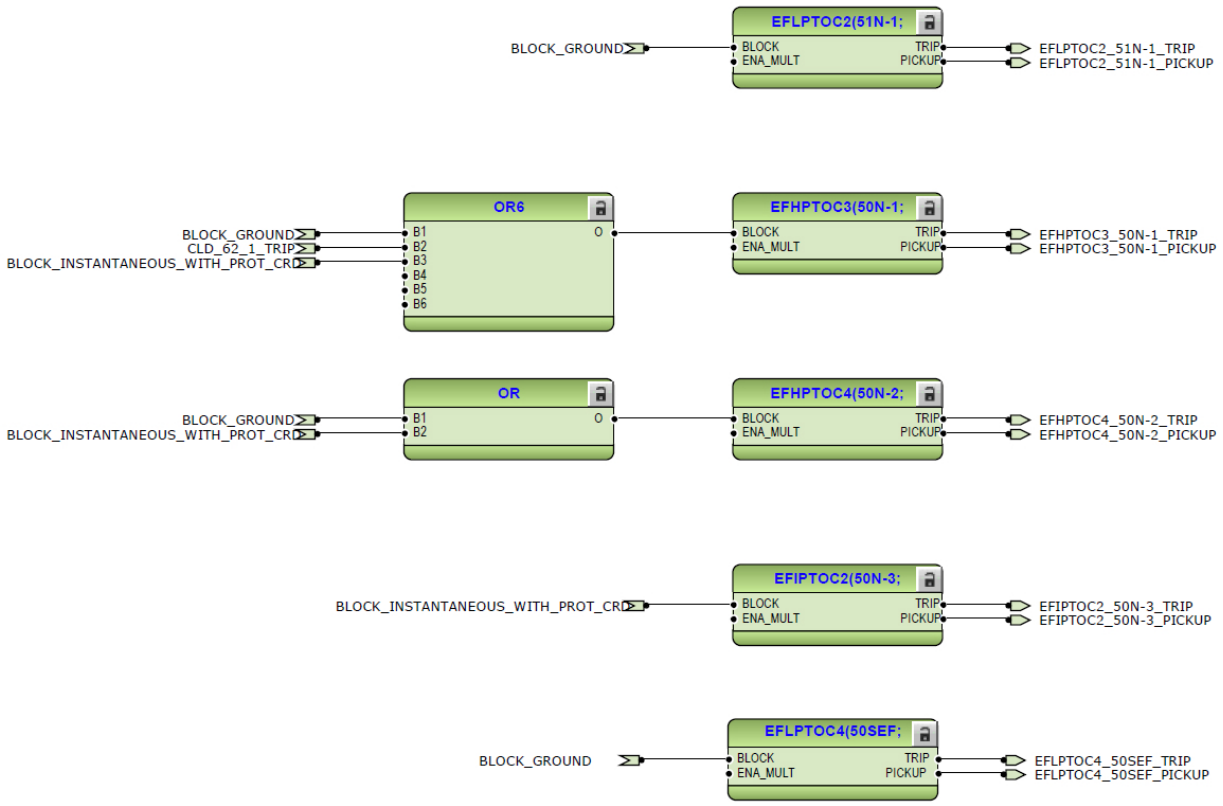


Figure 40: Non-directional neutral overcurrent protection

SEF and HIZ functions are included if sensitive SEF/HIZ measuring option is ordered.

The operation of 51G, 50G-1 and 50G-2 will be blocked if GROUND_BLOCKING input is active. The 50G-1 will also be blocked if the cold load detection logic is activated. The operation of ground overcurrent protection functions is connected to alarm LED 4.

The alarm LED 5 is used to indicate time delayed trips and the alarm LED 6 instantaneous trips of the current based protection functions.

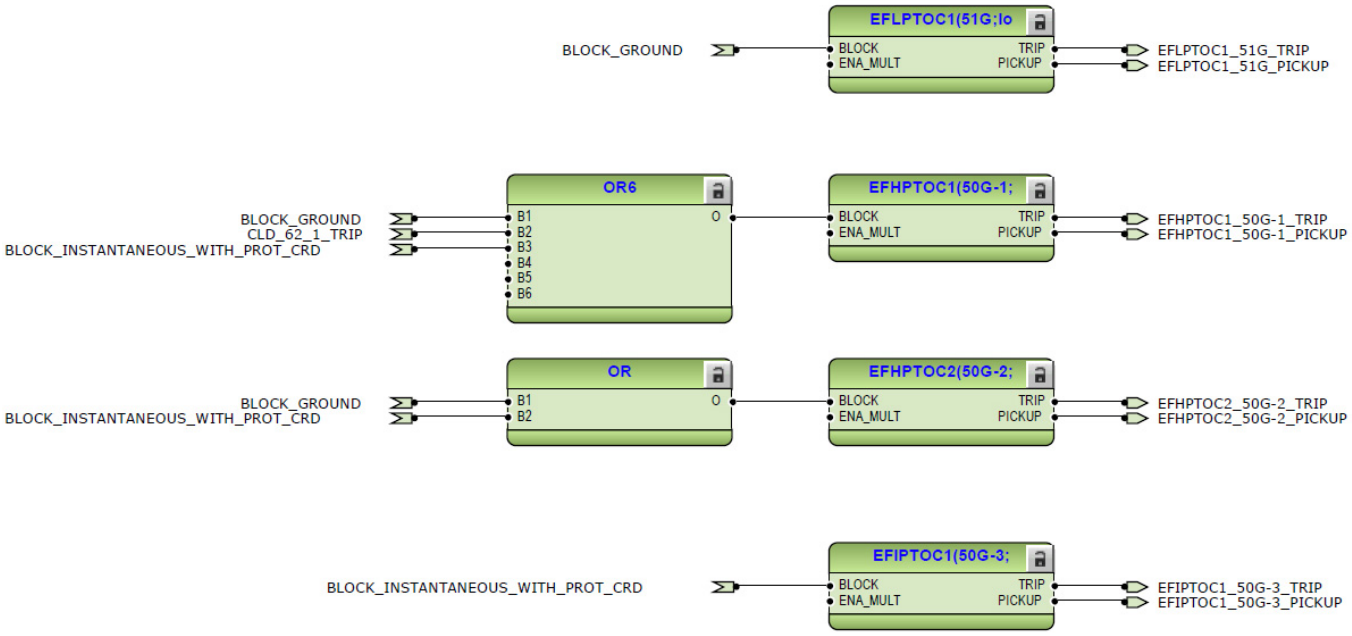


Figure 41: Non-directional ground overcurrent protection

51G, 50G-1, 50G-2 and 50G-3 are included if ground measuring option is used.

Three stages are offered for directional ground-fault protection (67/51N, 67/50N-1, 67/50N2). By default all stages will be blocked by activating the GROUND_BLOCKING input. If the cold load situation is detected the (67/50N-1) function will be blocked. Also if the fuse failure situation is detected all directional ground-fault protection functions will be blocked. While setting the directional element, it is necessary to choose either Vo calculated or Negative sequence voltage polarization. While either one may be selected with WYE connected VT, it is essential to choose negative sequence voltage polarization with V (Delta) connected VT input from which zero sequence voltage cannot be derived. The directional protections are arranged to energize the LED 9

The internal ground directional function in protections such as 67/50N, 67/51N, 32N etc. , when selected with zero sequence operating current, looks for the angle difference between Vo (alternatively V2) and -Io to arrive at the source impedance angle which is highly reactive for grounded systems. There are typically two options to select the Io input for the above. One is "Calculated Io" and the other "Measured Io". The Calculated Io is derived out of the phase currents and phase reversed before fed into above function internally.

Hence, with the connections and polarity indicated in this manual and with default polarity settings (setting "Reverse Polarity" set as "False"), the functions 67/51N, 67/50N, 32N would correctly operate for fault direction shown in diagrams with a "Characteristic angle" setting say -75 degrees for grounded system if "Io signal Sel" of the function is selected as "Calculated Io".

However, when the setting "Measured IG" is given as operating current, the polarity reversal of Io has to be accounted for by an external factor. In such a case, one needs to either set the Characteristic angle shifted by 180 degrees or set "Reverse Polarity" setting as "True".

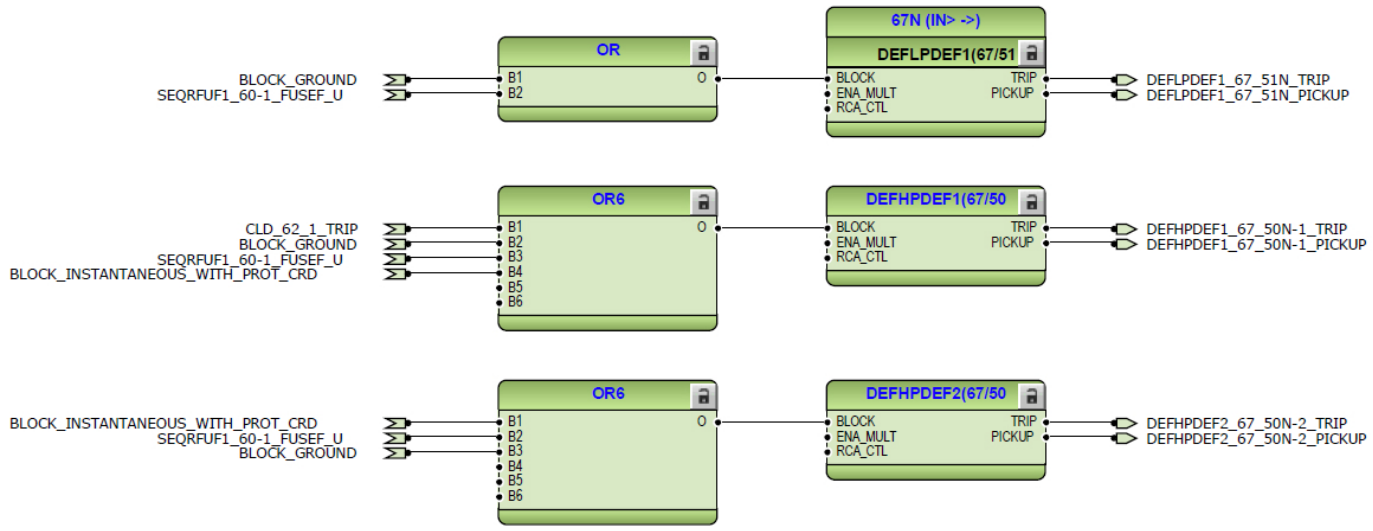


Figure 42: Directional neutral overcurrent protection

Two negative-sequence overcurrent protection (46-1 and 46-2) stages are provided for phase unbalance protection. These functions are used to protect the feeder against phase unbalance. The negative sequence protections are arranged to energize the LED 8

The phase discontinuity protection (46PD) provides protection for interruptions in the normal three-phase load supply, like in downed conductor situations.

The operation of 46-1, 46-2 and 46PD is not blocked as default by any functionality. The pickup signals are connected to OC_PICKUP_ALARM variable in logic.

The undercurrent protection function (37-1) is offered for protection against loss of phase situations. The trip signal is connected to the disturbance recorder by default.

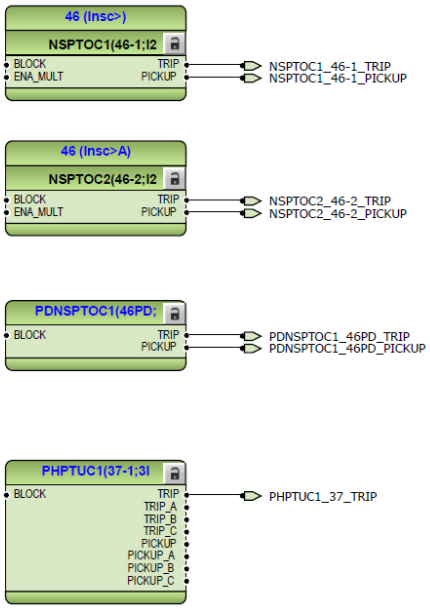


Figure 43: Negative sequence, phase discontinuity and undercurrent protection

All overcurrent pickup signals are merged together as variable OC_PICKUP_ALARM. This simulates DPU2000R's PUA logic. This alarm is by default connected to disturbance recorder channel. It can be mapped also e.g. for alarming or blocking purposes to the binary output relays.

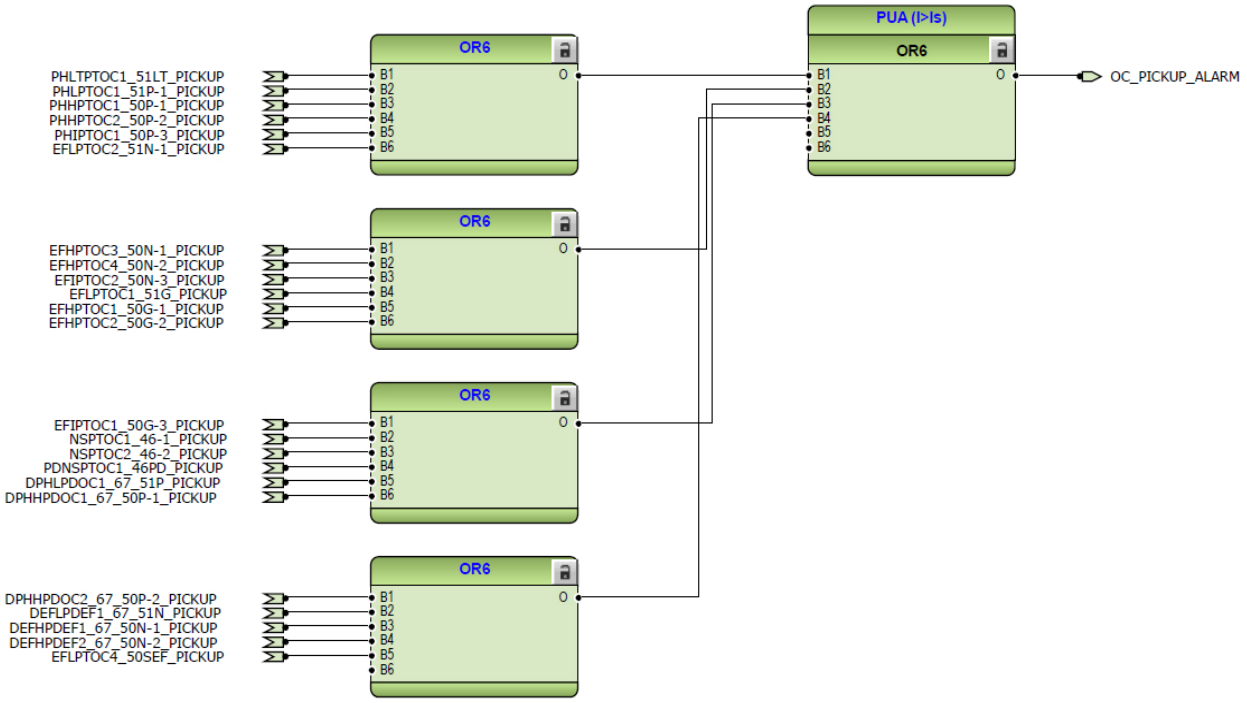


Figure 44: Overcurrent pickup alarm

The directional positive sequence power protection (32P-1) and directional negative sequence power protection (32N-1) are offered in configuration. The output information of these functions can be used e.g. releasing or blocking purposes but by default those are not connected. Directional power protection functions are blocked by default configuration connection if fuse failure is detected.

The internal ground directional function in protections such as 67/50N, 67/51N, 32N etc. , when selected with zero sequence operating current, look for the angle difference between Vo (alternatively V2) and -Io to arrive at the source impedance angle which is highly reactive for grounded systems. There are typically two options to select the Io input for the above. One is "Calculated Io" and the other "Measured Io". The Calculated Io is derived out of the phase currents and phase reversed before fed into above function internally.

Hence, with the connections and polarity indicated in this manual and with default polarity settings (setting "Reverse Polarity" set as "False"), the functions 67/51N, 67/50N, 32N would correctly operate for fault direction shown in diagrams with a "Characteristic angle" setting say -75 degrees for grounded system if "Io signal Sel" of the function is selected as "Calculated Io".

However, when the setting "Measured IG" is given as operating current, the polarity reversal of Io has to be accounted for by an external factor. In such a case, one needs to either set the Characteristic angle shifted by 180 degrees or set "Reverse Polarity" setting as "True".

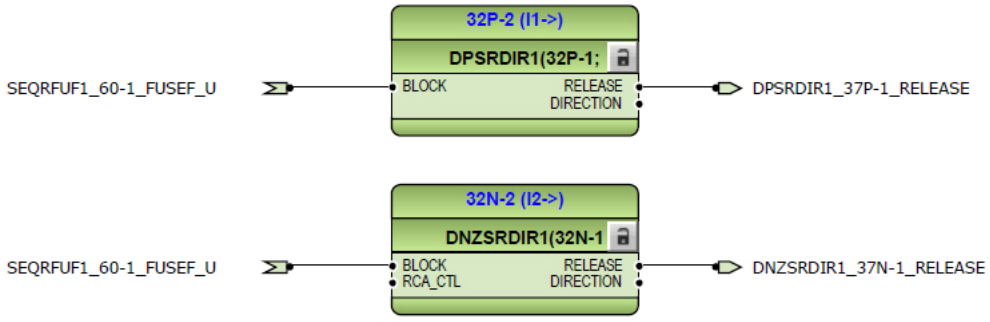


Figure 45: Directional power protection

Two overvoltage and undervoltage protection stages (27-1, 27-2 and 59-1, 59-2) offer protection against abnormal phase voltage conditions. The operation of voltage functions is connected to alarm LED 10. A failure in the voltage measuring circuit is detected by the fuse failure function and the activation is connected to undervoltage protection functions to avoid faulty undervoltage tripping.

Negative-sequence overvoltage (47-1 and 47-2) protection functions enable voltage-based unbalance protection. The operation signals of voltage-sequence functions are connected to alarm LED 10, which is a combined voltage protection alarm LED.

The residual overvoltage protection (59N & 59G) provide ground-fault protection by detecting abnormal level of residual voltage. It can be used, for example, as a nonselective backup protection for the selective directional ground-fault functionality. The input signal for 59N1 is calculated internally from WYE connected VT input, while the signal for 59G is measured at the protection relay input terminals.

Depending on the order type the input signal terminals for 59G and syncro check function 25 may differ.

The operation signal is connected to alarm LED 10.

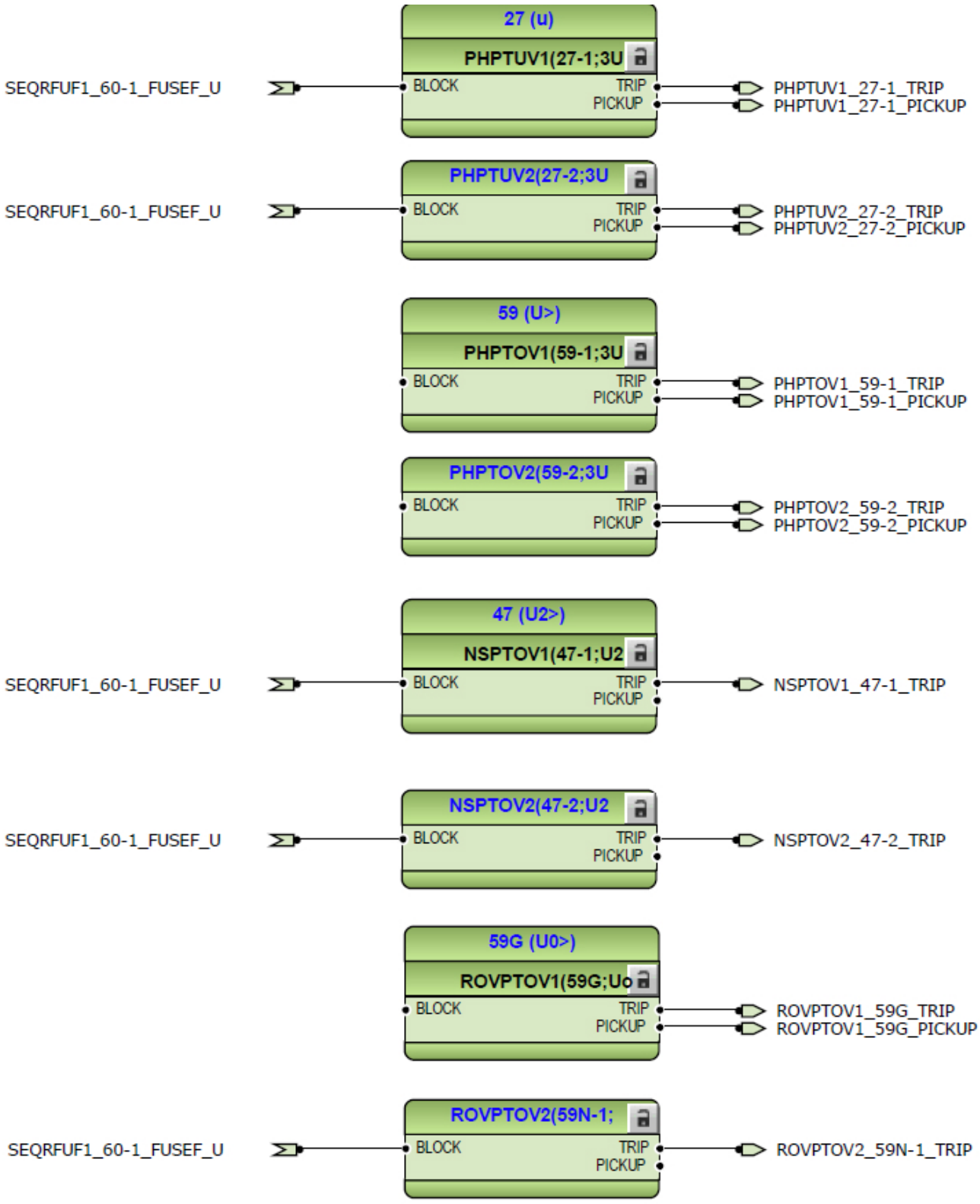


Figure 46: Voltage protection functions

The over excitation protection function (24) is offered as standard. By the default the TRIP output is connected only to alarm LED 10.

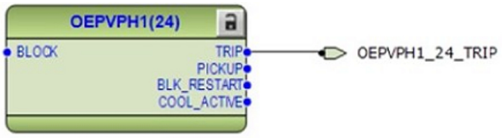


Figure 47: Over excitation protection

The thermal overload protection function (49F-1) detects short and long term overloads under varying load conditions.

The trip of the thermal overload protection function is connected to the LED 5 and DR. If required the signal may be configured to trip the feeder breaker.

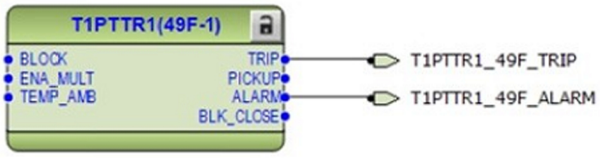


Figure 48: Thermal overload protection

According to the order code the configuration includes restricted low-impedance ground-fault protection function (87LOZREF). The function is available with 1/5A ground CT input.

The numerical differential current stage operates exclusively on ground faults occurring in the protected area, that is, in the area between the phase and ground current transformers. A ground fault in this area appears as a differential current between the residual current of the phase currents and the neutral current of the conductor between the star-point of the transformer and ground.

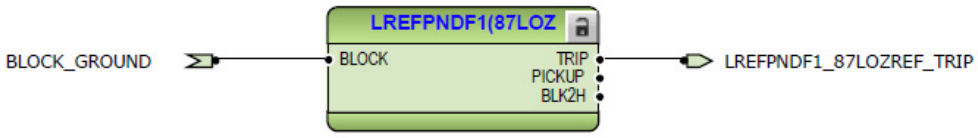


Figure 49: Low impedance restricted ground fault protection

The circuit-breaker failure protection (50BF) is initiated via the PICKUP input by a functions connected to the Master Trip 1 and by opening command of the circuit breaker. 50BF offers different operating modes associated with the circuit-breaker position and the measured phase and the measured ground (IG) current in this configuration.
50BF has two operating outputs: TRRET and TRBU. The TRBU output can be used to give a backup trip to the circuit breaker feeding upstream.

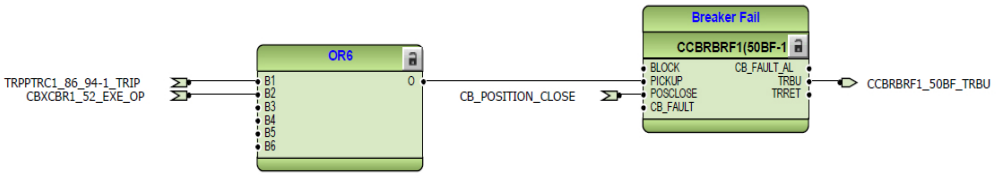


Figure 50: Circuit breaker failure protection

Three arc protection (AFD-1, AFD-2 and AFD-3) stages are included as an optional function. The arc protection offers individual function blocks for three ARC sensors that can be connected to the protection relay. Each arc protection function block has two different operation modes, with or without the phase and residual current check.

When ordered with high speed output, the arc protections are configured to energize each one of the outputs. Depending on the location of the Arc detector, say the bus or breaker chamber or the outgoing cable chamber, the contacts may be used to trip the upstream incoming / bus bar or the protected feeder breaker.

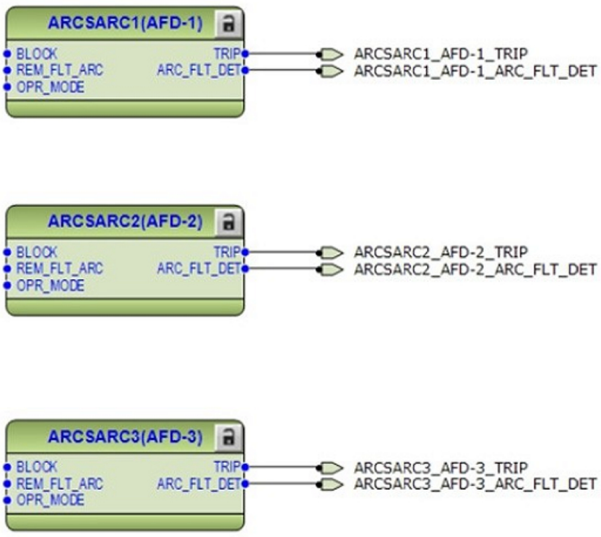


Figure 51: Arc protection

According to the order code the configuration includes high impedance fault protection function (HIZ). The function is available with functional application AB which is with sensitive 0.2/1A CT input. The trip of the high impedance protection function is connected to the disturbance recorder.

Figure 52: High impedance fault protection

The selectable under frequency or over frequency protection (81-1 and 81-2) prevents damage to network components under unwanted frequency conditions.

Both functions contain a selectable rate of change of the frequency (gradient) protection to detect an increase or decrease in the fast power system frequency at an early stage. This can be used as an early indication of a disturbance in the system. The operation signals are connected to alarm LED 7.

Two load shedding and restoration stages are offered in the standard configuration.

The load shedding and restoration function (81LSH-1 and 81LSH-2) is capable of shedding load based on under frequency and the rate of change of the frequency. The load that is shed during the frequency disturbance can be restored once the frequency is stabilized to the normal level. Also manual restore commands can be given via binary inputs but by the default it is not connected. The operation signal is connected to the alarm LED 7.

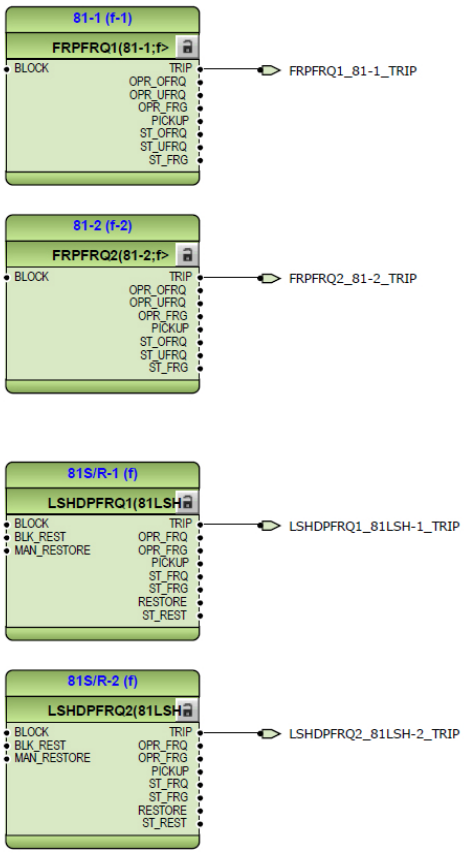


Figure 53: Frequency and Load shedding functions

Two Master Trip logics (86/94-1 and 86/94-2) are provided as a trip command collector. 86/94-1 collects the trip signals from 46, 46PD, 50P, 50N, 50G, 51LT, 51P, 51N, 51G, 67P, 67N, and SEF protection functions and is connected to trip output contact.

Open control commands to the circuit breaker from the local or remote is also connected directly to an output from circuit breaker control (52) function block.

86/94-2 collects the trip signals from AFD-1, AFD-2 and AFD-3 protection functions. The output may be configured, if required, to a another contact for tripping or signalling purpose..

86/94-1 and 86/94-2 provides the lockout/latching function, event generation and the trip signal duration setting. If the lockout operation mode is selected, one binary input can be reassigned to the RST_LKOUT input of the Master Trip to enable external reset with a pushbutton.

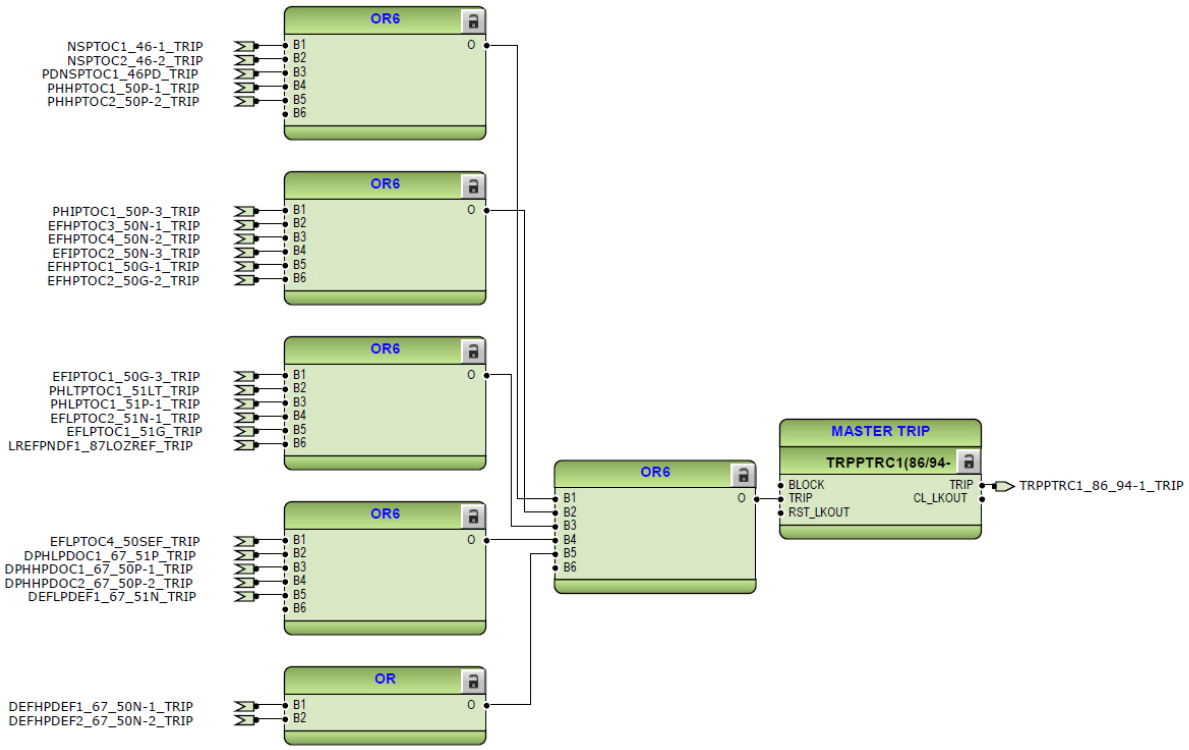


Figure 54: Master trip logic 1

Figure 55: Master trip logic 2

3.3.7 Functional diagrams for control functions

The circuit breaker closing is enabled when the ENA_CLOSE input is activated. The input can be activated by the configuration logic, which is e.g. a combination of the disconnector or breaker truck and ground switch position status and the status of the Master Trip logics and gas pressure alarm and circuit-breaker spring charging. With the present configuration, the activation of ENA_CLOSE input is configured using only Master Trip logic 86/94-1 and 86/94-2 i.e. the circuit breaker cannot be closed in case Master Trip is active.

The ITL_BYPASS input can be used, for example, to always enable the closing of the circuit breaker when the circuit breaker truck is in the test position, despite of the interlocking conditions being active when the circuit breaker truck is closed in service position.

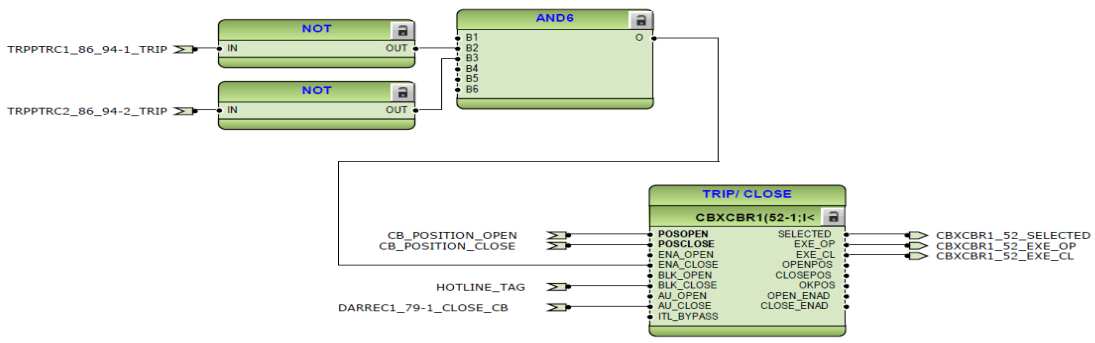


Figure 56: Circuit breaker control

If the ENA_CLOSE and BLK_CLOSE signals are completely removed from the breaker control function block 52 with PCM600, the function assumes that the breaker close commands are allowed continuously.

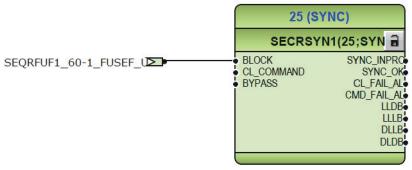


Figure 57: Synchrocheck function

In default configuration, the output of 25 function is not configured to interlock with close command.

The protection relay is provided with synchrocheck (25) function as a standard. In default configuration, the output of the function is not configured to interlock with the close function of the breaker. When a VT is available on the feeder side and wired to the protection relay and when it is desirable to provide synchrocheck, the following additional connection may be configured by the user.

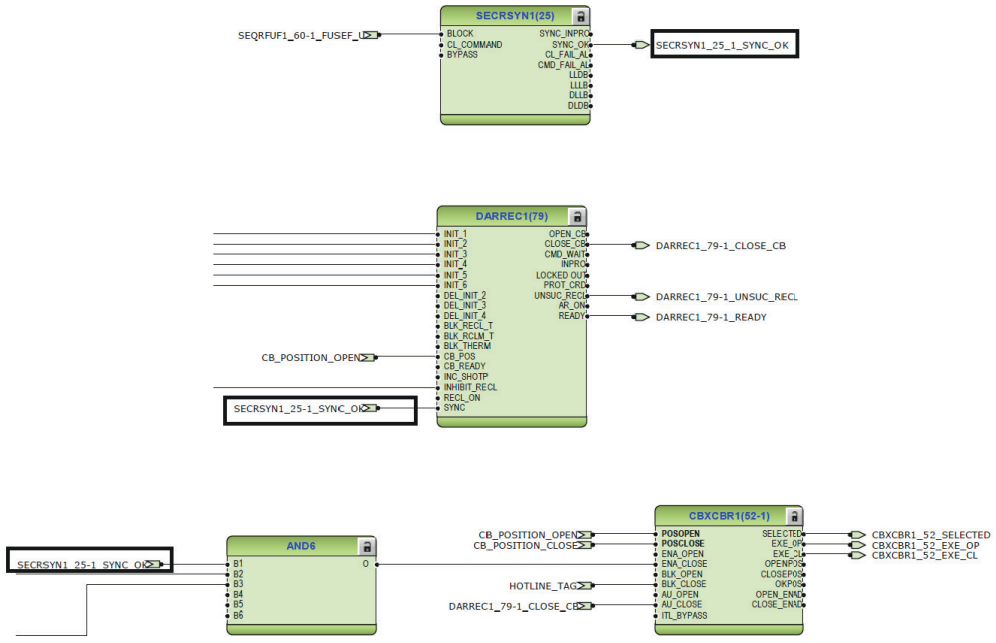


Figure 58: Interlocking synchrocheck with close functions

The autorecloser functionality (79) is configured to be initiated by operate signals from a number of protection stages through the INIT1...5 inputs. It is possible to create individual autoreclose sequences for each input.

The autoreclose function can be blocked with the INHIBIT_RECL input. By default, the operation of selected protection functions and commands from remote protocols are connected to this input. A control command to the circuit breaker, either local or remote, also blocks the autoreclose function via the CBXCBR-selected signal. The circuit breaker availability for the autoreclosure sequence is expressed with the CB_READY input in DARREC1.

The unsuccessful autoreclosing UNSUC_RECL is connected to the disturbance recorder.

The CB_CLOSE command output of autoreclose function is also used to count the number of autoreclose shots issued in a sequence using a shift register. The counter gets reset whenever the autoreclose function returns to quiescent state based on the signal autoreclose READY.

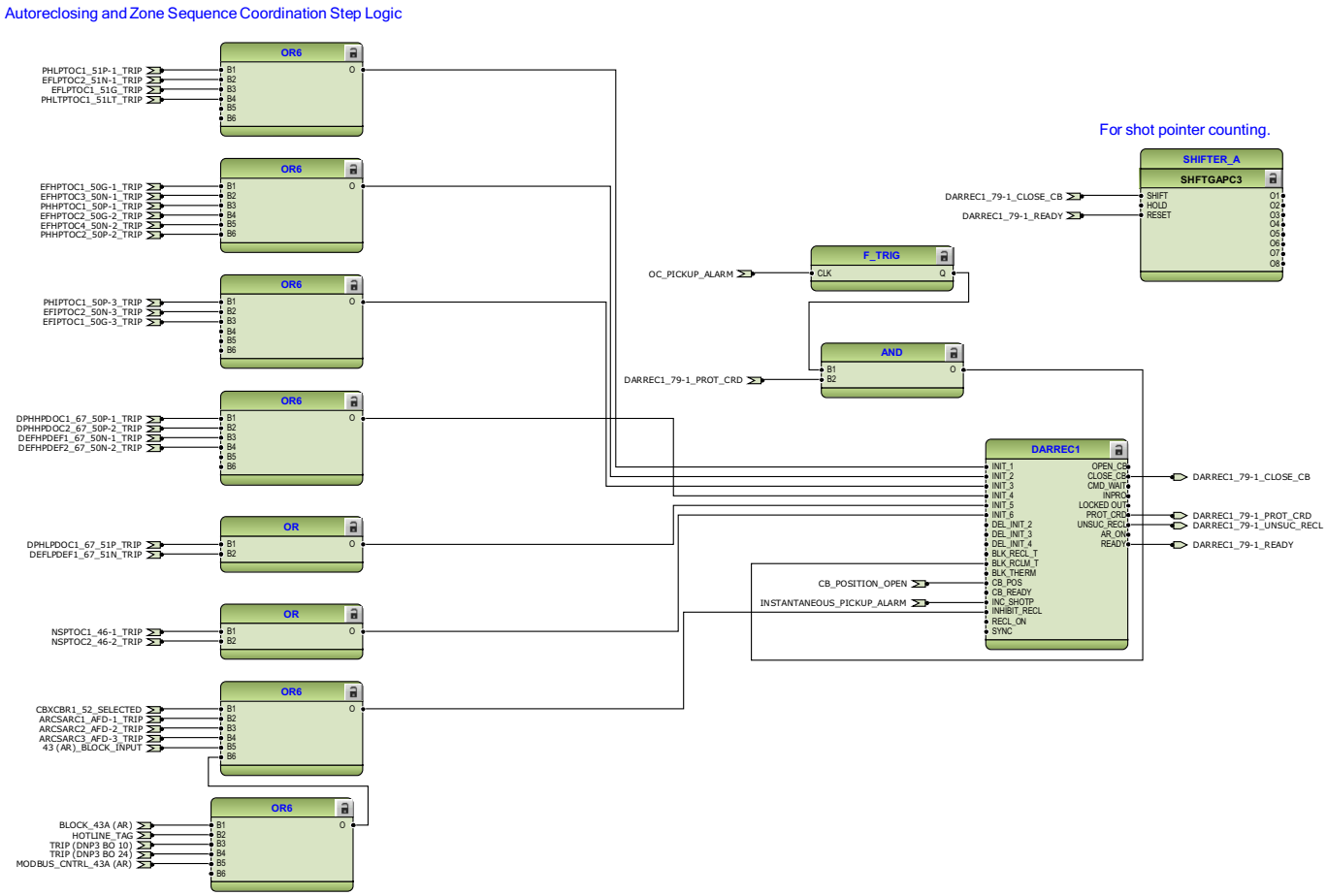


Figure 59: Autoreclosing

3.3.8 Functional diagrams for condition monitoring

By default the protection relay is not configured to have trip circuit monitoring. However, if required, the following logic can be quickly configured to have supervision of the breaker trip circuit. One of the binary inputs has to be used to supervise the status, which is indicated as TCM(TCS)_Input in the following figure.

The status of MVGAPC8 Q1 is the Trip Circuit Failure Alarm

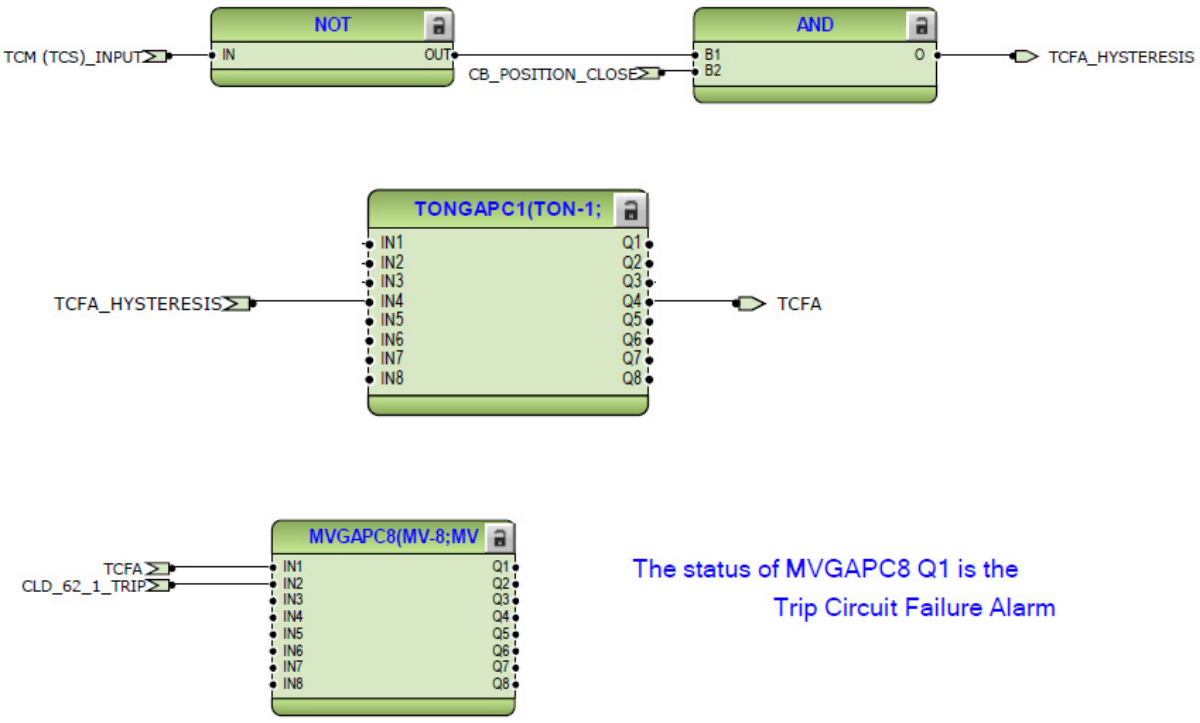


Figure 60: Trip circuit monitoring

A failure in current measuring circuits is detected by current circuit supervision function (CCM). When a failure is detected, function activates and can be used to block protection functions which operates using calculated sequence component currents for example 46, thus avoiding mal-operation.

Figure 61: Current circuit supervision

By default the FAIL output from CCM function is only connected to disturbance recorder.

The fuse failure supervision SEQRFUF1 detects failures in voltage measurement circuits. Failures, such as an open miniature circuit breaker, are detected and the alarm is connected to the few voltage based protection functions to avoid misoperation. The fuse fail function is connected to alarm LED11

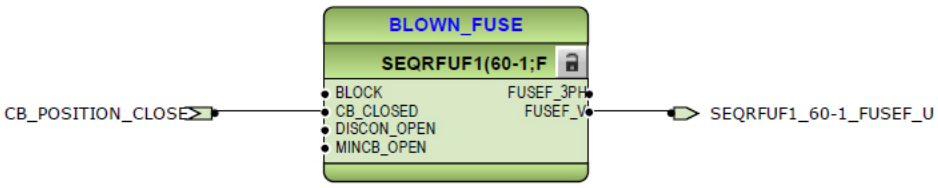


Figure 62: Fuse failure monitoring

The circuit breaker condition monitoring function (52CM) supervises the circuit breaker status based on the binary input information connected and measured current levels. The function introduces various supervision alarms.

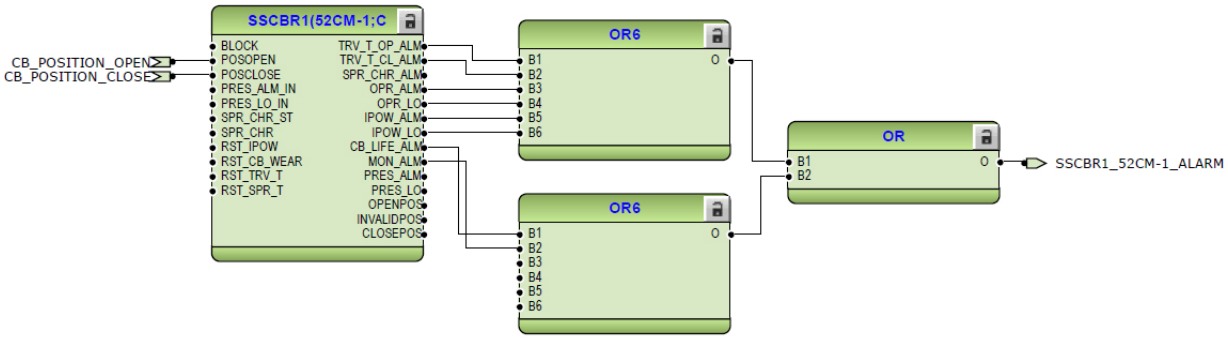


Figure 63: Circuit breaker condition monitoring

Cable fault detector (CFD) is offered for detecting self clearing in the feeder.

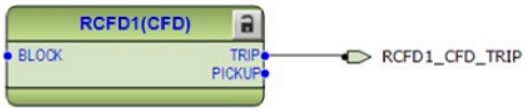


Figure 64: Cable fault detector

By default the TRIP output from CFD function is only connected to disturbance recorder.

3.3.9 Functional diagrams for measurements

The phase current inputs to the protection relay are measured by three-phase current measurement (IA, IB, IC) function block. The current input is connected to the X120 card. Similarly the sequence and residual current are measured by sequence current measurement (I1, I2, I0) and residual current measurement (IG) function blocks respectively.

The phase voltage input is connected to the X130 card. The voltages are measured by (VA,VB,VC) function block. Similarly the sequence voltages are measured by sequence

voltage measurement (V1, V2, V0) function block respectively.The residual voltage input voltage is measured by (VG) functin block.

The measurements can be seen from the LHMI and is available using the measurement option in the menu selection. Based on the settings, function blocks can generate low alarm/warning, high alarm/warning signals for the measured current values.

The frequency measurement of the power system (f) is available. Also single (SPEMMXU1) and three phase (PEMMXU1) power measurements are available.

The power quality function (PQI-1) is used to measure the harmonic contents of the phase current. This functionality is included according to ordercode selection.

The power quality function (PQVPH-1) is used to measure the harmonic contents of the phase voltages. This functionality is included according to ordercode selection.

The power quality function (PQSS-1) is used to measure the voltage variation i.e. sags and swells. This functionality is included according to ordercode selection.

The voltage unbalance power quality function PQVUB monitors voltage unbalance conditions in power networks. It is used to monitor the commitment of power supply utility of providing a balanced voltage supply on a continuous basis. The function provides statistics which can be used to verify compliance of the power quality.

The load profile (LoadProf) function is also included into measurements sheet. The load profile function offers ability to observe the history of the loading of the corresponding feeder.

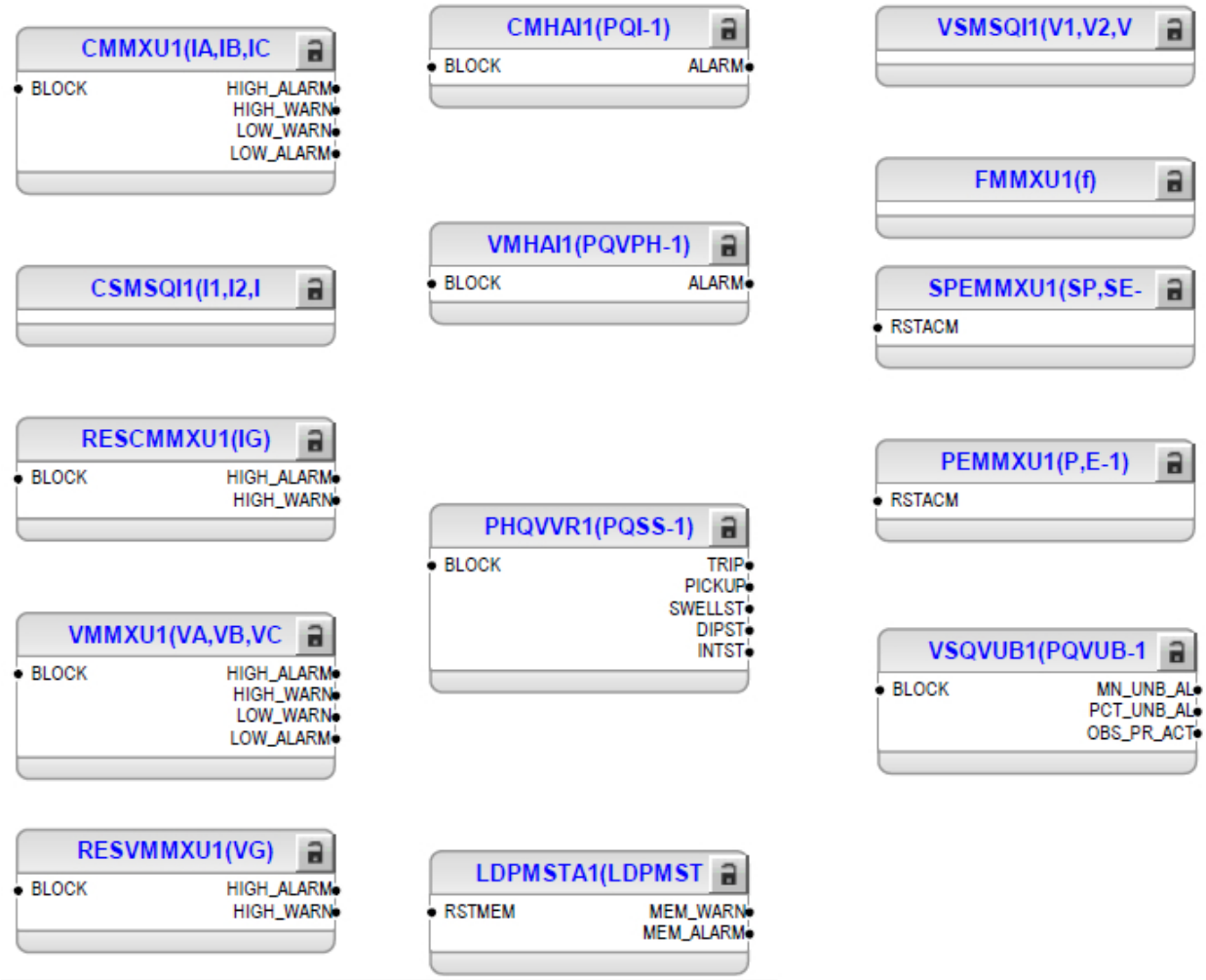


Figure 65: Current, voltage, power and energy measurements and load profile function

3.3.10 Functional diagrams for other functions

Configuration also includes other miscellaneous basic functions which are not configured, but can be used for creating general purpose logics. These functions include:

- Four instance of Minimum Pulse Timer TP(1), TP(2), TP(3) and TP(4)
- Two instance of Pulse Timer PT-1 and PT-2,
- Two instance of Time delay off TOF-1 and TOF-2

TOF-2 may be used to emulate DPU2000R physical and feedback output Dropout-After-Operate (DOAOO) timer

- Two instance of Time delay on TON-1 and TON-2

TON-2 may be used to emulate DPU2000R physical and feedback output Pickup-Before-Operate (PUBO) timer

- Four instance of Set reset logic SR-1, SR-2, SR-3 and SR-4,

SR-1 may be used to emulate DPU2000R LIS1-8, LIR1-8 and LO1-8

- Eight instance of Move logic MV-1, MV-2, MV-3, MV-4, MV-5, MV-6, MV-7 and MV-8

Instances MV-1 and MV-2 may be used to emulate DPU2000R ULI 1-16 where they are connected to ULO1-16, see RCNTRL below.

- Three instance of Generic control points CNTRL-1, CNTRL-2 and CNTRL-3,
- One Remote Generic Control Points, RCNTRL-1,

RCNTR-1 may be used to emulate DPU2000R remote controlling ULO1-16 where they are connected from ULI1-16

- One Local Generic Control Points, LCNTRL-1,
- Three Generic Up-Down counters UDFNCT1, UDFCNT2 and UDFCNT3, the last being optional.
- One Programmable buttons (16 buttons) FKEY.
- Three shift registers SHFT-1, SHFT-2 and SHFT-3

3.3.11 Functional diagrams for logging functions

The disturbance recorder DFR consists of 12 analog and 64 binary channels. The analog channels are pre configured in the protection relay as follows for this specific configuration:

Table 15: List of analog channels connected to DFR (REF615R Config A)

Ch. No	Channel
1	IA
2	IB
3	IC
4	IG
5	VA
6	VB
7	VC
8	VG
9	VA2[1]
10	
11	
12	

Note: 1) Channel designated VA2 is the Vsynch input to the protection relay

A few channels of the binary channel are connected to trigger the digital fault recorder as shown in Figure 66. As shown in the figure, only the first channel is enabled. Based on the application and requirement, more channels can be enabled. Also when disturbance recorder is triggered the analog values available at the analog inputs are recorded by fault recorder FR as a waveform or by the Load Profile record as a trend/cycle depending on the storage mode setting under Configuration>Disturbance recording>Analog Channel n > Storage mode for channel 'n'.

When opted for Load Profile Record, there are a number of channels available which can be selected for each channel described as part of the function in Technical Manual. Typically all the input analog channels and some of the power measurement functions such as real, reactive, apparent power, power factor can be selected.

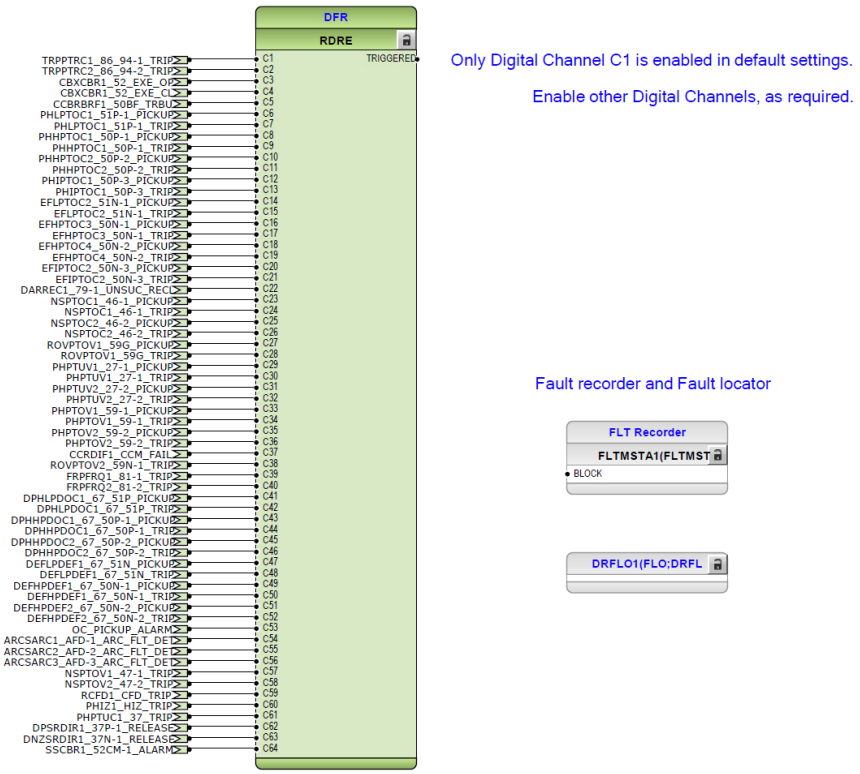


Figure 66: 64 channel Disturbance fault recorder and locator (Typical for a specific order code)

3.3.12 Functional diagrams for I/O and Alarm LEDs

The default binary I/O connected in the configuration and Alarm LEDs are indicated in Figure 67 to Figure 73.

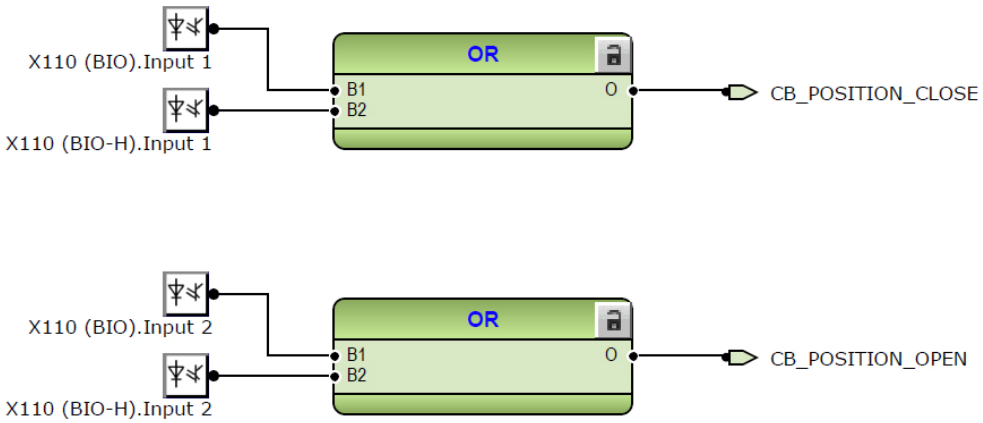


Figure 67: Binary inputs 1 and 2

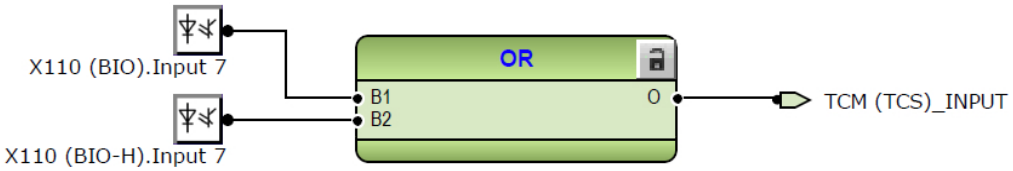


Figure 68: Binary input 7

Input 7 is indicated by default if Trip Circuit Monitoring is used. If the existing DPU2000R has IN8 as Trip Circuitonitoring, in order to avoid rewiring, replace the Input 7 in the configuration with X100(BIO).Input8 for wire-alike solution if standard output contacts are ordered in REF615R. If High-speed output configuration is ordered in REF615R, replace the input configuration with X130(AIM).Input9

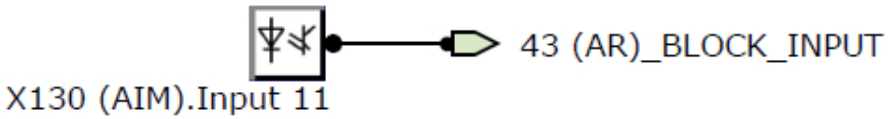


Figure 69: Binary input 11

Input 11 is indicated by default if external Auto reclose block input is to be wired from a selector switch 43AR. Replace the suggested Hardware Channel Input with X110IBIO).Input x or X110(BIO-H).Input x for standard Output or High Speed output configuration respectively, where "x" matches the existing DPU2000R physical input number used in the existing installation to block reclosing.

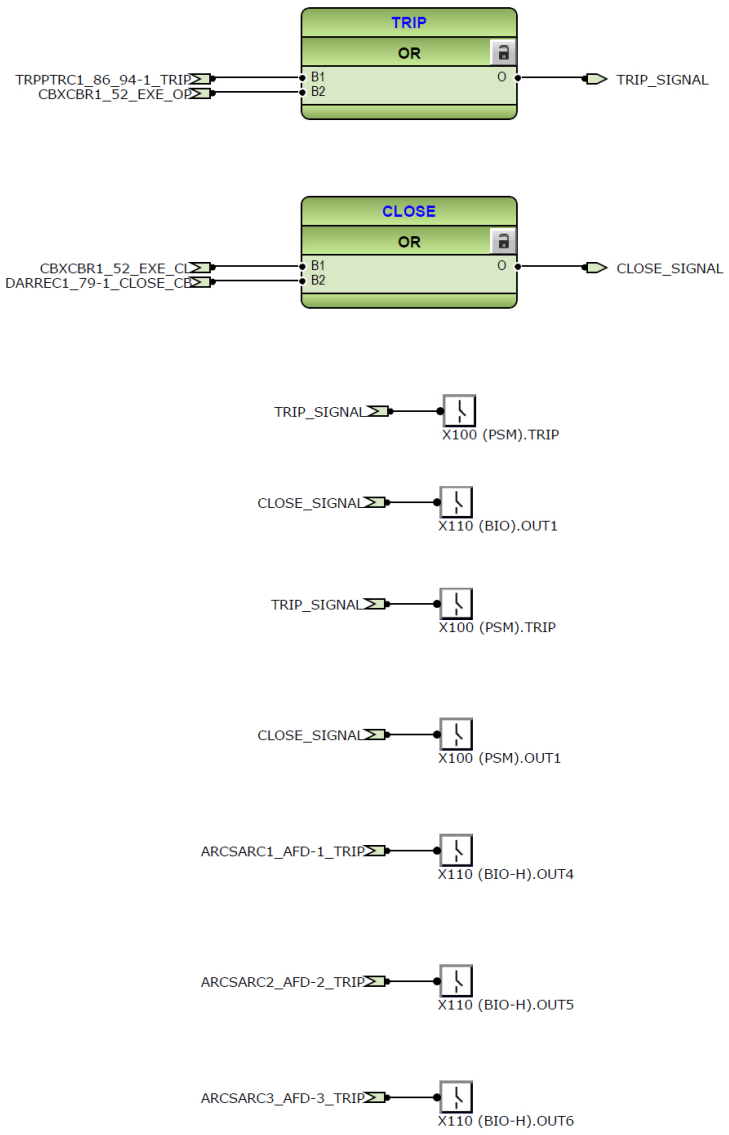


Figure 70: Binary outputs

High speed binary outputs (HSO) are available only if protection relay with High speed binary card has been ordered.

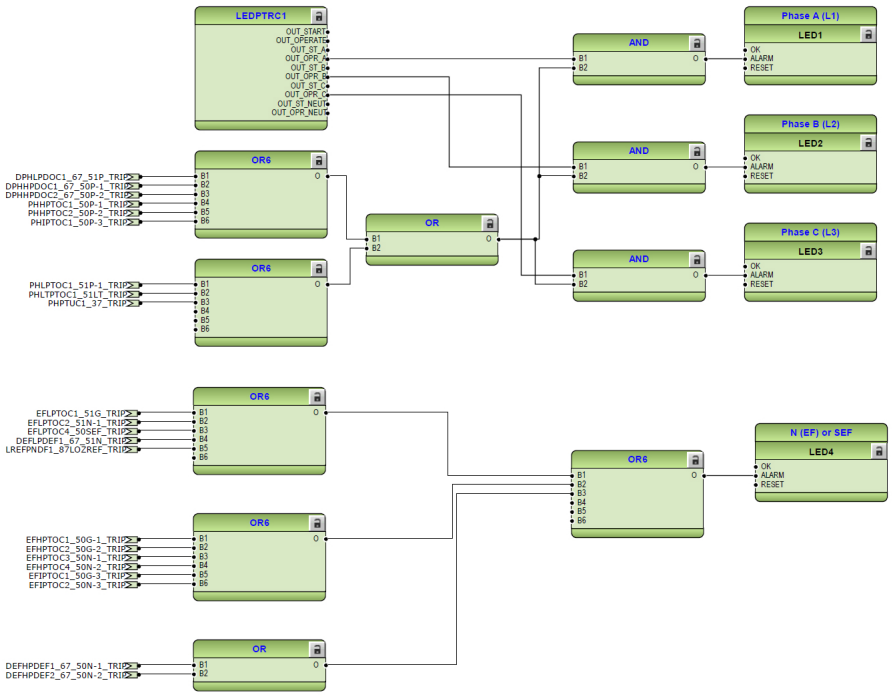


Figure 71: *Alarm LEDs 1 – 4*

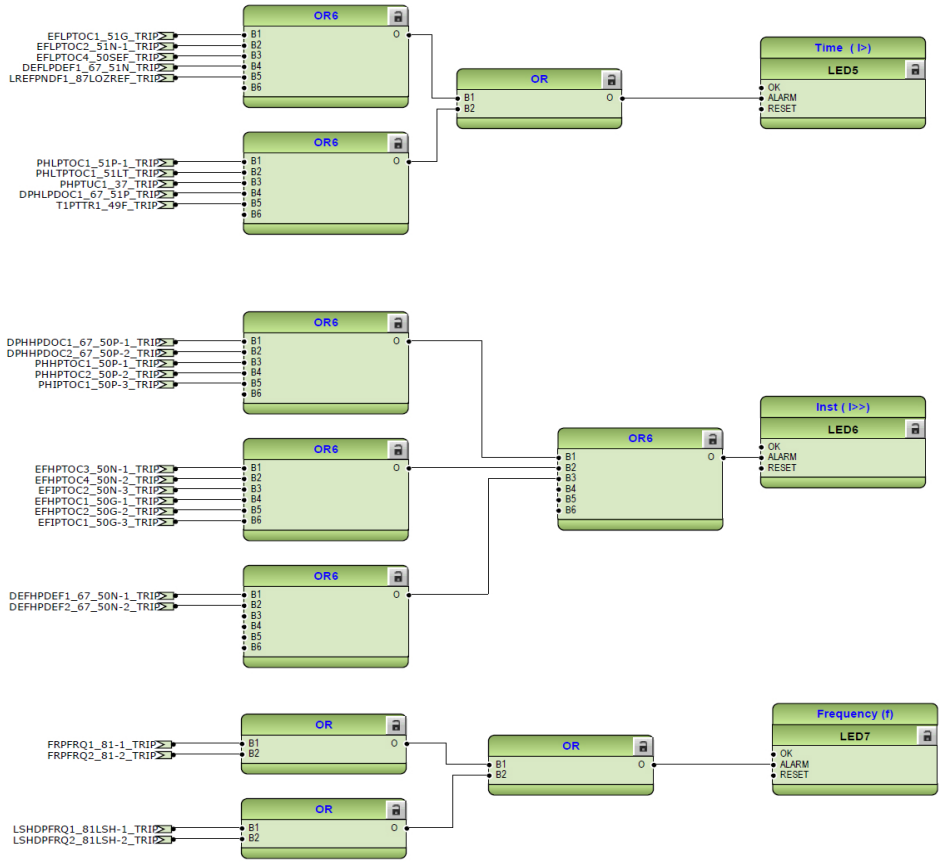


Figure 72: *Alarm LEDs 5– 7*

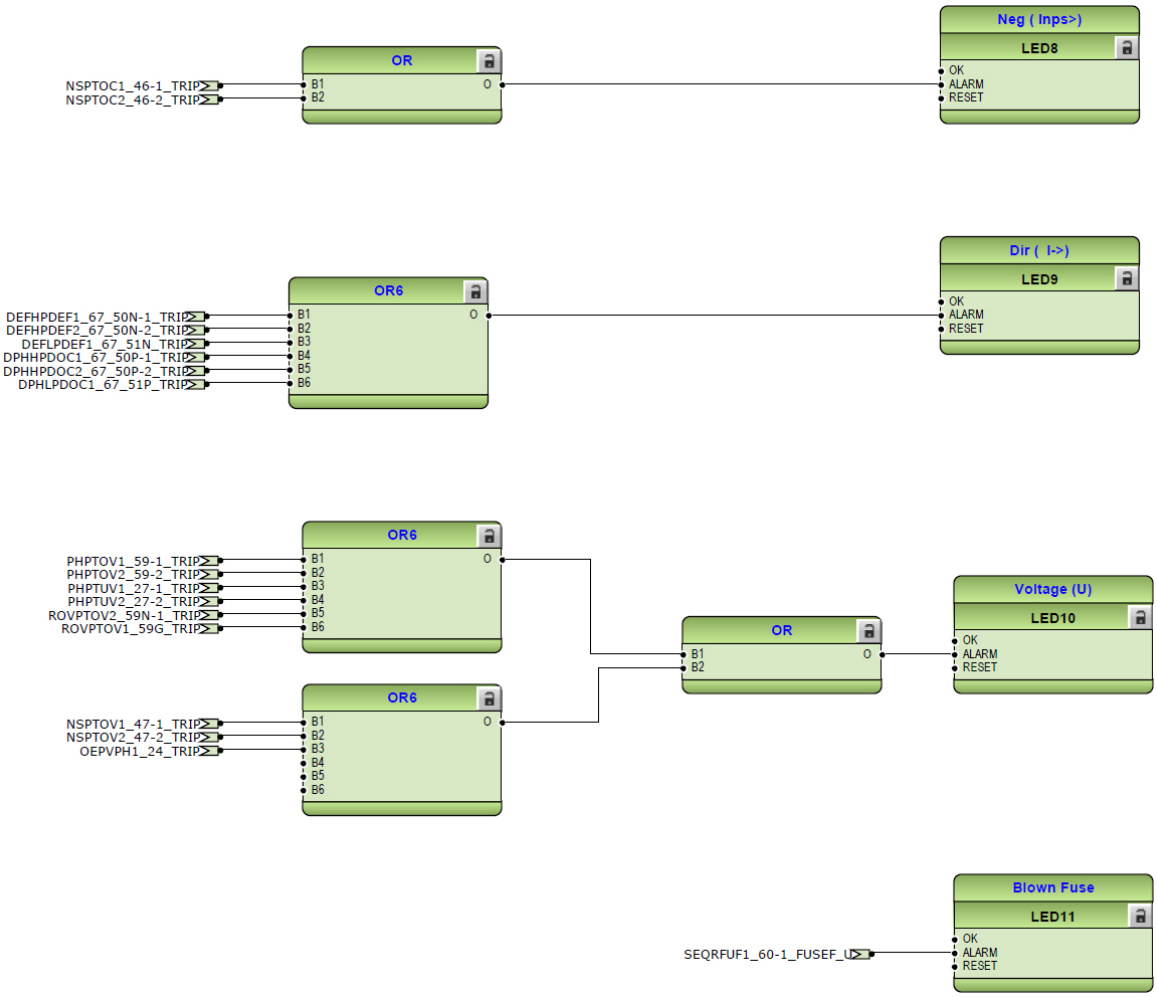


Figure 73: *Alarm LEDs 8 – 11*

Section 4 Requirement of current transformers

4.1 Current transformer requirement for protection

For reliable and correct operation of 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 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. Appropriate 'C' class CT should be used based on the total resistances of the CT secondary circuit.

4.1.1 AC saturation:

The TOC curve of the earlier electromechanical relays was achieved by allowing partial saturation of the internal magnetic circuits. Currents much higher than the higher limits of the TOC relays, which cause 'partial' saturation of the CTs should not affect the applications. However, if an application involves severe CT saturation, the relay may not function. Where the CT ratio is very low, CT secondary currents could exceed 20 times rated current causing severe saturation. The net outputs of such CTs may become so low (Figure 74) that operation of most of the protections become impossible.

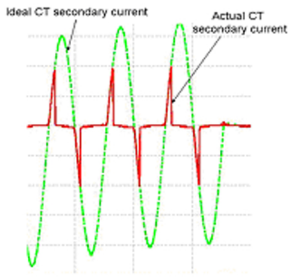


Figure 74: CT secondary waveform when severe AC saturation occurs

To avoid saturation, the CT shall develop adequate voltage such that

$$V_X > I_f (R_{CT}+R_L+R_B)$$ Equation 1

where,

I_f = Fault current on CT secondary (Amps)
R_{CT} = CT Secondary resistance (Ohms)
R_L = CT Secondary total lead resistance (Ohms)
and R_B = CT secondary connected burden (Ohms)

The lead resistance R_L is the total secondary loop lead resistance. In case of single phase to ground faults, the current from the CT secondary flows through the phase connection and returns through the neutral wire. Hence twice the 'one-way' lead resistance shall be considered. In case of multi-phase faults, the phase currents cancel out with negligible current in the common neutral return lead. Hence the lead resistance for such faults will be just that of the 'one-way' lead. Special cases arise with delta connected CTs. In all such cases a very careful evaluation of how the CT under question drives currents through the leads would be necessary.

4.1.2 Transient saturation:

Transients, especially the decaying DC waveform in the primary current, cause the CT to go into saturation and produce distorted current waveform. Once the transients vanish the steady state performance of the CT gets restored.

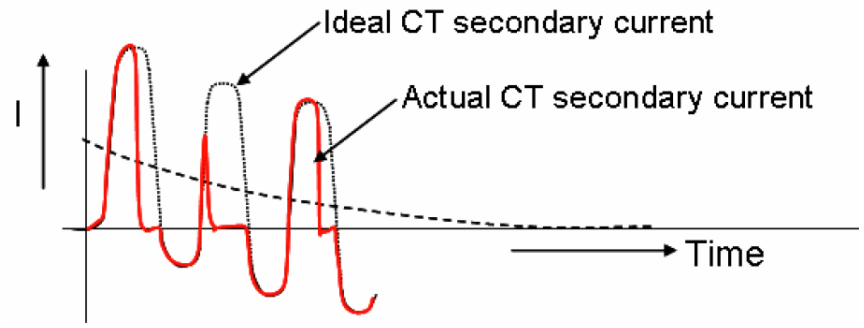


Figure 75: CT waveform when saturation occurs due to DC transients

It can be shown that the CT shall have enough capacity to develop the following voltage not to saturate at all for a combination of AC and DC transient.

$$V_X > I_f (1+X/R) (R_{CT}+R_L+R_B)$$ Equation 2

where,

I_f = Fault current on CT secondary (Amps)
X = System Primary Reactance (in Ohms)
R_{CT} = CT Secondary resistance (Ohms)
R_L = CT Secondary total lead resistance (Ohms)
and R_B =CT secondary connected burden (Ohms)

Note that there is an additional factor (1+X/R) on the right side of the equation compared to the equation applied for AC saturation, Equation (1).

The ANSI specifies CTs for protection performance by a letter (IEEE Std C57.13- 1993). The classification codes are **C**, **K** and **T**. The classification **C** is widely used for protection. They indicate that the winding is uniformly wound around the core with negligible leakage flux. The **C** class CT is furnished with excitation characteristics which can be used to "**C**alculate" the CT performance. The standard ratings are C100, C200, C400, C800 corresponding to 100, 200, 400 and 800 volts respectively at 100A CT secondary. This would mean the design burdens are 1, 2, 4 and 8 Ohms respectively. Other burdens such as 0.1, 0.2 and 0.5 with corresponding voltages 10, 20, 50 are also specified but are not often used for HV and EHV applications. ANSI specifies the power factor of the burden at 0.5.

A steady state current error of 10% is allowed at 100A secondary, which translates into 10A excitation current. It is easy to look up the CT excitation characteristics corresponding to 10A excitation current and find out the induced voltage inside the CT. Subtracting the internal drop of $\mathbf{R_{CT}}$ through 100A fault current from the voltage should be above 100, 200, 400 or 800V to classify the CT as either C100, C200, 400 or 800.

The **K** classification is the same as **C** rating but the knee-point voltage must be at least 70% of the secondary terminal voltage rating. The letter **T** indicates the ratio error must be determined by '**T**est'. There are other classification types **H** and **L**, which are older specifications and are no longer in use.

An ANSI C800 CTs will have a saturation voltage of about,

$$Vx = 100(R_{CT} + 8)$$

Equation 3

Here 100 represents the recommended maximum CT secondary current of the CT during fault conditions (= 20 times nominal current of 5A), 8 is the burden expected to be connected to C800 class CT.

Comparing against the earlier equation (3), to avoid saturation,

$$100(R_{CT} + 8) > I_f\ (1+X/R)\ (R_{CT}+R_L+R_B)$$

Equation 4

Define Ni = 100/If

$$Nr = \{R_{CT} + 8(\text{design burden for C800})\} / (R_{CT}+R_L+R_B)$$

Substituting in (4) above,

$$(1+X/R) < Ni\ Nr$$

Equation 5

4.1.3 Remanence flux:

An additional dimension to the above issue is the residual magnetizing field left over in the CT core on clearance of a fault. When a fault with a heavy DC transient occurs, the flux density may go to a very high level. Once the fault is cleared, due to magnetic retention of the excited material, a certain amount of magnetism is retained. This has been found to be as high as 90% in some of the magnetic material.

In other words, in order to design a CT which will always reproduce the currents accurately, it may be necessary to increase the CT size by a term **(1+X/R)**/ (1-**ψ**) where **ψ** represents the per unit of maximum flux remaining in the CT core after removal of the primary fault current.

For example if the residual flux is 25%, **ψ** = 0.25. So the resultant CT sizing requirement goes up by a factor **1/ (1- ψ)** = 1/ (1-0.25) =1.33. In other words the requirement goes up by 33%. In case the CT retains 90% residual flux, it can be seen that the requirement of the CT size goes up by a factor of 900%.

The continuity or polarity of a current transformer is tested before putting it into service. DC test current injected into the CT will cause a unidirectional flux build up, sufficient to cause adequate remanence magnetic flux that may interfere with relay operation. It is very difficult to get rid of the remanence flux once established. Special de-magnetizing procedure is adopted to reduce the remaining flux.

Various methods are used to reduce the effects of remanence (Std. IEEE C37.110):

a Using different grades of steel for the core

b Gapped core

c Biased core CTs.

Of the three, the second method is widely practiced.

4.1.4 Practical CT sizing considering CT saturation:

The inequality considered earlier assumes no saturation. Modern high-speed relays operate quite fast, often taking an internal trip decision quite earlier than the onset of saturation even after considering remanence.

It is possible to calculate the time to saturate for any CT given the set of saturation voltage, remanence level, details of connected burden etc. Once the time to saturation is known a quick check against the time of operation of the protective relay would indicate whether the application would function properly with respect to the CT characteristics. Special care is needed when high speed autoreclose is concerned since the remanence magnetism and the CT secondary transient effects are the maximum when a reclose is attempted with a permanent fault on the line. Figure 76 provides a graphical representation of time to

saturation of a CT. Detailed mathematical terms to calculate 'time-to-saturate' are available in IEEE C37.110.

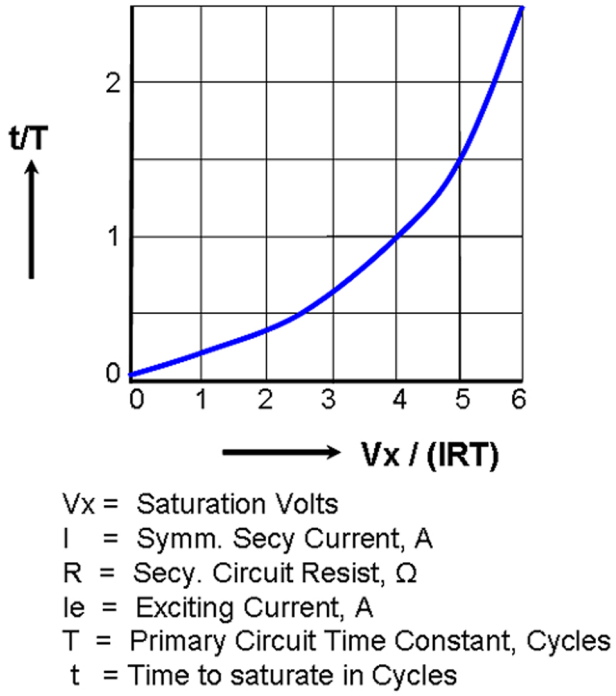


Figure 76: Time to saturate as a function of the saturation voltage and secondary circuit resistance

IEC standards have special classifications for CTs with gaps and specify their performance and remanence limits (IEC-60044-6).

4.1.5 CT Requirements for various protection applications

Once the CT specifications are known, it is necessary to match against the requirements of the protections. The following highlight some of the most often used protections and how CTs are matched for proper performance.

4.1.5.1 Time OC protection

TOC protection demands currents up to about 20 to 30 times the set current. The transient saturation is not of concern since the protection operating times are much after the CT comes out of saturation. AC saturation is of concern and CT saturation voltage has to be checked against the voltage generated during maximum fault conditions at which grading with other protections are provided.

4.1.5.2 High set

The operating times of High-set Phase or Ground OC elements are of the order of about a cycle. To ensure high speed of operation, it is essential to check both AC saturation as well as transient saturation of the CT. Where CT saturation cannot be avoided, it is necessary that the highset operates before the CT starts saturating on transients.

Section 5 Protection relay physical connections

5.1 Inputs

5.1.1 Auxiliary supply voltage input

Table 16: Auxiliary voltage supply

Terminal	Description
VDC+	+ Input
VDC-	- Input

5.1.2 Binary inputs

The binary inputs can be used, for example, to generate a blocking signal, to unlatch output contacts, to trigger the digital fault recorder or for remote control of protection relay settings. Binary inputs are available typically as part of Analog Input Modules (AIM) located in Slot ID X120 or X130 and in Binary Input and Output Modules (BIO)s located in Slot ID X110.

Table 17: Binary input terminals in protection relays with normal Binary outputsA

Terminal	Protection Relay Type	
	Protection Relays with Normal BO Contacts	protection relays with High Speed Contacts
4 3	IN1+ Common-	IN1+ Common-
5 3	IN2+ Common-	IN2+ Common-
6 3	IN3+ Common-	IN3+ Common-
7 3	IN4+ Common-	IN4+ Common-
8 3	IN5+ Common-	IN5+ Common-
9 3	IN6+ Common-	IN6+ Common-
10 11	IN7+ IN7-	IN7+ Common-
12 13	IN8+ IN8-	IN8+ Common-
39 40	IN9+ IN9-	IN9+ IN9-
41 42	IN10+ IN10-	IN10+ IN10-
43 44	IN11+ IN11-	IN11+ IN11-
Note: 1) Binary inputs 1-8 in protection relays with High Speed output contacts have common negative terminals 3, 11, and 13		

5.1.3 Optional light sensor inputs

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

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

Table 18: Light sensor input connectors

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

5.2 Outputs

5.2.1 Outputs for tripping and controlling

Output contacts in REF615R are heavy-duty trip contacts capable of controlling most circuit breakers.

Table 19: Trip Output (TO) contacts

	Protection Relay Type	
	Protection Relays with Normal BO Contacts	Protection Relays with High Speed Contacts
Terminal	Description	Description
29	Trip *	Trip *
30	Trip *	Trip *
27	OUT1 *	OUT1
28	OUT1 *	OUT1
25	OUT2 *	OUT2
26	OUT2 *	OUT2
23	OUT3	OUT3
24	OUT3	OUT3
21	OUT4	OUT4**
22	OUT4	OUT4
19	OUT5	OUT5**
20	OUT5	OUT5
17	OUT6	OUT6**
18	OUT6	OUT6

Notes: * TRIP outputs in all models and OUT1 & OUT2 contacts in protection relays ordered with normanl BO output can be configured as either NO or NC.
** High Speed Trip OUT4, OUT5, OUT6 contacts in protection relays ordered with high speed contacts.

5.2.2 IRF

The IRF contact functions as an output contact for the self-supervision system of the protection protection relay. Under normal operating conditions, the protection relay is energized and the contact is closed (15-16). When a fault is detected by the self-supervision system or the auxiliary voltage is disconnected, the output contact drops off and the contact closes (15-14).

Table 20: IRF contact

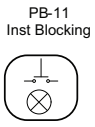
Terminal	Description
15	IRF, common
14	Closed; IRF, or V_{aux} disconnected
16	Closed; no IRF, and V_{aux} connected

Section 6 Glossary

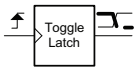
615 Series / 615R	ABB Relion® family's series of numerical protection relays for basic to mid-range protection and supervision applications of utility substations, and industrial switchgear and equipment. REF615R is a wire-alike replacement option for DPU2000R with the same form factor
100BASE-FX	A physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses fibre-optic cabling
100BASE-TX	A Physical media defined in the IEEE 802.3 Ethernet standard for local area networks (LANs) that uses twisted-pair cabling category 5 or higher with RJ-45 connectors
ANSI	American National Standards Institute
BI	Binary input
BI/O	Binary input/output
BO	Binary output
CB	Circuit breaker
CT	Current transformer
CBCT	Core Balance Current Transformer
DFR	Digital fault recorder
DPU2000R	ABB's Distribution Protection Unit 2000R, an advanced microprocessor-based relay that protects electrical power subtransmission and distribution systems
DNP3	A distributed network protocol originally developed by Westronic. The DNP3 Users Group has the ownership of the protocol and assumes responsibility for its evolution.
EMC	Electromagnetic compatibility
GOOSE	Generic Object Oriented Substation Event
HMI	Human-machine interface
HW	Hardware
HSO	High-speed Output is a hybrid discrete/electromechanical output that is rated as a power output.
IEC 61850	International standard for substation communication and modelling
Protection relay	Intelligent electronic device

IP address	A set of four numbers between 0 and 255, separated by periods. Each server connected to the Internet is assigned a unique IP address that specifies the location for the TCP/IP protocol.
IRIG-B	Inter-Range Instrumentation Group's time code format B
LAN	Local area network
LC	Connector type for glass fiber cable
LCD	Liquid crystal display
LED	Light-emitting diode
LHMI	Local human-machine interface
Modbus	A serial communication protocol developed by the Modicon company in 1979. Originally used for communication in PLCs and RTU devices.
MV	Medium voltage
PCM600	Protection and Control Protection Relay Manager
PO	Power output
RJ-45	Galvanic connector type
RS-232	Serial interface standard
RS-485	Serial link according to EIA standard RS485
SO	Signal output
TCP/IP	Transmission Control Protocol/Internet Protocol
TCS	Trip-circuit supervision
VT	Voltage Transformer
WAN	Wide area network
WCT	Window Type CT (Also refer to CBCT)
WHMI	Web human machine interface

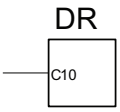
Legend



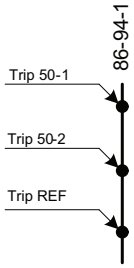
Pushbutton (with embedded LED) 11 on the front of the IED with legend 'Inst Blocking'



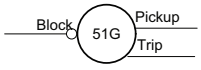
T Flip Flop
(output changes state on input rising edge)



Disturbance Recorder
(C10 - Input Channel 10)

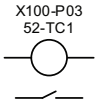


Signals Trip 50-1, Trip 50-2 and Trip REF are ORed to form signal 86-94-1



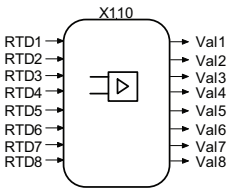
Protection Function 51G, with Pickup and Trip signal outputs, Protection blocked when input signal Block is high

Alarm LED 1 on the front of the IED, with legend 'A Ph'



Binary Output PO 3, on Slot ID X100, configured with signal 52-TC1
(PO- Power contact, SO- Signal Contact, HSO- High Speed output)

Binary Input B 12, on Slot ID X100, configured with signal Input 52a



RTD Input Slot ID X 110, Configured with signals from Bearing temp., Ambient Temperature etc.

Val Max ouptut is the maximum of three analog input values Val 1, Val2 and Val3

Figure 77: Legend

Contact us

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