ABB

Line Differential Protection and Control RED615

Product Guide

Contents

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Conformity

This product complies with following directive and regulations.

Directives of the European parliament and of the council:

- Electromagnetic compatibility (EMC) Directive 2014/30/EU
- Low-voltage Directive 2014/35/EU
- RoHS Directive 2011/65/EU

UK legislations:

- Electromagnetic Compatibility Regulations 2016
- Electrical Equipment (Safety) Regulations 2016
- The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012

These conformities are the result of tests conducted by the third-party testing in accordance with the product standard EN / BS EN 60255-26 for the EMC directive / regulation, and with the product standards EN / BS EN 60255-1 and EN / BS EN 60255-27 for the low voltage directive / safety regulation.

The product is designed in accordance with the international standards of the IEC 60255 series.

1. Description

RED615 is a phase-segregated two-end line differential protection and control relay designed for utility and industrial power systems, including radial, looped and meshed distribution networks with or without distributed power generation. RED615 is also designed for the protection of line differential applications with a transformer within the protection zone. RED615 relays communicate between substations over a fiber optic link or a galvanic pilot wire connection. RED615 is a member of ABB's Relion ® product family and part of its 615 protection and control product series. The 615 series relays are characterized by their compactness and withdrawable-unit design. Re-engineered from the ground up, the 615 series has been guided by the IEC 61850 standard for communication and interoperability of substation automation equipment.

The relay provides unit type main protection for overhead lines and cable feeders in distribution networks. The relay also features current-based protection functions for remote back-up for down-stream protection relays and local back-up for the line differential main protection. Further, standard configurations B and C also include earth-fault protection. Standard configurations D and E include directional overcurrent and voltage based protection functions.

The relay is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance earthed, compensated (impedance earthed) and solidly earthed

networks. Once the relay has been given the application-specific settings, it can directly be put into service.

The 615 series relays support a range of communication protocols including IEC 61850 with Edition 2 support, process bus according to IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported by using the protocol converter SPA-ZC 302.

2. Standard configurations

RED615 is available with five alternative standard configurations. The standard signal configuration can be altered by means of the signal matrix or the graphical application functionality of the Protection and Control IED Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions utilizing various logical elements including timers and flip-flops. By combining protection functions with logic function blocks the relay configuration can be adapted to user specific application requirements.

The relay is delivered from the factory with default connections described in the functional diagrams for binary inputs, binary outputs, function-to-function connections and alarm LEDs. Some of the supported functions in RED615 must be added with the Application Configuration tool to be available in the Signal Matrix tool and in the relay. The positive measuring direction of directional protection functions is towards the outgoing feeder.
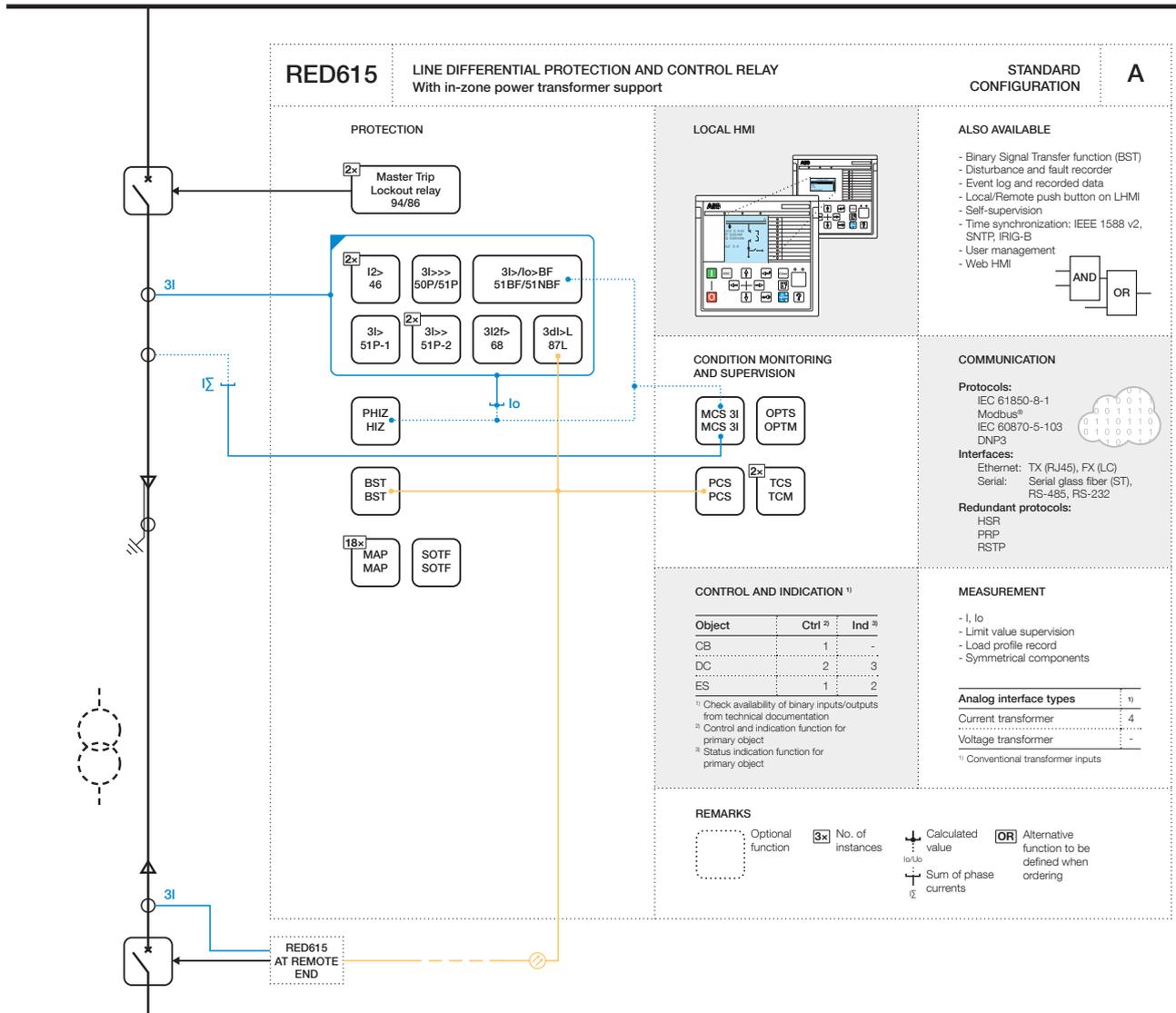
| RED615 | LINE DIFFERENTIAL PROTECTION AND CONTROL RELAY
With in-zone power transformer support | STANDARD
CONFIGURATION | A |

PROTECTION

2× Master Trip Lockout relay 94/86

2×		
I2> 46	3I>>> 50P/51P	3I>/Io>BF 51BF/51NBF
3I> 51P-1	2× 3I>> 51P-2	3I2f> 68	3dI>L 87L

PHIZ HIZ

BST BST

18×
MAP MAP

SOTF SOTF

LOCAL HMI

CONDITION MONITORING AND SUPERVISION

MCS 3I MCS 3I

OPTS OPTM

PCS PCS

2× TCS TCM

CONTROL AND INDICATION [1]

Object	Ctrl [2]	Ind [3]
CB	1	-
DC	2	3
ES	1	2

[1] Check availability of binary inputs/outputs from technical documentation
[2] Control and indication function for primary object
[3] Status indication function for primary object

ALSO AVAILABLE

- Binary Signal Transfer function (BST)
- Disturbance and fault recorder
- Event log and recorded data
- Local/Remote push button on LHMI
- Self-supervision
- Time synchronization: IEEE 1588 v2, SNTP, IRIG-B
- User management
- Web HMI

AND OR

COMMUNICATION

Protocols:
　IEC 61850-8-1
　Modbus®
　IEC 60870-5-103
　DNP3
Interfaces:
　Ethernet:　TX (RJ45), FX (LC)
　Serial:　Serial glass fiber (ST), RS-485, RS-232
Redundant protocols:
　HSR
　PRP
　RSTP

MEASUREMENT

- I, Io
- Limit value supervision
- Load profile record
- Symmetrical components

Analog interface types	[1]
Current transformer	4
Voltage transformer	-

[1] Conventional transformer inputs

REMARKS

┈ Optional function

3× No. of instances

⊥ Calculated value Io/Uo

⊥ Sum of phase currents IΣ

OR Alternative function to be defined when ordering

RED615 AT REMOTE END

Figure 1: Functionality overview for standard configuration A

RED615 — LINE DIFFERENTIAL PROTECTION AND CONTROL RELAY
With in-zone power transformer support — STANDARD CONFIGURATION **B**

PROTECTION

Master Trip Lockout relay 94/86 (2×)

I2> 46	I2/I1> 46PD	3Ith>F 49F
3Ith>T/G/C 49T/G/C	3I>>> 50P/51P	
3I>/Io>BF 51BF/51NBF	3I> 51P-1	
3I>> 51P-2 (2×)	3I2f> 68	3dI>L 87L

Io

BST BST

Io

Io

Io>> 51N-2	PHIZ HIZ
Io>→ 67N-1 (2×)	Io>>→ 67N-2	Io>IEF→ 67NIEF
Yo>→ 21YN (3×)	Po>→ 32N (3×)	Io>HA 51NHA
	OR	OR
Uo> 59G (3×)	MAP MAP (18×)	SOTF SOTF

LOCAL HMI

CONDITION MONITORING AND SUPERVISION

| CBCM CBCM | MCS 3I MCS 3I | OPTS OPTM |
| PCS PCS | | TCS TCM (2×) |

CONTROL AND INDICATION [1]

Object	Ctrl [2]	Ind [3]
CB	1	
DC	2	3
ES	1	2

[1] Check availability of binary inputs/outputs from technical documentation
[2] Control and indication function for primary object
[3] Status indication function for primary object

O→I 79

REMARKS

Optional function ┊ No. of instances (3×) ┊ Calculated value Io/Uo ┊ OR Alternative function to be defined when ordering

ALSO AVAILABLE

- Binary Signal Transfer function (BST)
- Disturbance and fault recorder
- Event log and recorded data
- Local/Remote push button on LHMI
- Self-supervision
- Time synchronization: IEEE 1588 v2, SNTP, IRIG-B
- User management
- Web HMI

AND OR

COMMUNICATION

Protocols:
IEC 61850-8-1
Modbus®
IEC 60870-5-103
DNP3
Interfaces:
Ethernet:　TX (RJ45), FX (LC)
Serial:　　Serial glass fiber (ST), RS-485, RS-232
Redundant protocols:
HSR
PRP
RSTP

MEASUREMENT

- I, Io, Uo
- Limit value supervision
- Load profile record
- Symmetrical components

Analog interface types	[1]
Current transformer	4
Voltage transformer	1

[1] Conventional transformer inputs

RED615 AT REMOTE END

Figure 2: Functionality overview for standard configuration B

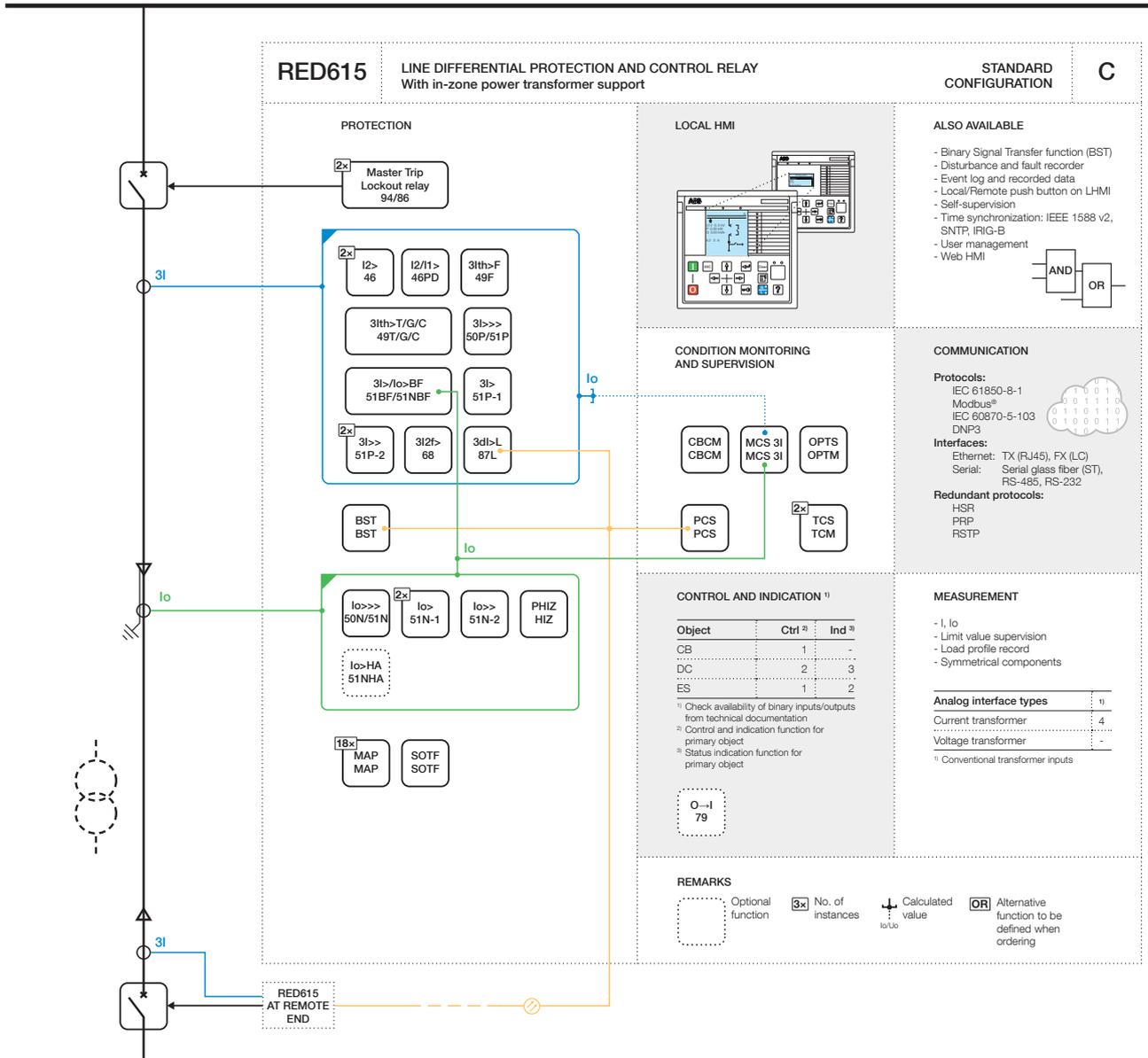*Figure 3: Functionality overview for standard configuration C*

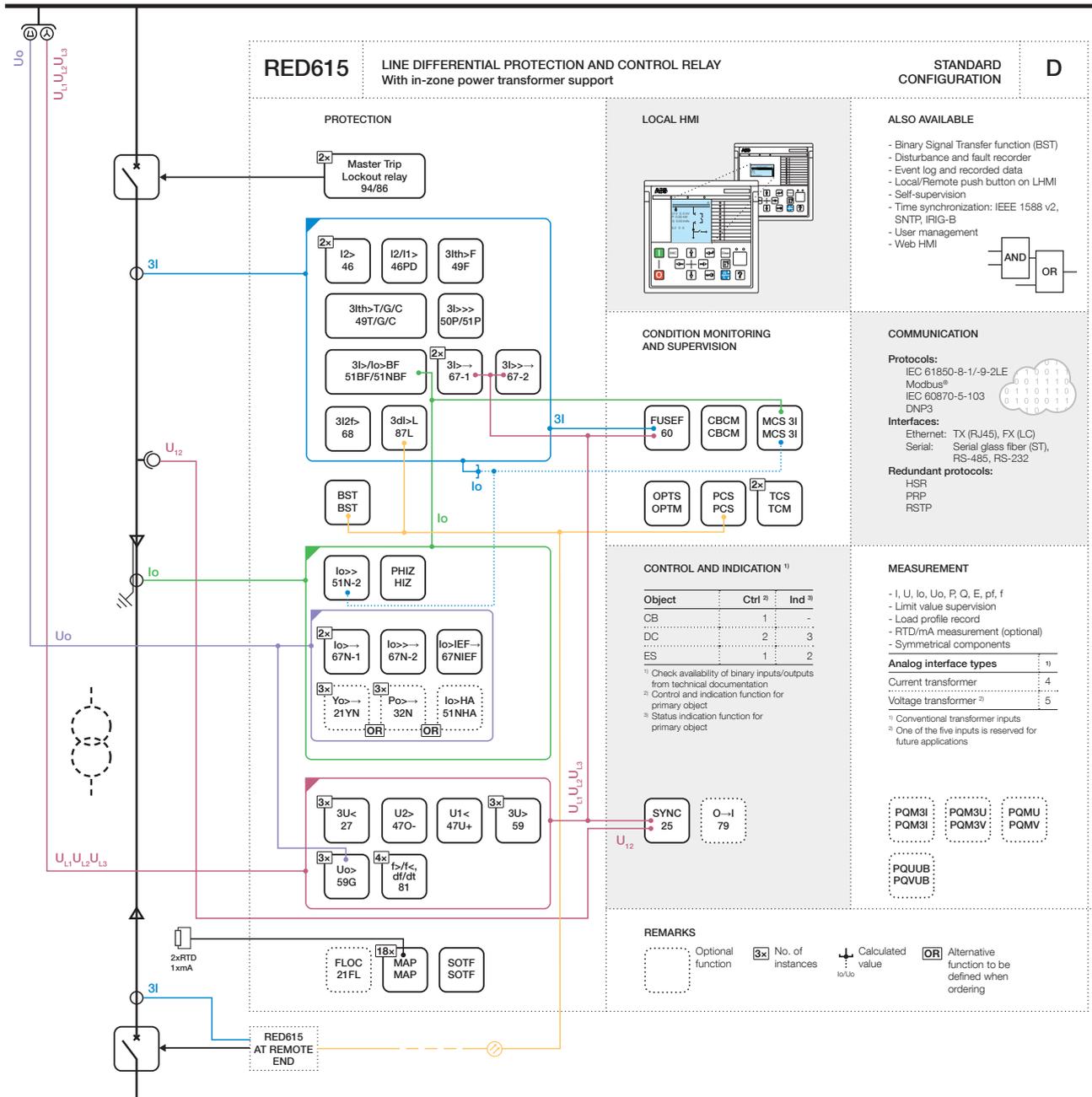*Figure 4: Functionality overview for standard configuration D*

Figure 5: Functionality overview for standard configuration E

Table 1: Standard configurations

Description	Std.conf
Line differential protection	A
Line differential protection with directional earth-fault protection and circuit-breaker condition monitoring	B
Line differential protection with non-directional earth-fault protection and circuit-breaker condition monitoring	C

Table continues on the next page

Description	Std.conf
Line differential protection with directional overcurrent and earth-fault protection, voltage and frequency based protection and measurements, synchro-check and circuit-breaker condition monitoring (RTD option, optional power quality and fault locator)	D
Line differential protection with directional overcurrent and earth-fault protection, voltage and frequency based protection and measurements, and circuit-breaker condition monitoring (sensor inputs, optional power quality, fault locator and synchro-check with IEC 61850-9-2 LE)	E

Table 2: Supported functions

Function	IEC 61850	A	B	C	D	E
Protection						
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	1	1	1		
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	2	2	2		
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC				2	2
Three-phase directional overcurrent protection, high stage	DPHHPDOC				1	1
Non-directional earth-fault protection, low stage	EFLPTOC			2		
Non-directional earth-fault protection, high stage	EFHPTOC			1		
Non-directional earth-fault protection, instantaneous stage	EFIPTOC			1		
Directional earth-fault protection, low stage	DEFLPDEF		2		2	2
Directional earth-fault protection, high stage	DEFHPDEF		1 [1]		1	1 [2]
Admittance-based earth-fault protection	EFPADM		(3) [1] [3]		(3) [3]	(3) [2] [3]
Wattmetric-based earth-fault protection [3]	WPWDE		(3) [1] [3]		(3) [3]	(3) [2] [3]
Transient/intermittent earth-fault protection	INTRPTEF		1 [1]		1 [4]	1 [2] [4]
Harmonics-based earth-fault protection [3]	HAEFPTOC		(1) [3] [4]	(1) [3] [4]	(1) [3] [4]	(1) [3] [4]
Non-directional (cross-country) earth-fault protection, using calculated Io	EFHPTOC		1		1	1
Negative-sequence overcurrent protection	NSPTOC	2	2	2	2	2
Phase discontinuity protection	PDNSPTOC		1	1	1	1
Residual overvoltage protection	ROVPTOV		3 [1]		3	3 [2]
Three-phase undervoltage protection	PHPTUV				3	3
Three-phase overvoltage protection	PHPTOV				3	3

Table continues on the next page

_____

[1] "Uo measured" is always used.
[2] "Uo calculated" is always used.
[3] One of the following can be ordered as an option: admittance-based E/F, wattmetric-based E/F or harmonics-based E/F.
[4] "Io measured" is always used.

Function	IEC 61850	A	B	C	D	E
Positive-sequence undervoltage protection	PSPTUV				1	1
Negative-sequence overvoltage protection	NSPTOV				1	1
Frequency protection	FRPFRQ				4	4
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR		1	1	1	1
Three-phase thermal overload protection, two time constants	T2PTTR		1	1	1	1
Binary signal transfer	BSTGGIO	1	1	1	1	1
Circuit breaker failure protection	CCBRBRF	1	1	1	1	1
Three-phase inrush detector	INRPHAR	1	1	1	1	1
Switch onto fault	CBPSOF	1	1	1	1	1
Master trip	TRPPTRC	2	2	2	2	2
Multipurpose protection	MAPGAPC	18	18	18	18	18
Fault locator	SCEFRFLO				(1)	(1)
Line differential protection with in-zone power transformer	LNPLDF	1	1	1	1	1
High-impedance fault detection	PHIZ	1	1	1	1	
Power quality						
Current total demand distortion	CMHAI				(1)	(1) [6]
Voltage total harmonic distortion	VMHAI				(1) [6]	(1) [6]
Voltage variation	PHQVVR				(1) [6]	(1) [6]
Voltage unbalance	VSQVUB				(1) [6]	(1) [6]
Control						
Circuit-breaker control	CBXCBR	1	1	1	1	1
Disconnector control	DCXSWI	2	2	2	2	2
Earthing switch control	ESXSWI	1	1	1	1	1
Disconnector position indication	DCSXSWI	3	3	3	3	3
Earthing switch indication	ESSXSWI	2	2	2	2	2
Autoreclosing	DARREC		(1)	(1)	(1)	(1)
Synchronism and energizing check	SECRSYN				1	(1)
Condition monitoring and supervision						
Circuit-breaker condition monitoring	SSCBR		1	1	1	1
Trip circuit supervision	TCSSCBR	2	2	2	2	2
Current circuit supervision	CCSPVC	1	1	1	1	1
Fuse failure supervision	SEQSPVC				1	1

Table continues on the next page

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[5] "Io calculated" is always used.

[6] Power quality option includes current total demand distortion, voltage total harmonic distortion, voltage variation and voltage unbalance.

[7] Available only with IEC 61850-9-2

Function	IEC 61850	A	B	C	D	E
Protection communication supervision	PCSITPC	1	1	1	1	1
Runtime counter for machines and devices	MDSOPT	1	1	1	1	1
Measurement						
Disturbance recorder	RDRE	1	1	1	1	1
Load profile record	LDPRLRC	1	1	1	1	1
Fault record	FLTRFRC	1	1	1	1	1
Three-phase current measurement	CMMXU	1	1	1	1	1
Sequence current measurement	CSMSQI	1	1	1	1	1
Residual current measurement	RESCMMXU		1	1	1	1
Three-phase voltage measurement	VMMXU				2	1 (1) [7]
Residual voltage measurement	RESVMMXU		1		1	
Sequence voltage measurement	VSMSQI				1	1
Three-phase power and energy measurement	PEMMXU				1	1
RTD/mA measurement	XRGGIO130				(1)	
Frequency measurement	FMMXU				1	1
IEC 61850-9-2 LE sampled value sending [7]	SMVSENDER				(1)	(1)
IEC 61850-9-2 LE sampled value receiving (voltage sharing) [7] [8]	SMVRCV				(1)	(1)
Other						
Minimum pulse timer (2 pcs)	TPGAPC	4	4	4	4	4
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	1	1	1	1	1
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	1	1	1	1	1
Pulse timer (8 pcs)	PTGAPC	2	2	2	2	2
Time delay off (8 pcs)	TOFGAPC	4	4	4	4	4
Time delay on (8 pcs)	TONGAPC	4	4	4	4	4
Set-reset (8 pcs)	SRGAPC	4	4	4	4	4
Move (8 pcs)	MVGAPC	2	2	2	2	2
Generic control point (16 pcs)	SPCGAPC	2	2	2	2	2
Analog value scaling (4 pcs)	SCA4GAPC	4	4	4	4	4
Integer value move (4 pcs)	MVI4GAPC	1	1	1	1	1

1, 2, ... = Number of included instances. The instances of a protection function represent the number of identical protection function blocks available in the standard configuration.

() = optional

3. Protection functions

The relay offers two-stage phase-segregated line differential protection, phase overcurrent

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[8] Available only with COM0031...0037

protection, negative-sequence overcurrent protection and circuit breaker failure protection. Depending on the chosen standard configuration, the basic functionality can be extended by thermal overload protection, non-directional or directional overcurrent protection, directional or non-directional earth-fault protection, sensitive earth-fault protection, phase discontinuity protection, transient/ intermittent earth-fault protection, residual overvoltage protection, phase-voltage and frequency based protection and three-pole multishot autoreclosing functions for overhead line feeders. For standard configurations B, D and E, admittancebased, wattmetric-based or harmonics-based earth-fault protection is offered as an option in addition to the directional earth-fault protection.

The line differential protection function includes a stabilized low stage and an instantaneous high stage. The stabilized low stage provides sensitive differential protection and remains stable during, for example, current transformer saturation conditions. The low-stage operation can be restrained using second harmonic detection if an out-of-zone power transformer is to be energized. The instantaneous high stage offers less sensitive differential protection but enables fast operation during high fault currents. If there is an in-zone transformer in the protection zone, the vector group is automatically compensated based on the winding types and clock number setting values.

The operating time characteristic for the low stage can be set to definite time or inverse definite time mode. The direct intertrip function ensures that both ends are always simultaneously tripped, independent of the fault current contribution.

4. Application

RED615 can be used in a variety of applications requiring an absolutely selective unit type protection system. The zone-ofprotection of a line differential protection system is the feeder section defined by the location of the current transformers in the local and the remote substation. RED615 can also be used for line differential protection if there is an in-zone transformer in the protected feeder section.

Combining horizontal GOOSE communication over a station bus and binary signal transfer over the protection communication link offers new application possibilities beyond traditional line differential protection. One interesting application based on inter-substation signal transfer is loss-ofmains (LOM) protection in networks with distributed generation. The performance of the combination of binary signal transfer and horizontal GOOSE communication performance as to speed, selectivity and reliability are hard to match with conventional loss-of-mains protection.

RED615 is the ideal relay for the protection of feeders in network configurations containing closed loops. Under normal operating conditions the feeder loop is closed. The aim of the closed loop is to secure the availability of power for the end users. As a result of the closed loop configuration, any fault spot in the system will be fed with fault current from two directions. Using plain overcurrent protection, either directional or non-directional, it is difficult to obtain fast and selective short circuit protection. With RED615 line differential protection relays the faulty part of the network can be selectively isolated, thus securing power distribution to the healthy part of the network.

The standard configuration E includes one conventional residual current (Io) input and three combi-sensor inputs for phase currents and phase voltages. The connection of the three combi-sensors is made with RJ-45 type of connectors.

Sensors offer certain benefits compared to conventional current and voltage instrument transformers. For example, current sensors do not saturate at high currents, they consume less energy and they weigh less. In voltage sensors the risk of ferro-resonance is eliminated. The sensor inputs also enable the use of the relay in compact medium voltage switchgears, such as ABB's UniGear Digital, SafeRing and SafePlus, with limited space for conventional measuring transformers, thus requiring the use of sensor technology. Further, the adapters also enable the use of sensors with Twin-BNC connectors.

Under certain operational circumstances, such as maintenance of primary equipment or substation extension projects there will be a need to interconnect network parts, which normally are separated. To avoid major re-

parameterization of the protection devices of the network when the network topology is changed, line differential protection relays can

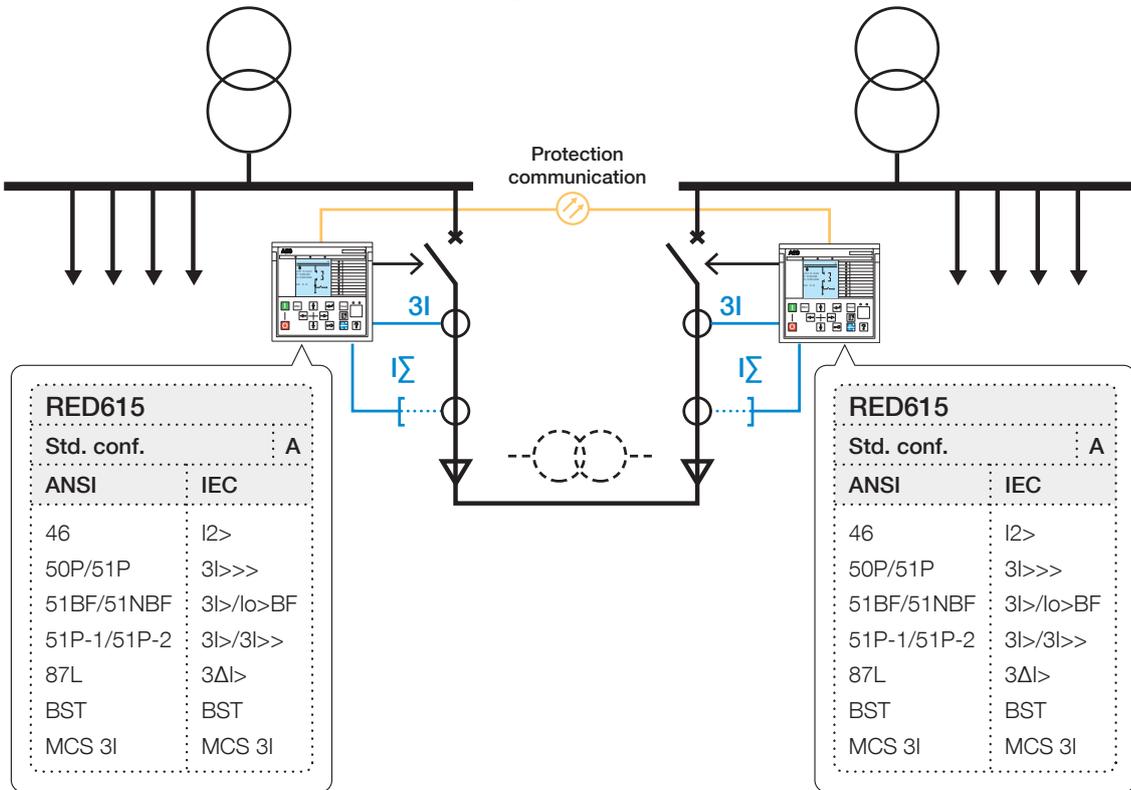be used to obtain absolutely selective feeder protection in looped networks.

Figure 6: Line differential protection for an interconnecting feeder between two primary distribution substations using standard configuration A

Figure 6 illustrates line differential protection for an interconnecting feeder between two primary distribution substations using standard configuration A. Additionally,

protection is offered for a in-zone power transformer, when available and located in the protection zone.

RED615	
Std. conf.	D
ANSI	**IEC**
46	I2>
47O-/59	U2>/3U>
47U+/27	U1</3U<
50P/51P	3I>>>
51BF/51NBF	3I>/Io>BF
67N-1/67N-2	Io>→/Io>>→
87L	3ΔI>
BST	BST
MCS 3I	MCS 3I

RED615	
Std. conf.	B/C
ANSI	**IEC**
46	I2>
49F/49T	3Ith>F/3Ith>T
50P/51P	3I>>>
51BF/51NBF	3I>/Io>BF
51N	Io>
87L	3ΔI>
BST	BST
MCS 3I	MCS 3I
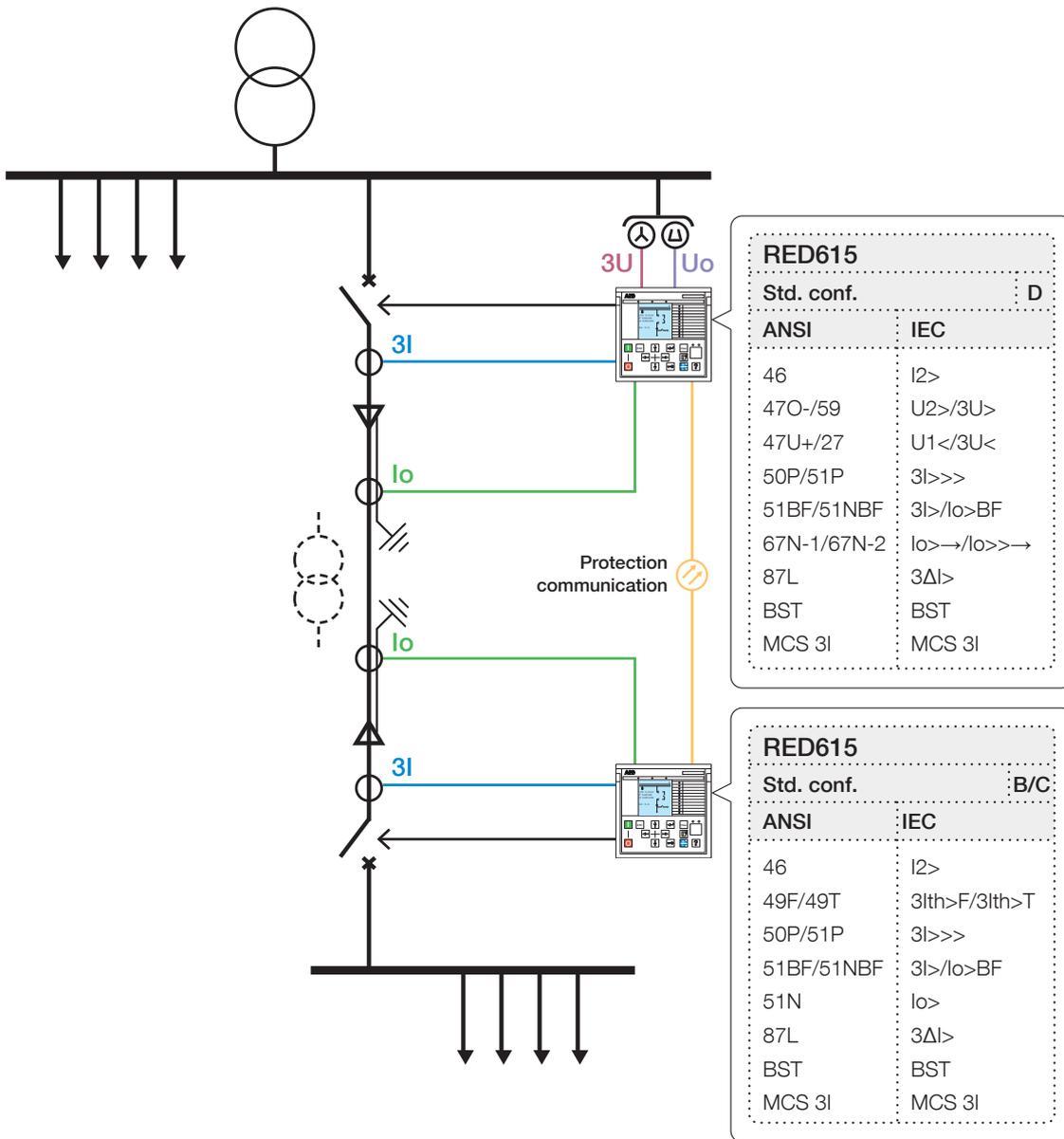
Figure 7: Line differential protection of a feeder using the standard configurations D and B or C

Line differential protection of a feeder using the standard configurations D and B or C is shown in *Figure 7*. Additionally, protection is offered for an in-zone power transformer, when available and located in the protection zone.
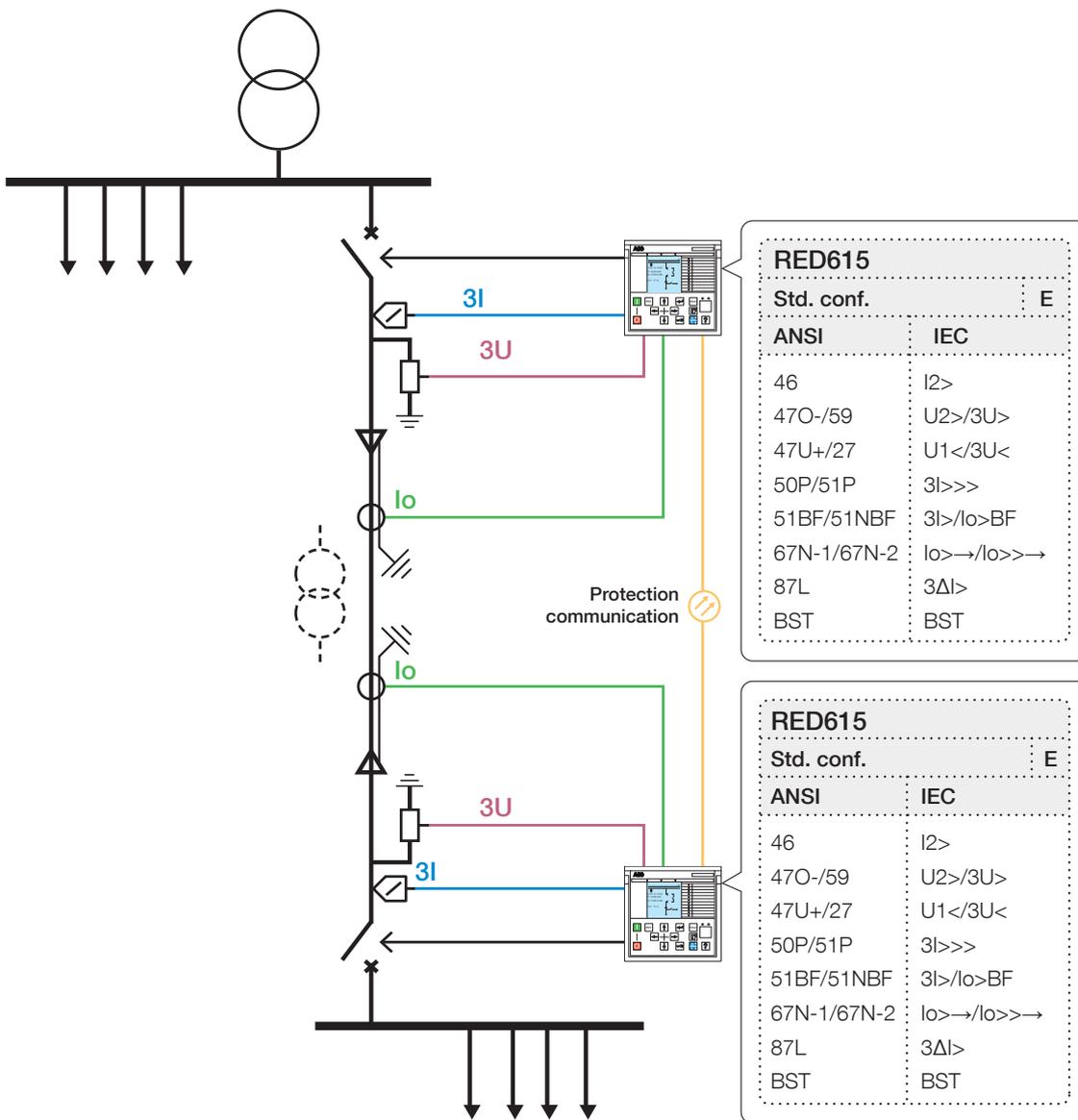
Figure 8: Line differential protection of a feeder using the standard configuration E

Figure 8 illustrates line differential protection of a feeder using the standard configuration E, in which current sensors (Rogowski coil) and voltage sensors (voltage divider) are used for the measurements. Additionally, protection is offered for an in-zone power transformer, when available and located in the protection zone. The standard configuration E has been preconfigured especially for ABB switchgears, for example, UniGear Digital. However, the use of this configuration is not restricted for this purpose only.

Standard configurations D and E are not designed for using all the available functionality content in one relay at the same time.

Frequency protection functions and third instances of voltage protection functions must be added with the Application Configuration tool. To ensure the performance of the relay, the user-specific configuration load is verified with the Application Configuration tool in PCM600.

5. Supported ABB solutions

The 615 series protection relays together with the Substation Management Unit COM600S constitute a genuine IEC 61850 solution for reliable power distribution in utility and industrial power systems. To facilitate the

system engineering, ABB's relays are supplied with connectivity packages. The connectivity packages include a compilation of software and relay-specific information, including single-line diagram templates and a full relay data model. The data model includes event and parameter lists. With the connectivity packages, the relays can be readily configured using PCM600 and integrated with COM600S or the network control and management system MicroSCADA Pro.

The 615 series relays offer native support for IEC 61850 Edition 2 also including binary and analog horizontal GOOSE messaging. In addition, process bus with the sending of sampled values of analog currents and voltages and the receiving of sampled values of voltages is supported. Compared to traditional hard-wired, inter-device signaling, peer-to-peer communication over a switched Ethernet LAN offers an advanced and versatile platform for power system protection. Among the distinctive features of the protection system approach, enabled by the full implementation of the IEC 61850 substation automation standard, are fast communication capability, continuous supervision of the protection and communication system's integrity, and an inherent flexibility regarding reconfiguration and upgrades.This protection relay series is able to optimally utilize interoperability provided by the IEC 61850 Edition 2 features.

At substation level, COM600S uses the data content of the baylevel devices to enhance substation level functionality. COM600S features a Web browser-based HMI, which provides a customizable graphical display for visualizing single-line mimic diagrams for switchgear bay solutions. The SLD feature is especially useful when 615 series relays without the optional single-line diagram feature are used. The Web HMI of COM600S also provides an overview of the whole substation, including relay-specific single-line diagrams, which makes information easily accessible. Substation devices and processes can also be remotely accessed through the Web HMI, which improves personnel safety.

In addition, COM600S can be used as a local data warehouse for the substation's technical documentation and for the network data collected by the devices. The collected network data facilitates extensive reporting and analyzing of network fault situations by using the data historian and event handling features of COM600S. The historical data can be used for accurate monitoring of process and equipment performance, using calculations based on both real-time and historical values. A better understanding of the process dynamics is achieved by combining time-based process measurements with production and maintenance events.

COM600S can also function as a gateway and provide seamless connectivity between the substation devices and network-level control and management systems, such as MicroSCADA Pro and System 800xA.

GOOSE Analyzer interface in COM600S enables the following and analyzing the horizontal IEC 61850 application during commissioning and operation at station level. It logs all GOOSE events during substation operation to enable improved system supervision.

Table 3: Supported ABB solutions

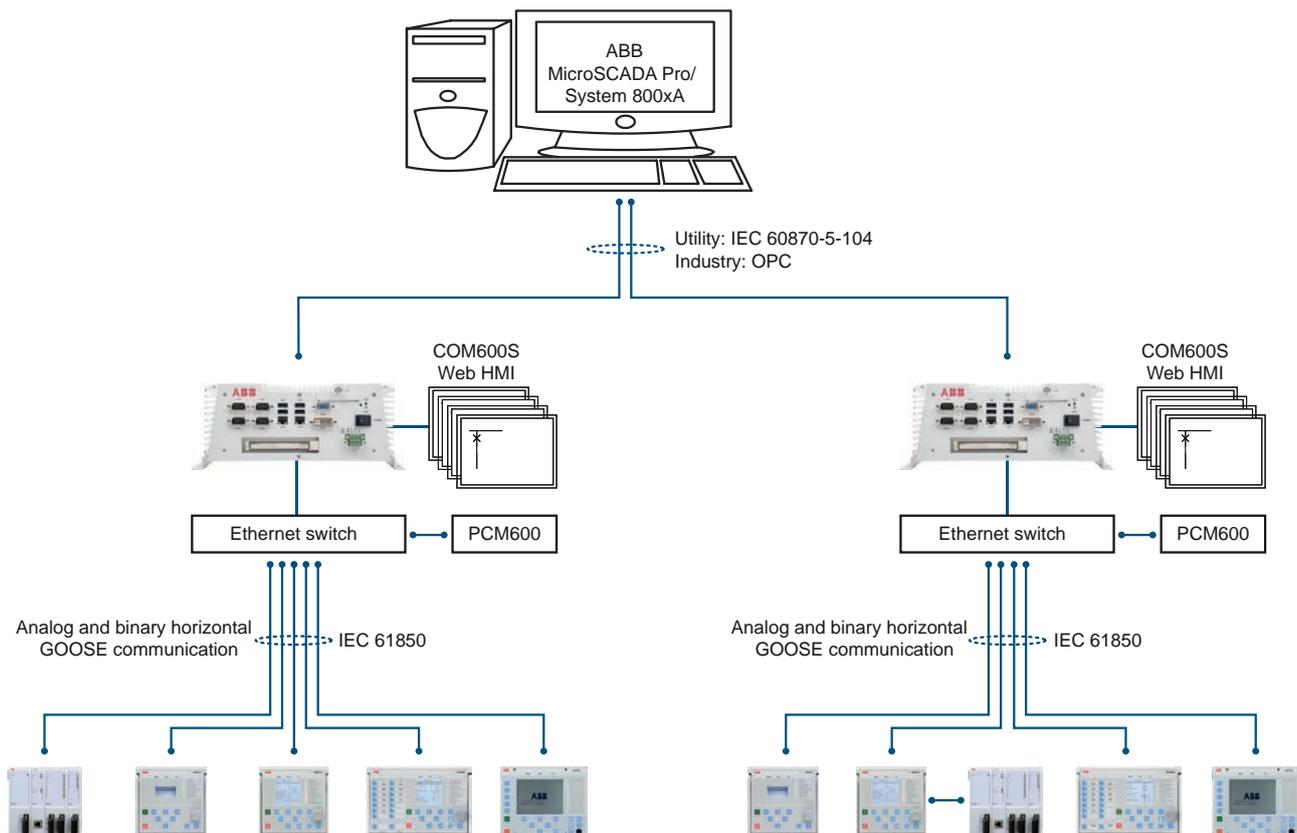| Product	Version
Substation Management Unit COM600S	4.0 SP1 or later
	4.1 or later (Edition 2)
MicroSCADA Pro SYS 600	9.3 FP2 or later
	9.4 or later (Edition 2)
System 800xA	5.1 or later

Figure 9: ABB power system example using Relion relays, COM600S and MicroSCADA Pro/System 800xA

6. Control

RED615 integrates functionality for the control of a circuit breaker via the front panel HMI or by means of remote controls. In addition to the circuit-breaker control the relay features two control blocks which are intended for motor-operated control of disconnectors or circuit breaker truck and for their position indications. Further, the relay offers one control block which is intended for motor-operated control of one earthing switch control and its position indication.

Two physical binary inputs and two physical binary outputs are needed in the relay for each controllable primary device taken into use. The number of unused binary inputs and binary outputs varies depending on the chosen standard configuration. Further, some standard configurations also offer optional hardware modules that increase the number of available binary inputs and outputs.

If the amount of available binary inputs or outputs of the chosen standard configuration is not sufficient, the standard configuration can be modified to release some binary inputs or outputs which have originally been configured for other purposes, when applicable, or an external input or output module such as RIO600 can be integrated to the relay. The binary inputs and outputs of the external I/O module can be used for the less time critical binary signals of the application. The integration enables the releasing of some initially reserved binary inputs and outputs of the relay in the standard configuration.

The suitability of the relay's binary outputs which have been selected for controlling of primary devices should be carefully verified, for example, the make and carry as well as the breaking capacity should be considered. In case the requirements for the control-circuit of the primary device are not met, the use of external auxiliary relays should be considered.

The optional large graphical LCD of the relay's HMI includes a single-line diagram (SLD) with position indication for the relevant

primary devices. Interlocking schemes required by the application are configured using the signal matrix or the application configuration functionality of PCM600.

7. Measurements

The relay continuously measures the phase currents, the symmetrical components of the currents and the residual current. If the relay includes voltage measurements, it also measures the residual voltage. The relay also calculates the demand value of the current over a user-selectable, pre-set time frame, the thermal overload of the protected object, and the phase unbalance based on the ratio between the negativesequence and positive-sequence current.

Furthermore, the relay monitors the phase differential, bias and remote-end phase currents.

The measured values can be accessed via the local HMI or remotely via the communication interface of the relay. The values can also be accessed locally or remotely using the Web HMI.

The relay is provided with a load profile recorder. The load profile feature stores the historical load data captured at a periodical time interval (demand interval). The records are in COMTRADE format.

8. Power quality

In the EN standards, power quality is defined through the characteristics of the supply voltage. Transients, short-duration and long-duration voltage variations and unbalance and waveform distortions are the key characteristics describing power quality. The distortion monitoring functions are used for monitoring the current total demand distortion and the voltage total harmonic distortion.

Power quality monitoring is an essential service that utilities can provide for their industrial and key customers. A monitoring system can provide information about system disturbances and their possible causes. It can also detect problem conditions throughout the system before they cause customer complaints, equipment malfunctions and even equipment damage or failure. Power quality problems are not limited to the utility side of the system. In

fact, the majority of power quality problems are localized within customer facilities. Thus, power quality monitoring is not only an effective customer service strategy but also a way to protect a utility's reputation for quality power and service.

The protection relay has the following power quality monitoring functions.

- Voltage variation
- Voltage unbalance
- Current harmonics
- Voltage harmonics

The voltage unbalance and voltage variation functions are used for measuring short-duration voltage variations and monitoring voltage unbalance conditions in power transmission and distribution networks.

The voltage and current harmonics functions provide a method for monitoring the power quality by means of the current waveform distortion and voltage waveform distortion. The functions provide a short-term three-second average and a long-term demand for total demand distortion TDD and total harmonic distortion THD.

9. Fault location

RED615 features an optional impedance-measuring fault location function suitable for locating short-circuits in radial distribution systems. Earth faults can be located in effectively and low-resistance earthed networks. Under circumstances where the fault current magnitude is at least of the same order of magnitude or higher than the load current, earth faults can also be located in isolated neutral distribution networks. The fault location function identifies the type of the fault and then calculates the distance to the fault point. An estimate of the fault resistance value is also calculated. The estimate provides information about the possible fault cause and the accuracy of the estimated distance to the fault point.

10. Disturbance recorder

The relay is provided with a disturbance recorder featuring up to 12 analog and 64 binary signal channels. The analog channels can

be set to record either the waveform or the trend of the currents and voltages measured.

The analog channels can be set to trigger the recording function when the measured value falls below or exceeds the set values. The binary signal channels can be set to start a recording either on the rising or the falling edge of the binary signal or on both.

By default, the binary channels are set to record external or internal relay signals, for example, the start or trip signals of the relay stages, or external blocking or control signals. Binary relay signals, such as protection start and trip signals, or an external relay control signal via a binary input, can be set to trigger the recording. Recorded information is stored in a nonvolatile memory and can be uploaded for subsequent fault analysis.

11. Event log

To collect sequence-of-events information, the relay has a nonvolatile memory capable of storing 1024 events with the associated time stamps. The non-volatile memory retains its data even if the relay temporarily loses its auxiliary supply. The event log facilitates detailed pre- and post-fault analyses of feeder faults and disturbances. The considerable capacity to process and store data and events in the relay facilitates meeting the growing information demand of future network configurations.

The sequence-of-events information can be accessed either via local HMI or remotely via the communication interface of the relay. The information can also be accessed locally or remotely using the Web HMI.

12. Recorded data

The relay has the capacity to store the records of the 128 latest fault events. The records can be used to analyze the power system events. Each record includes, for example, phase, differential and bias current values and a time stamp. The fault recording can be triggered by the start or the trip signal of a protection block, or by both. The available measurement modes include DFT, RMS and peak-to-peak. Fault records store relay measurement values at the moment when any protection function starts. In addition, the maximum demand current with time stamp is separately recorded. The records are stored in the non-volatile memory.
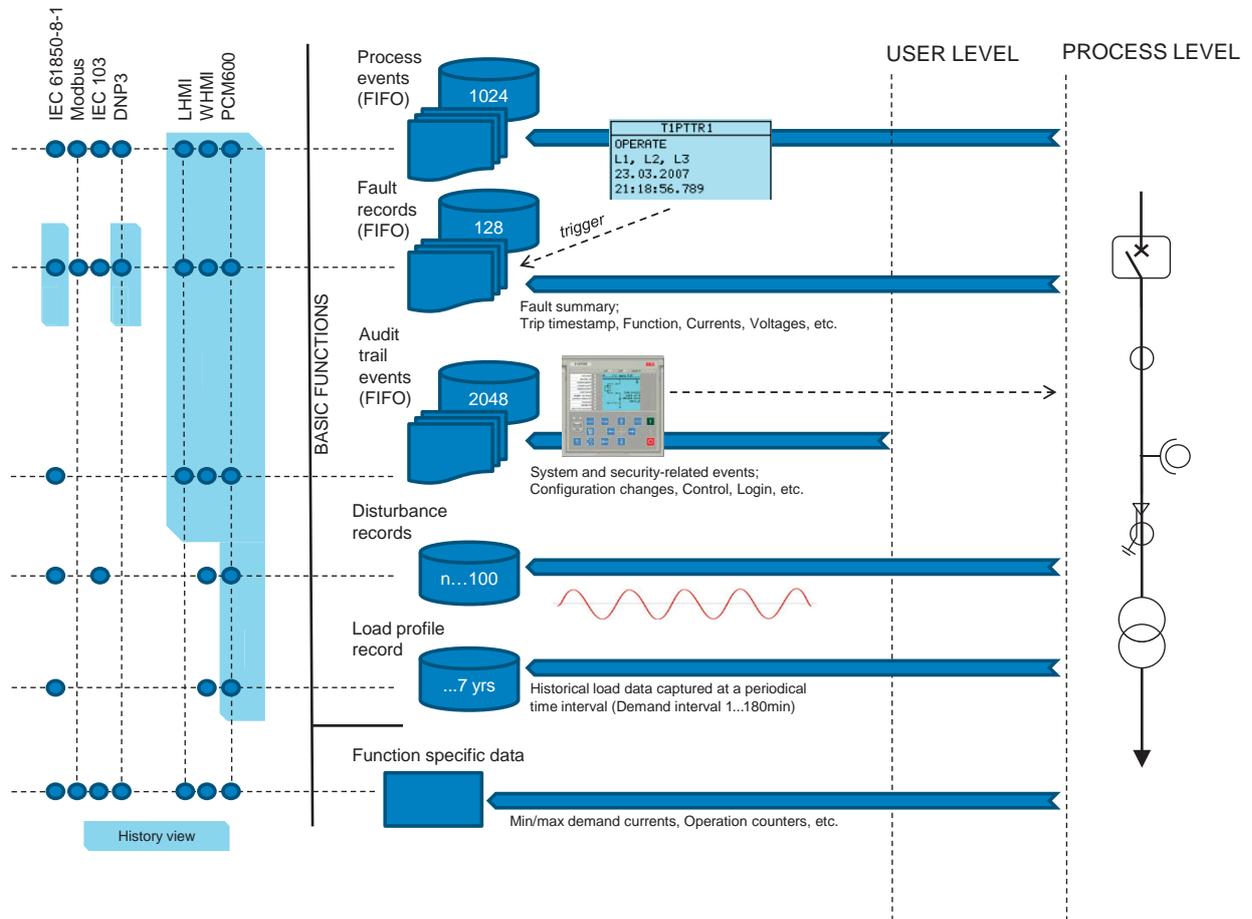
Figure 10: Recording and event capabilities overview

13. Condition monitoring

The condition monitoring functions of the relay constantly monitor the performance and the condition of the circuit breaker. The monitoring comprises the spring charging time, SF6 gas pressure, the travel time and the inactivity time of the circuit breaker.

The monitoring functions provide operational circuit breaker history data, which can be used for scheduling preventive circuit breaker maintenance.

In addition, the relay includes a runtime counter for monitoring of how many hours a protected device has been in operation thus enabling scheduling of time-based preventive maintenance of the device.

14. Trip-circuit supervision

The trip-circuit supervision continuously monitors the availability and operability of the trip circuit. It provides opencircuit monitoring both when the circuit breaker is in its closed and in its open position. It also detects loss of circuit-breaker control voltage.

15. Self-supervision

The relay's built-in self-supervision system continuously monitors the state of the relay hardware and the operation of the relay software. Any fault or malfunction detected is used for alerting the operator.

A permanent relay fault blocks the protection functions to prevent incorrect operation.

16. Current circuit supervision

The relay includes current circuit supervision. Current circuit supervision is used for detecting faults in the current transformer secondary circuits. On detecting of a fault the current circuit supervision function activates an alarm LED and blocks the line differential protection and negative-sequence overcurrent protection functions to avoid unintended operation. The current circuit supervision function calculates the sum of the phase currents from the protection cores and compares the sum with the measured single reference current from a core balance current transformer or from separate cores in the phase current transformers.

17. Protection communication and supervision

The communication between the relays is enabled by means of a dedicated fiber optic communication channel. 1310 nm multi-mode or single-mode fibers with LC connectors are used for line differential communication. The channel is used for transferring the phase segregated current value data between the relays. The current phasors from the two relays, geographically located apart from each other, must be time coordinated so that the current differential algorithm can be executed correctly. The so called echo method is used for time synchronization. No external devices such as GPS clocks are thereby needed for the line differential protection communication.

As an option to the fiber optic communication link a galvanic connection over a pilot wire link composed of a twisted pair cable and RPW600 link-end communication modems can be established. The optional pilot wire communication link is also an ideal and cost efficient retrofit solution for electromechanical line differential protection installations. Compared to conventional combined sequence line differential protection solutions with analog pilot wire communication, RED615 relays in combination with RPW600 communication modems offer a modern phase-segregated line differential protection solution over existing pilot wire cables.

The pilot wire link supports the same protection and communication functionality as the fiber optic link. The quality of service (QoS) is indicated by the modems and the communication link is continuously supervised by the relay. The RPW600 modem offers a 5 kV (RMS) level of isolation between the pilot wire terminals and ground. The RPW600 modems (master and follower) are galvanically connected to either end of the pilot wire and optically connected to the relays using short optical single-mode cables. Using 0.8 mm ^{2} twisted pair cables pilot wire link distances up to 8 km are typically supported. However, twisted pair pilot wire cables in good conditions may support even longer distances to be covered. The length of the supported pilot wire link also depends on the noise environment in the installation. Should the need arise to replace the pilot wire cables with fiber optic cables, the single mode fiber optic LC connectors of the relays can be utilized for direct connection of the fiber optic communication link.

Apart from the continued protection communication, the communication channel can also be used for binary signal transfer (BST) that is, transferring of user configurable binary information between the relays. There are a total of eight BST signals available for user definable purposes. The BST signals can originate from the relay's binary inputs or internal logics, and be assigned to the remote relay's binary outputs or internal logics.

The protection communication supervision continuously monitors the protection communication link. The relay immediately blocks the line differential protection function in case that severe interference in the communication link, risking the correct operation of the function, is detected. An alarm signal will eventually be issued if the interference, indicating permanent failure in the protection communication, persists. The two high-set stages of the overcurrent protection are further by default released.
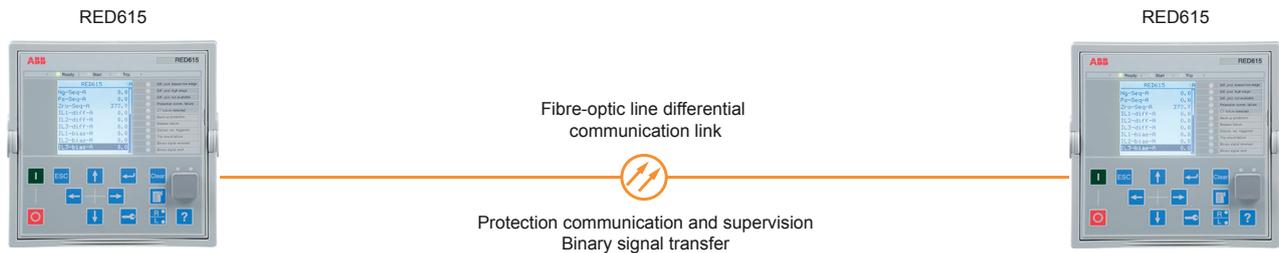
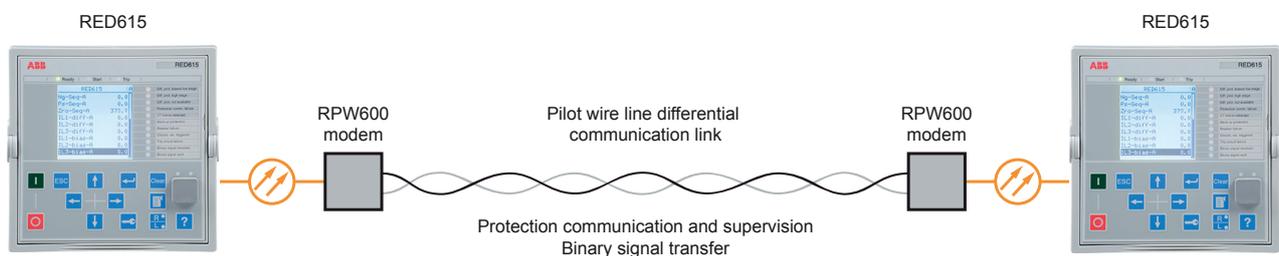Figure 11: Fiber optic protection communication link

Figure 12: Pilot wire protection communication link

18. Access control

To protect the relay from unauthorized access and to maintain information integrity, the relay is provided with a four-level, role-based authentication system with administrator-programmable individual passwords for the viewer, operator, engineer and administrator levels. The access control applies to the local HMI, the Web HMI and PCM600.

19. Inputs and outputs

Depending on the standard configuration selected, the relay is equipped with three phase-current inputs and one residual-current input for non-directional earth-fault protection and current circuit supervision, or three phase-current inputs, one residual-current input and one residual voltage input for directional earth-fault protection and current circuit supervision.

The standard configuration E includes one conventional residual current (Io 0.2/1 A) input and three sensor inputs for the direct connection of three combi-sensors with RJ-45

connectors. As an alternative to combi-sensors, separate current and voltage sensors can be utilized using adapters. Furthermore, the adapters also enable the use of sensors with Twin-BNC connectors.

The phase-current inputs are rated 1/5 A. Two optional residual-current inputs are available, that is, 1/5 A or 0.2/1 A. The 0.2/1 A input is normally used in applications requiring sensitive earth-fault protection and featuring core-balance current transformers. The residual-voltage input covers the rated voltages 60...210 V.

The phase-current input 1 A or 5 A, the residual-current input 1 A or 5 A, alternatively 0.2 A or 1 A, and the rated voltage of the residual voltage input are selected in the relay software. In addition, the binary input thresholds 16... 176 V DC are selected by adjusting the relay's parameter settings.

All binary input and output contacts are freely configurable with the signal matrix or application configuration functionality of PCM600.

See the Input/output overview table and the terminal diagrams for more information about the inputs and outputs.

Table 4: Input/output overview

Std. conf.	Order code digit		Analog channels			Binary channels			
	5-6	7-8	CT	VT	Combi sensor	BI	BO	RTD	mA
A	AC	AD	4	–	–	12	4 PO + 6 SO	–	–
		AF	4	–	–	18	4 PO + 9 SO	–	–
B	AA / AB	AC	4	1	–	11	4 PO + 6 SO	–	–
		AE	4	1	–	17	4 PO + 9 SO	–	–
C	AC	AD	4	–	–	12	4 PO + 6 SO	–	–
		AF	4	–	–	18	4 PO + 9 SO	–	–
D	FE / FF	AD	4	5	–	12	4 PO + 6 SO	2	1
		AG	4	5	–	16	4 PO + 6 SO	–	–
E	DA / DB	AH	1	–	3	8	4 PO + 6 SO	–	–

20. Station communication

The relay supports a range of communication protocols including IEC 61850 Edition 2, IEC 61850-9-2 LE, IEC 60870-5-103, Modbus® and DNP3. Profibus DPV1 communication protocol is supported with using the protocol converter SPA-ZC 302. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the relays, is only enabled by the IEC 61850 communication protocol.

The IEC 61850 protocol is a core part of the relay as the protection and control application is fully based on standard modelling. The relay supports Edition 2 and Edition 1 versions of the standard. With Edition 2 support, the relay has the latest functionality modelling for substation applications and the best interoperability for modern substations. It incorporates also the full support of standard device mode functionality supporting different test applications. Control applications can utilize the new safe and advanced station control authority feature.

The IEC 61850 communication implementation supports monitoring and control functions. Additionally, parameter settings, disturbance recordings and fault records can be accessed using the IEC 61850 protocol. Disturbance recordings are available to any Ethernet-based application in the standard COMTRADE file format. The relay supports simultaneous event reporting to five different clients on the station bus. The relay can exchange data with other devices using the IEC 61850 protocol.

The relay can send binary and analog signals to other devices using the IEC 61850-8-1 GOOSE (Generic Object Oriented Substation Event) profile. Binary GOOSE messaging can, for example, be employed for protection and interlocking-based protection schemes. The relay meets the GOOSE performance requirements for tripping applications in distribution substations, as defined by the IEC 61850 standard (<10 ms data exchange between the devices). The relay also supports the sending and receiving of analog values using GOOSE messaging. Analog GOOSE messaging enables easy transfer of analog measurement values over the station bus, thus facilitating for example the sending of measurement values between the relays when controlling parallel running transformers.

The relay also supports IEC 61850 process bus by sending sampled values of analog currents and voltages and by receiving sampled values of voltages. With this functionality the galvanic interpanel wiring can be replaced with Ethernet communication. The measured values are transferred as sampled values using IEC 61850-9-2 LE protocol. The intended application for sampled values shares the voltages to other 615 series relays, having voltage based functions and 9-2 support. 615 relays with

process bus based applications use IEEE 1588 for high accuracy time synchronization.

For redundant Ethernet communication, the relay offers two optical Ethernet network interfaces. Ethernet network redundancy can be achieved using the high-availability seamless redundancy (HSR) protocol or the parallel redundancy protocol (PRP) or a with self-healing ring using RSTP in managed switches. Ethernet redundancy can be applied to Ethernet-based IEC 61850, Modbus and DNP3 protocols.

All communication card variants support self-healing ring based Ethernet redundancy. Communication card variants with two optical interfaces for station bus communication have support for HSR and PRP redundancy protocols. These variants include also support for IEEE 1588 based time synchronization.

The IEC 61850 standard specifies network redundancy which improves the system availability for the substation communication. The network redundancy is based on two complementary protocols defined in the IEC 62439-3 standard: PRP and HSR protocols. Both the protocols are able to overcome a failure of a link or switch with a zero switch-over time. In both the protocols, each network node has two identical Ethernet ports dedicated for one network connection. The protocols rely on the duplication of all transmitted information and provide a zero switch-over time if the links or switches fail, thus fulfilling all the stringent real-time requirements of substation automation.

In PRP, each network node is attached to two independent networks operated in parallel. The networks are completely separated to ensure failure independence and can have different topologies. The networks operate in parallel, thus providing zero-time recovery and continuous checking of redundancy to avoid failures.
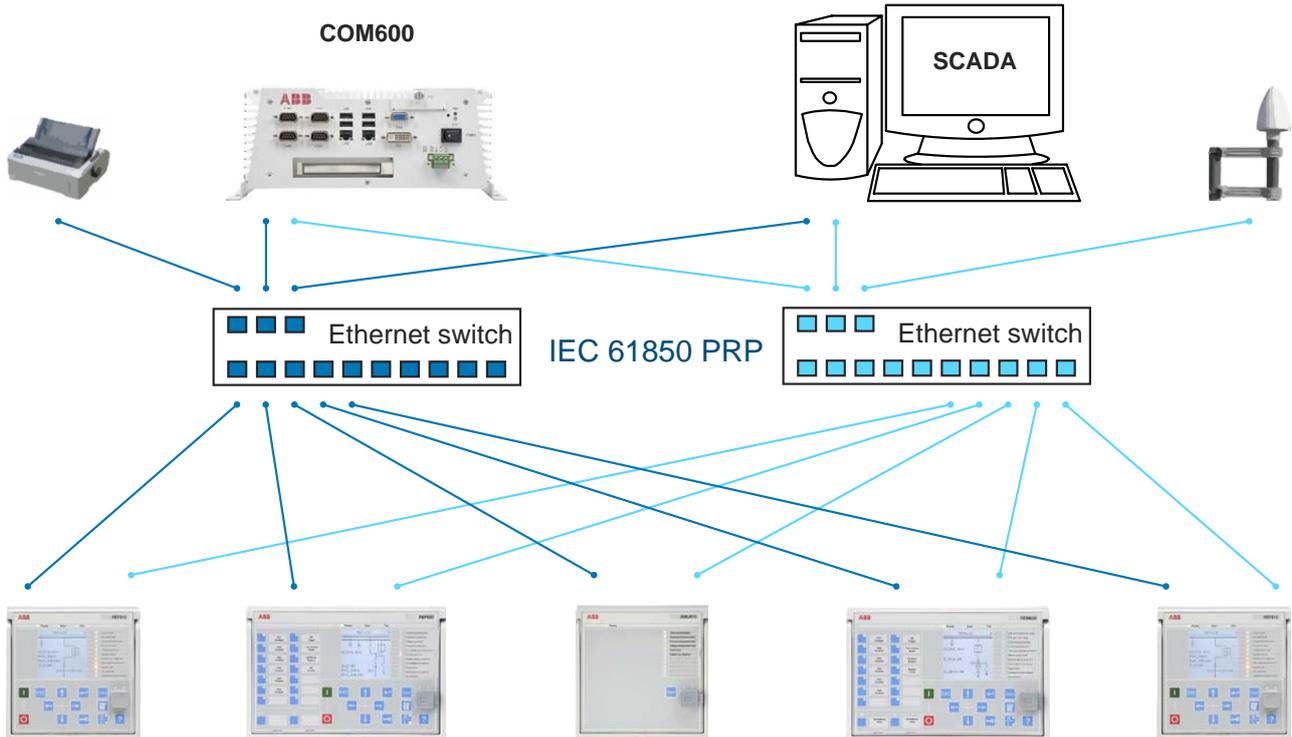

Figure 13: Parallel redundancy protocol (PRP) solution

HSR applies the PRP principle of parallel operation to a single ring. For each message sent, the node sends two frames, one through each port. Both the frames circulate in opposite directions over the ring. Every node forwards the frames it receives from one port to another to reach the next node. When the originating sender node receives the frame it sent, the sender node discards the frame to avoid loops. The HSR ring with 615 series relays supports the connection of up to 30 relays. If more than 30 relays are to be connected, it is recommended to split the network into several

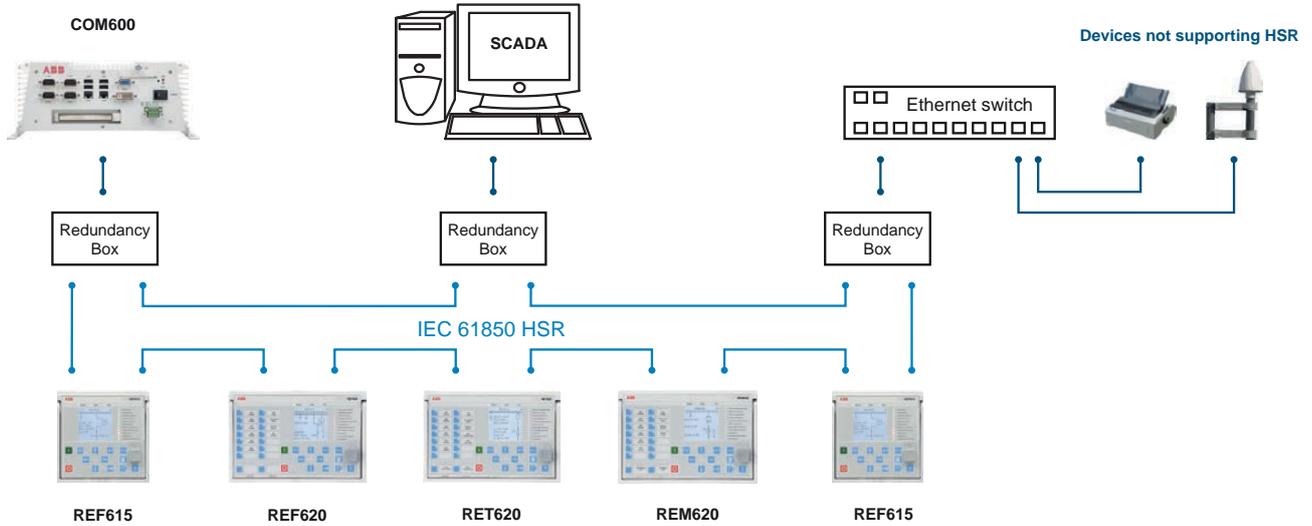rings to guarantee the performance for real-time applications.

Figure 14: High availability seamless redundancy (HSR) solution

The choice between the HSR and PRP redundancy protocols depends on the required functionality, cost and complexity.

The self-healing Ethernet ring solution enables a cost-efficient communication ring controlled by a managed switch with standard Rapid Spanning Tree Protocol (RSTP) support. The managed switch controls the consistency of the loop, routes the data and corrects the data flow in case of a communication switch-over. The relays in the ring topology act as unmanaged switches forwarding unrelated data traffic. The

Ethernet ring solution supports the connection of up to 30 615 series relays. If more than 30 relays are to be connected, it is recommended to split the network into several rings. The self-healing Ethernet ring solution avoids single point of failure concerns and improves the reliability of the communication.

The self-healing Ethernet ring solution avoids single point of failure concerns and improves the reliability of the communication. The solution can be applied for the Ethernetbased IEC 61850, Modbus and DNP3 protocols.
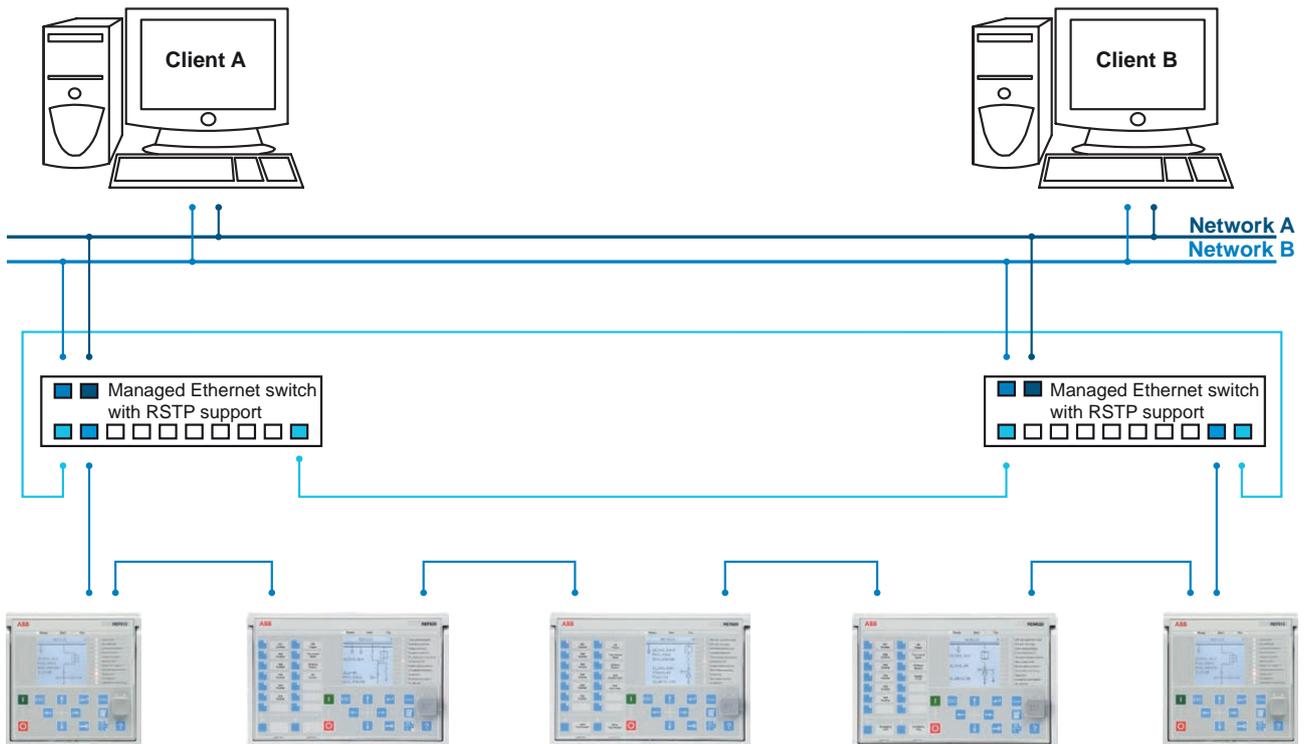
Figure 15: Self-healing Ethernet ring solution

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The relay can be connected to Ethernet-based communication systems via the RJ-45 connector (100Base-TX) or the fiber optic LC connector (100Base-FX).

Modbus implementation supports RTU, ASCII and TCP modes. Besides standard Modbus functionality, the relay supports retrieval of time-stamped events, changing the active setting group and uploading of the latest fault records. If a Modbus TCP connection is used, five clients can be connected to the relay simultaneously. Further, Modbus serial and Modbus TCP can be used in parallel, and if required both IEC 61850 and Modbus protocols can be run simultaneously.

The IEC 60870-5-103 implementation supports two parallel serial bus connections to two different masters. Besides basic standard functionality, the relay supports changing of the active setting group and uploading of disturbance recordings in IEC 60870-5-103 format. Further, IEC 60870-5-103 can be used at the same time with the IEC 61850 protocol.

DNP3 supports both serial and TCP modes for connection up to five masters. Changing of the

active setting and reading fault records are supported. DNP serial and DNP TCP can be used in parallel. If required, both IEC 61850 and DNP protocols can be run simultaneously.

615 series supports Profibus DPV1 with support of SPA-ZC 302 Profibus adapter. If Profibus is required the relay must be ordered with Modbus serial options. Modbus implementation includes SPA-protocol emulation functionality. This functionality enables connection to SPA-ZC 302.

When the relay uses the RS-485 bus for the serial communication, both two- and four wire connections are supported. Termination and pull-up/down resistors can be configured with jumpers on the communication card so external resistors are not needed.

The relay supports the following time synchronization methods with a time-stamping resolution of 1 ms.

Ethernet-based

• SNTP (Simple Network Time Protocol)

With special time synchronization wiring

• IRIG-B (Inter-Range Instrumentation Group - Time Code Format B)

Remote-end station time reference

- Line differential

The relay supports the following high accuracy time synchronization method with a time-stamping resolution of 4 μs required especially in process bus applications.

- PTP (IEEE 1588) v2 with Power Profile

The IEEE 1588 support is included in all variants having a redundant Ethernet communication module.

IEEE 1588 v2 features

- Ordinary Clock with Best Master Clock algorithm
- One-step Transparent Clock for Ethernet ring topology
- 1588 v2 Power Profile

- Receive (slave): 1-step/2-step
- Transmit (master): 1-step
- Layer 2 mapping
- Peer to peer delay calculation
- Multicast operation

Required accuracy of grandmaster clock is +/-1 μs. The relay can work as a master clock per BMC algorithm if the external grandmaster clock is not available for short term.

The IEEE 1588 support is included in all variants having a redundant Ethernet communication module.

In addition, the relay supports time synchronization via Modbus, DNP3 and IEC 60870-5-103 serial communication protocols.

Table 5: Supported station communication interfaces and protocols

Interfaces/Protocols	Ethernet		Serial	
	100BASE-TX RJ-45	**100BASE-FX LC**	**RS-485**	**Fiber optic ST**
IEC 61850-8-1	●	●	-	-
IEC 61850-9-2 LE	-	●		
MODBUS RTU/ASCII	-	-	●	●
MODBUS TCP/IP	●	●	-	-
DNP3 (serial)	-	-	●	●
DNP3 TCP/IP	●	●	-	-
IEC 60870-5-103	-	-	●	●
● = Supported				

21. Technical data

21.1 Dimensions

Table 6: Dimensions

Description	Value	
Width	Frame	177 mm
	Case	164 mm
Height	Frame	177 mm (4U)
	Case	160 mm
Depth		201 mm (153 + 48 mm)
Weight	Complete protection relay	4.1 kg
	Plug-in unit only	2.1 kg

21.2 Power supply

Table 7: Power supply

Description	Type 1	Type 2
Nominal auxiliary voltage U_n	100, 110, 120, 220, 240 V AC, 50 and 60 Hz	24, 30, 48, 60 V DC
	48, 60, 110, 125, 220, 250 V DC	
Maximum interruption time in the auxiliary DC voltage without resetting the relay	50 ms at U_n	
Auxiliary voltage variation	38...110% of U_n (38...264 V AC)	50...120% of U_n (12...72 V DC)
	80...120% of U_n (38.4...300 V DC)	
Start-up threshold		19.2 V DC (24 V DC × 80%)
Burden of auxiliary voltage supply under quiescent (P_q)/operating condition	DC <13.0 W (nominal)/<18.0 W (max.)	DC <13.0 W (nominal)/<18.0 W (max.)
	AC <16.0 W (nominal)/<21.0 W (max.)	
Ripple in the DC auxiliary voltage	Max 15% of the DC value (at frequency of 100 Hz)	
Fuse type	T4A/250 V	

21.3 Energizing inputs

Table 8: Energizing inputs

Description		Value	
Rated frequency		50/60 Hz	
Current inputs	Rated current, I_n	0.2/1 A [1]	1/5 A [2]
	Thermal withstand capability:		
	• Continuously	4 A	20 A
	• For 1 s	100 A	500 A
	Dynamic current withstand:		
	• Half-wave value	250 A	1250 A
	Input impedance	<100 mΩ	<20 mΩ
Voltage inputs	Rated voltage	60...210 V AC	
	Voltage withstand:		
	• Continuous	240 V AC	
	• For 10 s	360 V AC	
	Burden at rated voltage	<0.05 VA	

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[1] Ordering option for residual current input
[2] Residual current and/or phase current

21.4 Energizing inputs (sensors)

Table 9: Energizing Inputs (SIM0002)

Description		Value
Current sensor input	Rated current voltage	75 mV … 9000 mV [1]
	Continuous voltage withstand	125 V
	Input impedance at 50/60Hz	2…3 MΩ [2]
Voltage sensor input	Rated secondary voltage	346 mV…1733 mV [3]
	Continuous voltage withstand	50 V
	Input impedance at 50/60Hz	3 MΩ

Table 10: Energizing Inputs (SIM0005)

Description		Value
Current sensor input	Rated current voltage	75 mV … 9000 mV [1]
	Continuous voltage withstand	125 V
	Input impedance at 50/60Hz	2 MΩ
Voltage sensor input	Rated secondary voltage	346 mV…2339 mV [4]
	Continuous voltage withstand	50 V
	Input impedance at 50/60Hz	2 MΩ

21.5 Binary inputs

Table 11: Binary inputs

Description	Value
Operating range	±20% of the rated voltage
Rated voltage	24…250 V DC
Current drain	1.6…1.9 mA
Power consumption	31.0…570.0 mW
Threshold voltage	16…176 V DC
Reaction time	<3 ms

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[1] Equals the current range of 40 … 4000 A with 80A, 3mV/Hz Rogowski

[2] Depending on the used nominal current (hardware gain)

[3] Covers 6 kV … 30 kV sensors with division ratio of 10 000:1. Secondary voltages 600mV/√3 … 3 V / √3. Range up to 2 x Rated.

[4] Covers 6 kV … 40.5 kV sensors with division ratio of 10 000:1. Secondary voltages 600mV/√3 … 4.05V / √3. Range up to 2 x Rated.

21.6 RTD/mA measurement (XRGGIO130)

Table 12: RTD/mA measurement (XRGGIO130)

Description		Value	
RTD inputs	Supported RTD sensors	100 Ω platinum	TCR 0.00385 (DIN 43760)
		250 Ω platinum	TCR 0.00385
		100 Ω nickel	TCR 0.00618 (DIN 43760)
		120 Ω nickel	TCR 0.00618
		250 Ω nickel	TCR 0.00618
		10 Ω copper	TCR 0.00427
	Supported resistance range	0...2 kΩ	
	Maximum lead resistance (three-wire measurement)	25 Ω per lead	
	Isolation	2 kV (inputs to protective earth)	
	Response time	<4 s	
	RTD/resistance sensing current	Maximum 0.33 mA rms	
	Operation accuracy	Resistance	Temperature
		± 2.0% or ±1 Ω	±1°C
			10 Ω copper: ±2°C
mA inputs	Supported current range	0…20 mA	
	Current input impedance	44 Ω ± 0.1%	
	Operation accuracy	±0.5% or ±0.01 mA	

21.7 Signal outputs

Table 13: Signal output X100: SO1

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

Table 14: Signal outputs and IRF output

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	5 A
Make and carry for 3.0 s	10 A
Make and carry 0.5 s	15 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	1 A/0.25 A/0.15 A
Minimum contact load	10 mA at 5 V AC/DC

21.8 Double-pole power output relays with TCS function

Table 15: Double-pole power output relays with TCS function

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC (two contacts connected in series)	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC
Trip-circuit supervision (TCS):	
• Control voltage range	20…250 V AC/DC
• Current drain through the supervision circuit	~1.5 mA
• Minimum voltage over the TCS contact	20 V AC/DC (15…20 V)

21.9 Single-pole power output relays

Table 16: Single-pole power output relays

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	8 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R<40 ms, at 48/110/220 V DC	5 A/3 A/1 A
Minimum contact load	100 mA at 24 V AC/DC

21.10 High-speed output HSO with BIO0007

Table 17: High-speed output HSO with BIO0007

Description	Value
Rated voltage	250 V AC/DC
Continuous contact carry	6 A
Make and carry for 3.0 s	15 A
Make and carry for 0.5 s	30 A
Breaking capacity when the control-circuit time constant L/R <40 ms, at 48/110/220 V DC	5 A/3 A/1 A

Table continues on the next page

Description	Value
Operate time	<1 ms
Reset	<20 ms, resistive load

21.11 Front port Ethernet interfaces

Table 18: Front port Ethernet interfaces

Ethernet interface	Protocol	Cable	Data transfer rate
Front	TCP/IP protocol	Standard Ethernet CAT 5 cable with RJ-45 connector	10 MBits/s

21.12 Protection communication link

Table 19: Protection communication link

Connector	Fibre type	Wave length	Typical max. length[9]	Permitted path attenuation[10]
LC	MM 62.5/125 or 50/125 µm	1300 nm	2 km	<8 dB
LC	SM 9/125 µm[11]	1300 nm	20 km	<8 dB

21.13 IRIG-B

Table 20: IRIG-B

Description	Value
IRIG time code format	B004, B005 [1]
Isolation	500V 1 min
Modulation	Unmodulated
Logic level	5 V TTL
Current consumption	<4 mA
Power consumption	<20 mW

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[9] Maximum length depends on the cable attenuation and quality, the amount of splices and connectors in the path.

[10] Maximum allowed attenuation caused by connectors and cable altogether.

[11] Use single-mode fiber with recommended minimum length of 3 m to connect RED615 to the pilot wire modem RPW600.

[1] According to the 200-04 IRIG standard

21.14 Degree of protection of flush-mounted protection relay

Table 21: Degree of protection of flush-mounted protection relay

Description	Value
Front side	IP 54
Rear side, connection terminals	IP 20

21.15 Environmental conditions

Table 22: Environmental conditions

Description	Value
Operating temperature range	-25...+55ºC (continuous)
Short-time service temperature range	-40...+70ºC (<16 h) [12], [13]
Relative humidity	<93%, non-condensing
Atmospheric pressure	86...106 kPa
Altitude	Up to 2000 m
Transport and storage temperature range	-40...+85ºC

21.16 Electromagnetic compatibility tests

Table 23: Electromagnetic compatibility tests

Description	Type test value	Reference
1 MHz/100 kHz burst disturbance test		IEC 61000-4-18
		IEC 60255-26, class III
		IEEE C37.90.1-2002
• Common mode	2.5 kV	
• Differential mode	2.5 kV	
3 MHz, 10 MHz and 30 MHz burst disturbance test		IEC 61000-4-18
		IEC 60255-26, class III
• Common mode	2.5 kV	
Electrostatic discharge test		IEC 61000-4-2
		IEC 60255-26
		IEEE C37.90.3-2001
• Contact discharge	8 kV	
• Air discharge	15 kV	
Radio frequency interference test		

Table continues on the next page

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[12] Degradation in MTBF and HMI performance outside the temperature range of -25...+55 ºC
[13] For relays with an LC communication interface the maximum operating temperature is +70 ºC

Description	Type test value	Reference
	10 V (rms)	IEC 61000-4-6
	f = 150 kHz...80 MHz	IEC 60255-26, class III
	10 V/m (rms)	IEC 61000-4-3
	f = 80...2700 MHz	IEC 60255-26, class III
	10 V/m	ENV 50204
	f = 900 MHz	IEC 60255-26, class III
	20 V/m (rms)	IEEE C37.90.2-2004
	f = 80...1000 MHz	
Fast transient disturbance test		IEC 61000-4-4
		IEC 60255-26
		IEEE C37.90.1-2002
• All ports	4 kV	
Surge immunity test		IEC 61000-4-5
		IEC 60255-26
• Communication	1 kV, line-to-earth	
• Other ports	4 kV, line-to-earth	
	2 kV, line-to-line	
Power frequency (50 Hz) magnetic field immunity test		IEC 61000-4-8
• Continuous	300 A/m	
• 1...3 s	1000 A/m	
Pulse magnetic field immunity test	1000 A/m	IEC 61000-4-9
	6.4/16 µs	
Damped oscillatory magnetic field immunity test		IEC 61000-4-10
• 2 s	100 A/m	
• 1 MHz	400 transients/s	
Voltage dips and short interruptions	30%/10 ms	IEC 61000-4-11
	60%/100 ms	
	60%/1000 ms	
	>95%/5000 ms	
Power frequency immunity test	Binary inputs only	IEC 61000-4-16
		IEC 60255-26, class A
• Common mode	300 V rms	
• Differential mode	150 V rms	
Conducted common mode disturbances	15 Hz...150 kHz	IEC 61000-4-16
	Test level 3 (10/1/10 V rms)	

Table continues on the next page

Description	Type test value	Reference
Emission tests		EN 55011, class A
		IEC 60255-26
		CISPR 11
		CISPR 12
• Conducted		
0.15...0.50 MHz	<79 dB (μV) quasi peak	
	<66 dB (μV) average	
0.5...30 MHz	<73 dB (μV) quasi peak	
	<60 dB (μV) average	
• Radiated		
30...230 MHz	<40 dB (μV/m) quasi peak, measured at 10 m distance	
230...1000 MHz	<47 dB (μV/m) quasi peak, measured at 10 m distance	
1…3 GHz	<76 dB (μV/m) peak	
	<56 dB (μV/m) average, measured at 3 m distance	
3…6 GHz	<80 dB (μV/m) peak	
	<60 dB (μV/m) average, measured at 3 m distance	

21.17 Insulation tests

Table 24: Insulation tests

Description	Type test value	Reference
Dielectric tests	2 kV, 50 Hz, 1 min	IEC 60255-27
	500 V, 50 Hz, 1 min, communication	
	820 V, 50 Hz, 1 min, sensor inputs of SIM0005	IEC 61869-6
Impulse voltage test	5 kV, 1.2/50 μs, 0.5 J	IEC 60255-27
	1 kV, 1.2/50 μs, 0.5 J, communication	
	1,5 kV, 1,2/50 μs, 0,5 J, sensor inputs of SIM0005	IEC 61869-6
Insulation resistance measurements	>100 M Ω, 500 V DC	IEC 60255-27
Protective bonding resistance	<0.1 Ω, 4 A, 60 s	IEC 60255-27

21.18 Mechanical tests

Table 25: Mechanical tests

Description	Requirement	Reference
Vibration tests (sinusoidal)	Class 2	IEC 60068-2-6 (test Fc)
		IEC 60255-21-1
Shock and bump test	Class 2	IEC 60068-2-27 (test Ea shock)
		IEC 60068-2-29 (test Eb bump)
		IEC 60255-21-2
Seismic test	Class 2	IEC 60255-21-3

21.19 Environmental tests

Table 26: Environmental tests

Description	Type test value	Reference
Dry heat test	• 96 h at +55ºC • 16 h at +70ºC [14]	IEC 60068-2-2
Dry cold test	• 96 h at -25ºC • 16 h at -40ºC	IEC 60068-2-1
Damp heat test	• 6 cycles (12 h + 12 h) at +25°C…+55°C, humidity >93%	IEC 60068-2-30
Change of temperature test	• 5 cycles (3 h + 3 h) at -25°C…+55°C	IEC60068-2-14
Storage test	• 96 h at -40ºC • 96 h at +85ºC	IEC 60068-2-1 IEC 60068-2-2

21.20 Product safety

Table 27: Product safety

Description	Reference
LV directive	2014/35/EU
Standard	EN / BS EN 60255-27
	EN / BS EN 60255-1

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[14] For relays with an LC communication interface the maximum operating temperature is +70 ºC

21.21 EMC compliance

Table 28: EMC compliance

Description	Reference
EMC directive	2014/30/EU
Standard	EN / BS EN 60255-26

21.22 RoHS compliance

Table 29: RoHS compliance

Description
RoHS Directive 2011/65/EU

21.23 Protection functions

21.23.1 Three-phase non-directional overcurrent protection (PHxPTOC)

Table 30: Three-phase non-directional overcurrent protection (PHxPTOC)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
	PHLPTOC	±1.5% of the set value or ±0.002 × I_n		
	PHHPTOC	±1.5% of set value or ±0.002 × I_n		
	and	(at currents in the range of 0.1…10 × I_n)		
	PHIPTOC	±5.0% of the set value		
		(at currents in the range of 10…40 × I_n)		
Start time [15], [16]		Minimum	Typical	Maximum
	PHIPTOC:	16 ms	19 ms	23 ms
	I_{Fault} = 2 × set *Start value*			
	I_{Fault} = 10 × set *Start value*	11 ms	12 ms	14 ms
	PHHPTOC and PHLPTOC:			
	I_{Fault} = 2 × set *Start value*	23 ms	26 ms	29 ms
Reset time		Typically 40 ms		

Table continues on the next page

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[15] Set *Operate delay time* = 0,02 s, *Operate curve type* = IEC definite time, *Measurement mode* = default (depends on stage), current before fault = 0.0 × In, fn = 50 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[16] Includes the delay of the signal output contac

Characteristic	Value
Reset ratio	Typically 0.96
Retardation time	<40 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms [17]
Suppression of harmonics	RMS: No suppression
	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…
	Peak-to-Peak: No suppression
	P-to-P+backup: No suppression

21.23.2 Three-phase non-directional overcurrent protection (PHxPTOC) main settings

Table 31: Three-phase non-directional overcurrent protection (PHxPTOC) main settings

Parameter	Function	Value (Range)	Step
Start value	PHLPTOC	0.05…5.00 × I_n	0.01
	PHHPTOC	0.10…40.00 × I_n	0.01
	PHIPTOC	1.00…40.00 × I_n	0.01
Time multiplier	PHLPTOC and PHHPTOC	0.05…15.00	0.01
Operate delay time	PHLPTOC and PHHPTOC	40…200000 ms	10
	PHIPTOC	20…200000 ms	10
Operating curve type [18]	PHLPTOC	Definite or inverse time
		Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	
	PHHPTOC	Definite or inverse time
		Curve type: 1, 3, 5, 9, 10, 12, 15, 17	
	PHIPTOC	Definite time	

21.23.3 Three-phase directional overcurrent protection (DPHxPDOC)

Table 32: Three-phase directional overcurrent protection (DPHxPDOC)

Characteristic		Value
Operation accuracy		Depending on the frequency of the current/voltage measured: f_n ±2 Hz
	DPHLPDOC	Current:
		±1.5% of the set value or ±0.002 × I_n
		Voltage:
		±1.5% of the set value or ±0.002 × U_n
		Phase angle: ±2°

Table continues on the next page

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[17] Includes the delay of the heavy-duty output contact
[18] For further reference, see the Operation characteristics table

Characteristic		Value		
	DPHHPDOC	Current:		
		±1.5% of the set value or ±0.002 × I_n		
		(at currents in the range of 0.1…10 × I_n)		
		±5.0% of the set value		
		(at currents in the range of 10…40 × I_n)		
		Voltage:		
		±1.5% of the set value or ±0.002 × U_n		
		Phase angle: ±2°		
Start time [19], [20]		Minimum	Typical	Maximum
	I_{Fault} = 2.0 × set *Start value*	39 ms	43 ms	47 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [21]		
Suppression of harmonics		DFT: -50 dB at $f = n × f_n$, where n = 2, 3, 4, 5,…		

21.23.4 Three-phase directional overcurrent protection (DPHxPDOC) main settings

Table 33: Three-phase directional overcurrent protection (DPHxPDOC) main settings

Parameter	Function	Value (Range)	Step
Start value	DPHLPDOC	0.05. 5.00 × I n	0.01
	DPHHPDOC	0.10. 40.00 × I n	0.01
Time multiplier	DPHxPDOC	0.05…15.00	0.01
Operate delay time	DPHxPDOC	40…200000 ms	10
Directional mode	DPHxPDOC	1 = Non-directional 2 = Forward 3 = Reverse	-
Characteristic angle	DPHxPDOC	-179…180°	1

Table continues on the next page

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[19] *Measurement mode* and *Pol quantity* = default, current before fault = 0.0 × I_n, voltage before fault = 1.0 × U_n, f_n = 50 Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[20] Includes the delay of the signal output contact

[21] Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5…20

Parameter	Function	Value (Range)	Step
Operating curve type [22]	DPHLPDOC	Definite or inverse time	
		Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	
	DPHHPDOC	Definite or inverse time	
		Curve type: 1, 3, 5, 9, 10, 12, 15, 17	

21.23.5 Non-directional earth-fault protection (EFxPTOC)

Table 34: Non-directional earth-fault protection (EFxPTOC)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n ±2 Hz		
	EFLPTOC	±1.5% of the set value or ±0.002 × I_n		
	EFHPTOC	±1.5% of set value or ±0.002 × I_n		
	and	(at currents in the range of 0.1…10 × I_n)		
	EFIPTOC	±5.0% of the set value		
		(at currents in the range of 10…40 × I_n)		
Start time [23], [24]		Minimum	Typical	Maximum
	EFIPTOC:	16 ms	19 ms	23 ms
	I_{Fault} = 2 × set *Start value*			
	I_{Fault} = 10 × set *Start value*	11 ms	12 ms	14 ms
	EFHPTOC and EFLPTOC:	23 ms	26 ms	29 ms
	I_{Fault} = 2 × set *Start value*			
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<30 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode		±5.0% of the theoretical value or ±20 ms [25]		
Suppression of harmonics		RMS: No suppression		
		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		
		Peak-to-Peak: No suppression		

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[22] For further reference, see the Operating characteristics table

[23] *Measurement mode* = default (depends on stage), current before fault = 0.0 × I_n, f_n = 50 Hz, earth-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[24] Includes the delay of the signal output contact

[25] Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5…20

21.23.6 Non-directional earth-fault protection (EFxPTOC) main settings

Table 35: Non-directional earth-fault protection (EFxPTOC) main settings

Parameter	Function	Value (Range)	Step
Start value	EFLPTOC	$0.010...5.000 \times I_n$	0.005
	EFHPTOC	$0.10...40.00 \times I_n$	0.01
	EFIPTOC	$1.00...40.00 \times I_n$	0.01
Time multiplier	EFLPTOC and EFHPTOC	0.05...15.00	0.01
Operate delay time	EFLPTOC and EFHPTOC	40...200000 ms	10
	EFIPTOC	20...200000 ms	10
Operating curve type	EFLPTOC	Definite or inverse time Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	
	EFHPTOC	Definite or inverse time Curve type: 1, 3, 5, 9, 10, 12, 15, 17	
	EFIPTOC	Definite time	

21.23.7 Directional earth-fault protection (DEFxPDEF)

Table 36: Directional earth-fault protection (DEFxPDEF)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: $f_n \pm 2$ Hz		
	DEFLPDEF	Current: $\pm1.5\%$ of the set value or $\pm0.002 \times I_n$ Voltage $\pm1.5\%$ of the set value or $\pm0.002 \times U_n$ Phase angle: $\pm2°$		
	DEFHPDEF	Current: $\pm1.5\%$ of the set value or $\pm0.002 \times I_n$ (at currents in the range of $0.1...10 \times I_n$) $\pm5.0\%$ of the set value (at currents in the range of $10...40 \times I_n$) Voltage: $\pm1.5\%$ of the set value or $\pm0.002 \times U_n$ Phase angle: $\pm2°$		
Start time [27], [28]		Minimum	Typical	Maximum

Table continues on the next page

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[26] For further reference, see the Operation characteristics table

[27] Set *Operate delay time* = 0.06 s, *Operate curve type* = IEC definite time, *Measurement mode* = default (depends on stage), current before fault = $0.0 \times I_n$, f_n = 50 Hz, earth-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[28] Includes the delay of the signal output contact

Characteristic	Value		
DEFHPDEF I_{Fault} = 2 × set *Start value*	42 ms	46 ms	49 ms
DEFLPDEF I_{Fault} = 2 × set *Start value*	58 ms	62 ms	66 ms
Reset time	Typically 40 ms		
Reset ratio	Typically 0.96		
Retardation time	<30 ms		
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms [29]		
Suppression of harmonics	RMS: No suppression DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,… Peak-to-Peak: No suppression		

21.23.8 Directional earth-fault protection (DEFxPDEF) main settings

Table 37: Directional earth-fault protection (DEFxPDEF) main settings

Parameter	Function	Value (Range)	Step
Start value	DEFLPDEF	0.010...5.000 × I_n	0.005
	DEFHPDEF	0.10...40.00 × I_n	0.01
Directional mode	DEFLPDEF and DEFHPDEF	1 = Non-directional 2 = Forward 3 = Reverse	-
Time multiplier	DEFLPDEF	0.05...15.00	0.01
	DEFHPDEF	0.05...15.00	0.01
Operate delay time	DEFLPDEF	50...200000 ms	10
	DEFHPDEF	40...200000 ms	10
Operating curve type [30]	DEFLPDEF	Definite or inverse time Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	
	DEFHPDEF	Definite or inverse time Curve type: 1, 3, 5, 15, 17	
Operation mode	DEFxPDEF	1 = Phase angle 2 = IoSin 3 = IoCos 4 = Phase angle 80 5 = Phase angle 88	-

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[29] Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 1.5...20
[30] For further reference, see the Operating characteristics table

21.23.9 Admittance-based earth-fault protection (EFPADM)

Table 38: Admittance-based earth-fault protection (EFPADM)

Characteristic	Value		
Operation accuracy [31]	At the frequency $f = f_n$		
	±1.0% or ±0.01 mS		
	(In range of 0.5...100 mS)		
Start time [32]	Minimum	Typical	Maximum
	56 ms	60 ms	64 ms
Reset time	40 ms		
Operate time accuracy	±1.0% of the set value of ±20 ms		
Suppression of harmonics	-50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		

21.23.10 Admittance-based earth-fault protection (EFPADM) main settings

Table 39: Admittance-based earth-fault protection (EFPADM) main settings

Parameter	Function	Value (Range)	Step
Voltage start value	EFPADM	$0.01...2.00 \times U_n$	0.01
Directional mode	EFPADM	1 = Non-directional	-
		2 = Forward	
		3 = Reverse	
Operation mode	EFPADM	1 = Yo	-
		2 = Go	
		3 = Bo	
		4 = Yo, Go	
		5 = Yo, Bo	
		6 = Go, Bo	
		7 = Yo, Go, Bo	
Operate delay time	EFPADM	60...200000 ms	10
Circle radius	EFPADM	0.05...500.00 mS	0.01
Circle conductance	EFPADM	-500.00...500.00 mS	0.01
Circle susceptance	EFPADM	-500.00...500.00 mS	0.01
Conductance forward	EFPADM	-500.00...500.00 mS	0.01
Conductance reverse	EFPADM	-500.00...500.00 mS	0.01
Susceptance forward	EFPADM	-500.00...500.00 mS	0.01
Susceptance reverse	EFPADM	-500.00...500.00 mS	0.01
Conductance tilt Ang	EFPADM	-30...30°	1
Susceptance tilt Ang	EFPADM	-30...30°	1

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[31] Uo = 1.0 × Un
[32] Includes the delay of the signal output contact, results based on statistical distribution of 1000 measurements

21.23.11 Wattmetric-based earth-fault protection (WPWDE)

Table 40: Wattmetric-based earth-fault protection (WPWDE)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f^n ±2 Hz
	Current and voltage:
	±1.5% of the set value or ±0.002 × I_n
	Power:
	±3% of the set value or ±0.002 × P_n
Start time [33], [34]	Typically 63 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in IDMT mode	±5.0% of the set value or ±20 ms
Suppression of harmonics	-50 dB at f = n × fn, where n = 2,3,4,5,…

21.23.12 Wattmetric-based earth-fault protection (WPWDE) main settings

Table 41: Wattmetric-based earth-fault protection (WPWDE) main settings

Parameter	Function	Value (Range)	Step
Directional mode	WPWDE	2 = Forward 3 = Reverse	-
Current start value	WPWDE	0.010...5.000 × I_n	0.001
Voltage start value	WPWDE	0.010...1.000 × U_n	0.001
Power start value	WPWDE	0.003...1.000 × P_n	0.001
Reference power	WPWDE	0.050...1.000 × P_n	0.001
Characteristic angle	WPWDE	-179...180°	1
Time multiplier	WPWDE	0.05...2.00	0.01
Operating curve type	WPWDE	Definite or inverse time Curve type: 5, 15, 20	
Operate delay time	WPWDE	60...200000 ms	10
Min operate current	WPWDE	0.010...1.000 × I_n	0.001
Min operate voltage	WPWDE	0.01...1.00 × U_n	0.01

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[33] Io varied during the test, Uo = 1.0 × U_n = phase-to-earth voltage during earth fault in compensated or unearthed network, the residual power value before fault = 0.0 pu, f_n = 50 Hz, results based on statistical distribution of 1000 measurements

[34] Includes the delay of the signal output contact

[35] For further reference, refer to the Operating characteristics table

21.23.13 Transient/intermittent earth-fault protection (INTRPTEF)

Table 42: Transient/intermittent earth-fault protection (INTRPTEF)

Characteristic	Value
Operation accuracy (Uo criteria with transient protection)	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × Uo
Operate time accuracy	±1.0% of the set value or ±20 ms
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5

21.23.14 Transient/intermittent earth-fault protection (INTRPTEF) main settings

Table 43: Transient/intermittent earth-fault protection (INTRPTEF) main settings

Parameter	Function	Value (Range)	Step
Directional mode	INTRPTEF	1 = Non-directional 2 = Forward 3 = Reverse	-
Operate delay time	INTRPTEF	40...1200000 ms	10
Voltage start value	INTRPTEF	0.05...0.50 × U_n	0.01
Operation mode	INTRPTEF	1 = Intermittent EF 2 = Transient EF	-
Peak counter limit	INTRPTEF	2...20	1
Min operate current	INTRPTEF	0.01...1.00 × I_n	0.01

21.23.15 Harmonics-based earth-fault protection (HAEFPTOC)

Table 44: Harmonics-based earth-fault protection (HAEFPTOC)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±5% of the set value or ±0.004 × I_n
Start time [36], [37]	Typically 77 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Operate time accuracy in IDMT mode [38]	±5.0% of the set value or ±20 ms
Suppression of harmonics	-50 dB at $f = f_n$
	-3 dB at $f = 13 \times f_n$

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[36] Fundamental frequency current = 1.0 × I_n, harmonics current before fault = 0.0 × I_n, harmonics fault current 2.0 × *Start value*, results based on statistical distribution of 1000 measurements

[37] Includes the delay of the signal output contact

[38] Maximum *Start value* = 2.5 × I_n, *Start value* multiples in range of 2...20

21.23.16 Harmonics-based earth-fault protection (HAEFPTOC) main settings

Table 45: Harmonics-based earth-fault protection (HAEFPTOC) main settings

Parameter	Function	Value (Range)	Step
Start value	HAEFPTOC	$0.05...5.00 \times I_n$	0.01
Time multiplier	HAEFPTOC	0.05...15.00	0.01
Operate delay time	HAEFPTOC	100...200000 ms	10
Operating curve type	HAEFPTOC	Definite or inverse time Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	
Minimum operate time	HAEFPTOC	100...200000 ms	10

21.23.17 Negative-sequence overcurrent protection (NSPTOC)

Table 46: Negative-sequence overcurrent protection (NSPTOC)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f_n		
		$\pm1.5\%$ of the set value or $\pm0.002 \times I_n$		
Start time [40], [41]		Minimum	Typical	Maximum
	$I_{Fault} = 2 \times$ set *Start value*	23 ms	26 ms	28 ms
	$I_{Fault} = 10 \times$ set *Start value*	15 ms	18 ms	20 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		$\pm1.0\%$ of the set value or ±20 ms		
Operate time accuracy in inverse time mode		$\pm5.0\%$ of the theoretical value or ±20 ms [42]		
Suppression of harmonics		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,...		

21.23.18 Negative-sequence overcurrent protection (NSPTOC) main settings

Table 47: Negative-sequence overcurrent protection (NSPTOC) main settings

Parameter	Function	Value (Range)	Step
Start value	NSPTOC	$0.01...5.00 \times I_n$	0.01
Time multiplier	NSPTOC	0.05...15.00	0.01
Operate delay time	NSPTOC	40...200000 ms	10
Operating curve type [43]	NSPTOC	Definite or inverse time Curve type: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19	

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[39] For further reference, see Operation characteristics table
[40] Negative sequence current before fault = 0.0, f_n = 50 Hz, results based on statistical distribution of 1000 measurements
[41] Includes the delay of the signal output contact
[42] Maximum *Start value* = $2.5 \times I_n$, *Start value* multiples in range of 1.5...20
[43] For further reference, see the Operation characteristics table

21.23.19 Phase discontinuity protection (PDNSPTOC)

Table 48: Phase discontinuity protection (PDNSPTOC)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±2% of the set value
Start time	<70 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Retardation time	<35 ms
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…

21.23.20 Phase discontinuity protection (PDNSPTOC) main settings

Table 49: Phase discontinuity protection (PDNSPTOC) main settings

Parameter	Function	Value (Range)	Step
Start value	PDNSPTOC	10...100%	1
Operate delay time	PDNSPTOC	100...30000 ms	1
Min phase current	PDNSPTOC	$0.05...0.30 \times I_n$	0.01

21.23.21 Residual overvoltage protection (ROVPTOV)

Table 50: Residual overvoltage protection (ROVPTOV)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured voltage: f_n ±2 Hz		
		±1.5% of the set value or $±0.002 \times U_n$		
Start time [44], [45]		Minimum	Typical	Maximum
	$U_{Fault} = 2 \times$ set *Start value*	48 ms	51 ms	54 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		

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[44] Residual voltage before fault = $0.0 \times U_n$, f_n = 50 Hz, residual voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[45] Includes the delay of the signal output contact

21.23.22 Residual overvoltage protection (ROVPTOV) main settings

Table 51: Residual overvoltage protection (ROVPTOV) main settings

Parameter	Function	Value (Range)	Step
Start value	ROVPTOV	$0.010...1.000 \times U_n$	0.001
Operate delay time	ROVPTOV	40...300000 ms	1

21.23.23 Three-phase undervoltage protection (PHPTUV)

Table 52: Three-phase undervoltage protection (PHPTUV)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: $f_n \pm 2$ Hz		
		$\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$		
Start time [46], [47]		Minimum	Typical	Maximum
	$U_{Fault} = 0.9 \times$ set *Start value*	62 ms	66 ms	70 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		$\pm 1.0\%$ of the set value or ± 20 ms		
Operate time accuracy in inverse time mode		$\pm 5.0\%$ of the theoretical value or ± 20 ms [48]		
Suppression of harmonics		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		

21.23.24 Three-phase undervoltage protection (PHPTUV) main settings

Table 53: Three-phase undervoltage protection (PHPTUV) main settings

Parameter	Function	Value (Range)	Step
Start value	PHPTUV	$0.05...1.20 \times U_n$	0.01
Time multiplier	PHPTUV	0.05...15.00	0.01
Operate delay time	PHPTUV	60...300000 ms	10
Operating curve type[49]	PHPTUV	Definite or inverse time Curve type: 5, 15, 21, 22, 23	

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[46] *Start value* = $1.0 \times U_n$, Voltage before fault = $1.1 \times U_n$, f_n = 50 Hz, undervoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[47] Includes the delay of the signal output contact

[48] Minimum *Start value* = 0.50, *Start value* multiples in range of 0.90...0.20

[49] For further reference, see the Operation characteristics table

21.23.25 Three-phase overvoltage protection (PHPTOV)

Table 54: Three-phase overvoltage protection (PHPTOV)

Characteristic	Value		
Operation accuracy	Depending on the frequency of the measured voltage: f_n ±2 Hz		
	±1.5% of the set value or ±0.002 × U_n		
Start time [50], [51]	Minimum	Typical	Maximum
U_{Fault} = 1.1 × set *Start value*	23 ms	27 ms	31 ms
Reset time	Typically 40 ms		
Reset ratio	Depends on the set *Relative hysteresis*		
Retardation time	<35 ms		
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode	±5.0% of the theoretical value or ±20 ms [52]		
Suppression of harmonics	DFT: -50 dB at $f = n × f_n$, where n = 2, 3, 4, 5,…		

21.23.26 Three-phase overvoltage protection (PHPTOV) main settings

Table 55: Three-phase overvoltage protection (PHPTOV) main settings

Parameter	Function	Value (Range)	Step
Start value	PHPTOV	0.05...1.60 × U_n	0.01
Time multiplier	PHPTOV	0.05...15.00	0.01
Operate delay time	PHPTOV	40...300000 ms	10
Operating curve type [53]	PHPTOV	Definite or inverse time Curve type: 5, 15, 17, 18, 19, 20	

21.23.27 Positive-sequence undervoltage protection (PSPTUV)

Table 56: Positive-sequence undervoltage protection (PSPTUV)

Characteristic	Value		
Operation accuracy	Depending on the frequency of the measured voltage: f_n ±2 Hz		
	±1.5% of the set value or ±0.002 × U_n		
Start time [54],[55]	Minimum	Typical	Maximum

Table continues on the next page

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[50] *Start value* = 1.0 × U_n, Voltage before fault = 0.9 × U_n, f_n = 50 Hz, overvoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[51] Includes the delay of the signal output contact

[52] Maximum *Start value* = 1.20 × U_n, *Start value* multiples in range of 1.10...2.00

[53] For further reference, see the Operation characteristics table

[54] *Start value* = 1.0 × U_n, positive-sequence voltage before fault = 1.1 × U_n, f_n = 50 Hz, positive sequence undervoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[55] Includes the delay of the signal output contact

Characteristic		Value		
U_{Fault} = 0.99 × set *Start value*		52 ms	55 ms	58 ms
U_{Fault} = 0.9 × set *Start value*		44 ms	47 ms	50 ms
Reset time		Typically 40 ms		
Reset ratio		Depends on the set *Relative hysteresis*		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		

21.23.28 Positive-sequence undervoltage protection (PSPTUV) main settings

Table 57: Positive-sequence undervoltage protection (PSPTUV) main settings

Parameter	Function	Value (Range)	Step
Start value	PSPTUV	0.010…1.200 × U_n	0.001
Operate delay time	PSPTUV	40…120000 ms	10
Voltage block value	PSPTUV	0.01…1.00 × U_n	0.01

21.23.29 Negative-sequence overvoltage protection (NSPTOV)

Table 58: Negative-sequence overvoltage protection (NSPTOV)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the voltage measured: f_n		
		±1.5% of the set value or ±0.002 × U_n		
Start time [56],[57]		Minimum	Typical	Maximum
	U_{Fault} = 1.1 × set *Start value*	33 ms	35 ms	37 ms
	U_{Fault} = 2.0 × set *Start value*	24 ms	26 ms	28 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		<35 ms		
Operate time accuracy in definite time mode		±1.0% of the set value or ±20 ms		
Suppression of harmonics		DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…		

21.23.30 Negative-sequence overvoltage protection (NSPTOV) main settings

Table 59: Negative-sequence overvoltage protection (NSPTOV) main settings

Parameter	Function	Value (Range)	Step
Start value	NSPTOV	0.010…1.000 × U_n	0.001
Operate delay time	NSPTOV	40…120000 ms	1

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[56] Negative-sequence voltage before fault = 0.0 × U_n, f_n = 50 Hz, negative-sequence overvoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[57] Includes the delay of the signal output contact

21.23.31 Frequency protection (FRPFRQ)

Table 60: Frequency protection (FRPFRQ)

Characteristic		Value
Operation accuracy	f>/f<	±5 mHz
	df/dt	±50 mHz/s (in range |df/dt| <5 Hz/s)
		±2.0% of the set value (in range 5 Hz/s < |df/dt| < 15 Hz/s)
Start time	f>/f<	<80 ms
	df/dt	<120 ms
Reset time		<150 ms
Operate time accuracy		±1.0% of the set value or ±30 ms

21.23.32 Frequency protection (FRPFRQ) main settings

Table 61: Frequency protection (FRPFRQ) main settings

Parameter	Function	Value (Range)	Step
Operation mode	FRPFRQ	1 = Freq<	-
		2 = Freq>	
		3 = df/dt	
		4 = Freq< + df/dt	
		5 = Freq> + df/dt	
		6 = Freq< OR df/dt	
		7 = Freq> OR df/dt	
Start value Freq>	FRPFRQ	$0.9000...1.2000 \times f_n$	0.0001
Start value Freq<	FRPFRQ	$0.8000...1.1000 \times f_n$	0.0001
Start value df/dt	FRPFRQ	$-0.2000...0.2000 \times f_n/s$	0.005
Operate Tm Freq	FRPFRQ	80...200000 ms	10
Operate Tm df/dt	FRPFRQ	120...200000 ms	10

21.23.33 Three-phase thermal protection for feeders, cables and distribution transformers (T1PTTR)

Table 62: Three-phase thermal protection for feeders, cables and distribution transformers (T1PTTR)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	Current measurement: ±1.5% of the set value or $±0.002 \times I_n$ (at currents in the range of $0.01...4.00 \times I_n$)
Operate time accuracy [58]	±2.0% of the theoretical value or ±0.50 s

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[58] Overload current > 1.2 × Operate level temperature

21.23.34 Three-phase thermal protection for feeders, cables and distribution transformers (T1PTTR) main settings

Table 63: Three-phase thermal protection for feeders, cables and distribution transformers (T1PTTR) main settings

Parameter	Function	Value (Range)	Step
Env temperature Set	T1PTTR	-50...100°C	1
Current reference	T1PTTR	0.05...4.00 × I_n	0.01
Temperature rise	T1PTTR	0.0...200.0°C	0.1
Time constant	T1PTTR	60...60000 s	1
Maximum temperature	T1PTTR	20.0...200.0°C	0.1
Alarm value	T1PTTR	20.0...150.0°C	0.1
Reclose temperature	T1PTTR	20.0...150.0°C	0.1
Current multiplier	T1PTTR	1...5	1
Initial temperature	T1PTTR	-50.0...100.0°C	0.1

21.23.35 Three-phase thermal overload protection, two time constants (T2PTTR)

Table 64: Three-phase thermal overload protection, two time constants (T2PTTR)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	Current measurement: ±1.5% of the set value or ±0.002 x I_n (at currents in the range of 0.01...4.00 x I_n)
Operate time accuracy [59]	±2.0% of the theoretical value or ±0.50 s

21.23.36 Three-phase thermal overload protection, two time constants (T2PTTR) main settings

Table 65: Three-phase thermal overload protection, two time constants (T2PTTR) main settings

Parameter	Function	Value (Range)	Step
Temperature rise	T2PTTR	0.0...200.0°C	0.1
Max temperature	T2PTTR	0.0...200.0°C	0.1
Operate temperature	T2PTTR	80.0...120.0%	0.1
Short time constant	T2PTTR	6...60000 s	1
Weighting factor p	T2PTTR	0.00...1.00	0.01
Current reference	T2PTTR	0.05...4.00 × I_n	0.01
Operation	T2PTTR	1 = on 5 = off	-

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[59] Overload current > 1.2 x Operate level temperature

21.23.37 Binary signal transfer (BSTGGIO)

Table 66: Binary signal transfer (BSTGGIO)

Characteristic		Value
Signalling delay	Fiber optic link	<5 ms
	Galvanic pilot wire link	<10 ms

21.23.38 Circuit breaker failure protection (CCBRBRF)

Table 67: Circuit breaker failure protection (CCBRBRF)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: f_n ±2 Hz
	±1.5% of the set value or ±0.002 × I_n
Operate time accuracy	±1.0% of the set value or ±20 ms
Reset time	Typically 40 ms
Retardation time	<20 ms

21.23.39 Circuit breaker failure protection (CCBRBRF) main settings

Table 68: Circuit breaker failure protection (CCBRBRF) main settings

Parameter	Function	Value (Range)	Step
Current value	CCBRBRF	0.05...2.00 × I_n	0.05
Current value Res	CCBRBRF	0.05...2.00 × I_n	0.05
CB failure mode	CCBRBRF	1 = Current 2 = Breaker status 3 = Both	-
CB fail trip mode	CCBRBRF	1 = Off 2 = Without check 3 = Current check	-
Retrip time	CCBRBRF	0...60000 ms	10
CB failure delay	CCBRBRF	0...60000 ms	10
CB fault delay	CCBRBRF	0...60000 ms	10

21.23.40 Three-phase inrush detector (INRPHAR)

Table 69: Three-phase inrush detector (INRPHAR)

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$
	Current measurement:
	±1.5% of the set value or ±0.002 × I_n
	Ratio I2f/I1f measurement:
	±5.0% of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typically 0.96
Operate time accuracy	+35 ms / -0 ms

21.23.41 Three-phase inrush detector (INRPHAR) main settings

Table 70: Three-phase inrush detector (INRPHAR) main settings

Parameter	Function	Value (Range)	Step
Start value	INRPHAR	5...100%	1
Operate delay time	INRPHAR	20...60000 ms	1

21.23.42 Switch onto fault (CBPSOF)

Table 71: Switch onto fault (CBPSOF)

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

21.23.43 Switch onto fault (CBPSOF) main settings

Table 72: Switch onto fault (CBPSOF) main settings

Parameter	Function	Value (Range)	Step
SOTF reset time	CBPSOF	0...60000 ms	1

21.23.44 Multipurpose protection (MAPGAPC)

Table 73: Multipurpose protection (MAPGAPC)

Characteristic	Value
Operation accuracy	±1.0% of the set value or ±20 ms

21.23.45 Multipurpose protection (MAPGAPC) main settings

Table 74: Multipurpose protection (MAPGAPC) main settings

Parameter	Function	Value (Range)	Step
Start value	MAPGAPC	-10000.0...10000.0	0.1
Operate delay time	MAPGAPC	0...200000 ms	100
Operation mode	MAPGAPC	1 = Over 2 = Under	-

21.23.46 Fault locator (SCEFRFLO)

Table 75: Fault locator (SCEFRFLO)

Characteristic	Value
Measurement accuracy	At the frequency $f = f_n$
	Impedance: ±2.5% or ±0.25 Ω
	Distance: ±2.5% or ±0.16 km/0.1 mile
	XC0F_CALC: ±2.5% or ±50 Ω
	IFLT_PER_ILD: ±5% or ±0.05

21.23.47 Fault locator (SCEFRFLO) main settings

Table 76: Fault locator (SCEFRFLO) main settings

Parameter	Function	Value (Range)	Step
Z Max phase load	SCEFRFLO	1.0...10000.00 Ω	0.1
Ph leakage Ris	SCEFRFLO	20...1000000 Ω	1
Ph capacitive React	SCEFRFLO	10...1000000 Ω	1
R1 line section A	SCEFRFLO	0.000...1000.000 Ω/pu	0.001
X1 line section A	SCEFRFLO	0.000...1000.000 Ω/pu	0.001
R0 line section A	SCEFRFLO	0.000...1000.000 Ω/pu	0.001
X0 line section A	SCEFRFLO	0.000...1000.000 Ω/pu	0.001
Line Len section A	SCEFRFLO	0.000...1000.000 pu	0.001

21.23.48 Line differential protection with in-zone power transformer (LNPLDF)

Table 77: Line differential protection with in-zone power transformer (LNPLDF)

Characteristics	Value		
Operation accuracy [60]	Depending on the frequency of the measured current: f_n ±2 Hz		
	Low stage	±2.5% of the set value	
	High stage	±2.5% of the set value	
	Minimum	Typical	Maximum
High stage, operate time [61], [62]	22 ms	25 ms	29 ms
Reset time	Typically 40 ms		
Reset ratio	Typically 0.96		
Retardation time (Low stage)	<40 ms		
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms		
Operate time accuracy in inverse time mode	±5.0% of the set value or ±20 ms [63]		

21.23.49 Line differential protection with in-zone power transformer (LNPLDF) main settings

Table 78: Line differential protection with in-zone power transformer (LNPLDF) main settings

Parameter	Function	Value (Range)	Step
Low operate value	LNPLDF	10...200 % I_n	1
High operate value	LNPLDF	200...4000 % I_n	1
Start value 2.H	LNPLDF	10...50 %	1
Time multiplier	LNPLDF	0.05...15.00	0.01
Operate curve type	LNPLDF	1=ANSI Ext. inv.	-
		3=ANSI Norm. inv.	
		5=ANSI Def. Time	
		9=IEC Norm. inv.	
		10=IEC Very inv.	
		12=IEC Ext. inv.	
		15=IEC Def. Time	
Operate delay time	LNPLDF	45...200000 ms	1
CT ratio correction	LNPLDF	0.200...5.000	0.001

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[60] With the symmetrical communication channel (as when using dedicated fiber optic).

[61] Without additional delay in the communication channel (as when using dedicated fiber optic).

[62] Including the delay of the output contact. When differential current = 2 × *High operate value* and f_n = 50 Hz with galvanic pilot wire link + 5 ms.

[63] *Low operate value* multiples in range of 1.5...20.

21.23.50 High-impedance fault detection (PHIZ) main settings

Table 79: High-impedance fault detection (PHIZ) main settings

Parameter	Function	Value (Range)	Step
Security Level	PHIZ	1...10	1
System type	PHIZ	1 = Grounded 2 = Ungrounded	-

21.23.51 Operation characteristics

Table 80: Operation characteristics

Parameter	Value (Range)
Operating curve type	1 = ANSI Ext. inv.
	2 = ANSI Very. inv.
	3 = ANSI Norm. inv.
	4 = ANSI Mod inv.
	5 = ANSI Def. Time
	6 = L.T.E. inv.
	7 = L.T.V. inv.
	8 = L.T. inv.
	9 = IEC Norm. inv.
	10 = IEC Very inv.
	11 = IEC inv.
	12 = IEC Ext. inv.
	13 = IEC S.T. inv.
	14 = IEC L.T. inv
	15 = IEC Def. Time
	17 = Programmable
	18 = RI type
	19 = RD type
Operating curve type (voltage protection)	5 = ANSI Def. Time
	15 = IEC Def. Time
	17 = Inv. Curve A
	18 = Inv. Curve B
	19 = Inv. Curve C
	20 = Programmable
	21 = Inv. Curve A
	22 = Inv. Curve B
	23 = Programmable

21.24 Power quality functions

21.24.1 Voltage variation (PHQVVR)

Table 81: Voltage variation (PHQVVR)

Characteristic	Value
Operation accuracy	±1.5% of the set value or ±0.2% of reference voltage
Reset ratio	Typically 0.96 (Swell), 1.04 (Dip, Interruption)

21.24.2 Voltage variation (PHQVVR) main settings

Table 82: Voltage variation (PHQVVR) main settings

Parameter	Function	Value (Range)	Step
Voltage dip set 1	PHQVVR	10.0...100.0%	0.1
Voltage dip set 2	PHQVVR	10.0...100.0%	0.1
Voltage dip set 3	PHQVVR	10.0...100.0%	0.1
Voltage swell set 1	PHQVVR	100.0...140.0%	0.1
Voltage swell set 2	PHQVVR	100.0...140.0%	0.1
Voltage swell set 3	PHQVVR	100.0...140.0%	0.1
Voltage Int set	PHQVVR	0.0...100.0%	0.1
VVa Dur Max	PHQVVR	100...3600000 ms	100

21.24.3 Voltage unbalance (VSQVUB)

Table 83: Voltage unbalance (VSQVUB)

Characteristic	Value
Operation accuracy	±1.5% of the set value or ±0.002 × U_n
Reset ratio	Typically 0.96

21.24.4 Voltage unbalance (VSQVUB) main settings

Table 84: Voltage unbalance (VSQVUB) main settings

Parameter	Function	Value (Range)	Step
Operation	VSQVUB	1 = on 5 = off	-
Unb detection method	VSQVUB	1 = Neg Seq 2 = Zero Seq 3 = Neg to Pos Seq 4 = Zero to Pos Seq 5 = Ph vectors Comp	-

21.25 Control functions

21.25.1 Autoreclosing (DARREC)

Table 85: Autoreclosing (DARREC)

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

21.25.2 Synchronism and energizing check (SECRSYN)

Table 86: Synchronism and energizing check (SECRSYN)

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±1 Hz
	Voltage:
	±3.0% of the set value or ±0.01 × U_n
	Frequency:
	±10 mHz
	Phase angle:
	±3°
Reset time	<50 ms
Reset ratio	Typically 0.96
Operate time accuracy in definite time mode	±1.0% of the set value or ±20 ms

21.25.3 Synchronism and energizing check (SECRSYN) main settings

Table 87: Synchronism and energizing check (SECRSYN) main settings

Parameter	Function	Value (Range)	Step
Live dead mode	SECRSYN	-1 = Off	-
		1 = Both Dead	
		2 = Live L, Dead B	
		3 = Dead L, Live B	
		4 = Dead Bus, L Any	
		5 = Dead L, Bus Any	
		6 = One Live, Dead	
		7 = Not Both Live	
Difference voltage	SECRSYN	0.01...0.50 × U_n	0.01
Difference frequency	SECRSYN	0.001...0.100 × f_n	0.001
Difference angle	SECRSYN	5...90°	1

Table continues on the next page

Parameter	Function	Value (Range)	Step
Synchrocheck mode	SECRSYN	1 = Off 2 = Synchronous 3 = Asynchronous	-
Dead line value	SECRSYN	$0.1...0.8 \times U_n$	0.1
Live line value	SECRSYN	$0.2...1.0 \times U_n$	0.1
Max energizing V	SECRSYN	$0.50...1.15 \times U_n$	0.01
Control mode	SECRSYN	1 = Continuous 2 = Command	-
Close pulse	SECRSYN	200...60000 ms	10
Phase shift	SECRSYN	-180...180°	1
Minimum Syn time	SECRSYN	0...60000 ms	10
Maximum Syn time	SECRSYN	100...6000000 ms	10
Energizing time	SECRSYN	100...60000 ms	10
Closing time of CB	SECRSYN	40...250 ms	10

21.26 Condition monitoring and supervision functions

21.26.1 Circuit-breaker condition monitoring (SSCBR)

Table 88: Circuit-breaker condition monitoring (SSCBR)

Characteristic	Value
Current measuring accuracy	$\pm1.5\%$ or $\pm0.002 \times I_n$ (at currents in the range of $0.1...10 \times I_n$) $\pm5.0\%$ (at currents in the range of $10...40 \times I_n$)
Operate time accuracy	$\pm1.0\%$ of the set value or ±20 ms
Travelling time measurement	+10 ms / -0 ms

21.26.2 Current circuit supervision (CCSPVC)

Table 89: Current circuit supervision (CCSPVC)

Characteristic	Value
Operate time [64]	<30 ms

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[64] Including the delay of the output contact

21.26.3 Current circuit supervision (CCSPVC) main settings

Table 90: Current circuit supervision (CCSPVC) main settings

Parameter	Function	Value (Range)	Step
Start value	CCSPVC	$0.05...0.20 \times I_n$	0.01
Max operate current	CCSPVC	$1.00...5.00 \times I_n$	0.01

21.26.4 Fuse failure supervision (SEQSPVC)

Table 91: Fuse failure supervision (SEQSPVC)

Characteristic		Value	
Operate time [65]	NPS function	$U_{Fault} = 1.1 \times$ set *Neg Seq voltage Lev*	<33 ms
		$U_{Fault} = 5.0 \times$ set *Neg Seq voltage Lev*	<18 ms
	Delta function	$\Delta U = 1.1 \times$ set *Voltage change rate*	<30 ms
		$\Delta U = 2.0 \times$ set *Voltage change rate*	<24 ms

21.26.5 Runtime counter for machines and devices (MDSOPT)

Table 92: Runtime counter for machines and devices (MDSOPT)

Description	Value
Motor runtime measurement accuracy	±0.5%

21.27 Measurement functions

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[65] Includes the delay of the signal output contact, f_n = 50 Hz, fault voltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

[66] Of the reading, for a stand-alone relay, without time synchronization

21.27.1 Three-phase current measurement (CMMXU)

Table 93: Three-phase current measurement (CMMXU)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz
	$\pm 0.5\%$ or $\pm 0.002 \times I_n$
	(at currents in the range of $0.01...4.00 \times I_n$)
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…
	RMS: No suppression

21.27.2 Sequence current measurement (CSMSQI)

Table 94: Sequence current measurement (CSMSQI)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f/f_n = \pm 2$ Hz
	$\pm 1.0\%$ or $\pm 0.002 \times I_n$
	at currents in the range of $0.01...4.00 \times I_n$
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…

21.27.3 Residual current measurement (RESCMMXU)

Table 95: Residual current measurement (RESCMMXU)

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: $f/f_n = \pm 2$ Hz
	$\pm 0.5\%$ or $\pm 0.002 \times I_n$
	at currents in the range of $0.01...4.00 \times I_n$
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…
	RMS: No suppression

21.27.4 Three-phase voltage measurement (VMMXU)

Table 96: Three-phase voltage measurement (VMMXU)

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2 Hz
	At voltages in range 0.01…1.15 × U_n
	±0.5% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…
	RMS: No suppression

21.27.5 Residual voltage measurement (RESVMMXU)

Table 97: Residual voltage measurement (RESVMMXU)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: f/f_n = ±2 Hz
	±0.5% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…
	RMS: No suppression

21.27.6 Sequence voltage measurement (VSMSQI)

Table 98: Sequence voltage measurement (VSMSQI)

Characteristic	Value
Operation accuracy	Depending on the frequency of the voltage measured: f_n ±2 Hz
	At voltages in range 0.01…1.15 × U_n
	±1.0% or ±0.002 × U_n
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where n = 2, 3, 4, 5,…

21.27.7 Three-phase power and energy measurement (PEMMXU)

Table 99: Three-phase power and energy measurement (PEMMXU)

Characteristic	Value
Operation accuracy	At all three currents in range 0.10…1.20 × I_n
	At all three voltages in range 0.50…1.15 × U_n
	At the frequency f_n ±1 Hz
	±1.5% for apparent power S
	±1.5% for active power P and active energy [67]
	±1.5% for reactive power Q and reactive energy [68]
	±0.015 for power factor
Suppression of harmonics	DFT: -50 dB at f = n × f_n, where n = 2, 3, 4, 5,…

21.27.8 RTD/mA measurement (XRGGIO130)

Table 100: RTD/mA measurement (XRGGIO130)

Description		Value	
RTD inputs	Supported RTD sensors	100 Ω platinum	TCR 0.00385 (DIN 43760)
		250 Ω platinum	TCR 0.00385
		100 Ω nickel	TCR 0.00618 (DIN 43760)
		120 Ω nickel	TCR 0.00618
		250 Ω nickel	TCR 0.00618
		10 Ω copper	TCR 0.00427
	Supported resistance range	0…2 kΩ	
	Maximum lead resistance (three-wire measurement)	25 Ω per lead	
	Isolation	2 kV (inputs to protective earth)	
	Response time	<4 s	
	RTD/resistance sensing current	Maximum 0.33 mA rms	
	Operation accuracy	Resistance	Temperature
		± 2.0% or ±1 Ω	±1°C
			10 Ω copper: ±2°C
mA inputs	Supported current range	0…20 mA	
	Current input impedance	44 Ω ± 0.1%	
	Operation accuracy	±0.5% or ±0.01 mA	

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[67] |PF| >0.5 which equals |cosφ| >0.5
[68] |PF| <0.86 which equals |sinφ| >0.5

21.27.9 Frequency measurement (FMMXU)

Table 101: Frequency measurement (FMMXU)

Characteristic	Value
Operation accuracy	±5 mHz (in measurement range 35...75 Hz)

21.28 Other functions

21.28.1 Pulse timer (PTGAPC)

Table 102: Pulse timer (PTGAPC)

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

21.28.2 Time delay off (8 pcs) (TOFPAGC)

Table 103: Time delay off (8 pcs) (TOFPAGC)

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

21.28.3 Time delay on (8 pcs) (TONGAPC)

Table 104: Time delay on (8 pcs) (TONGAPC)

Characteristic	Value
Operate time accuracy	±1.0% of the set value or ±20 ms

22. Local HMI

The relay is available with two optional displays, a large one and a small one. The large display is suited for relay installations where the front panel user interface is frequently used and a single line diagram is required. The small display is suited for remotely controlled substations where the relay is only occasionally accessed locally via the front panel user interface.

Both LCD displays offer front-panel user interface functionality with menu navigation and menu views. However, the large display offers increased front-panel usability with less menu scrolling and improved information overview. In addition, the large display includes a user-configurable single line diagram (SLD) with position indication for the associated primary equipment. Depending on the chosen standard configuration, the relay displays the related measuring values, apart from the default single line diagram. The SLD view can also be accessed using the Web browser-based user interface. The default SLD can be modified according to user requirements by using the Graphical Display Editor in PCM600. The user can create up to 10 SLD pages.

The local HMI includes a push button (L/R) for local/remote operation of the relay. When the relay is in the local mode, it can be operated only by using the local front panel user interface. When the relay is in the remote mode, it can execute commands sent from a remote location. The relay supports the remote

selection of local/remote mode via a binary input. This feature facilitates, for example, the use of an external switch at the substation to ensure that all relays are in the local mode during maintenance work and that the circuit breakers cannot be operated remotely from the network control center.
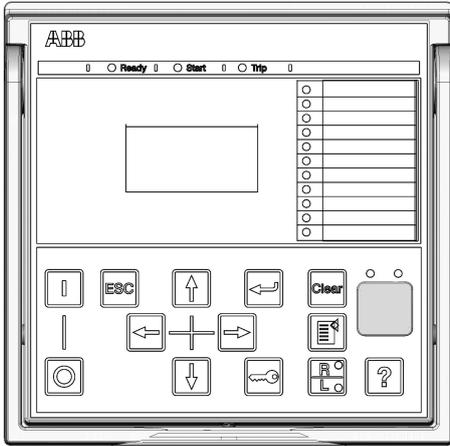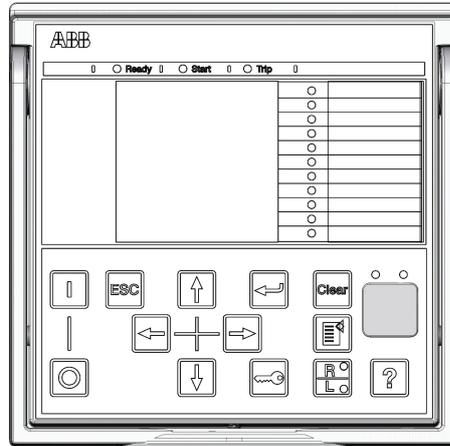

Figure 16: Small display

Figure 17: Large display

Table 105: Small display

Character size[80]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	5	20
Large, variable width (13 × 14 pixels)	3	8 or more

Table 106: Large display

Character size[80]	Rows in the view	Characters per row
Small, mono-spaced (6 × 12 pixels)	10	20
Large, variable width (13 × 14 pixels)	7	8 or more

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[80] Depending on the selected language

23. Mounting methods

By means of appropriate mounting accessories, the standard relay case can be flush mounted, semi-flush mounted or wall mounted. The flush mounted and wall mounted relay cases can also be mounted in a tilted position (25°) using special accessories.

Further, the relays can be mounted in any standard 19" instrument cabinet by means of 19" mounting panels available with cut-outs for one or two relays. Alternatively, the relays can be mounted in 19" instrument cabinets by means of 4U Combiflex equipment frames.

For routine testing purposes, the relay cases can be equipped with test switches, type RTXP

18, which can be mounted side by side with the relay cases.

Mounting methods

- Flush mounting
- Semi-flush mounting
- Semi-flush mounting in a 25° tilt
- Rack mounting
- Wall mounting
- Mounting to a 19" equipment frame
- Mounting with an RTXP 18 test switch to a 19" rack

Panel cut-out for flush mounting
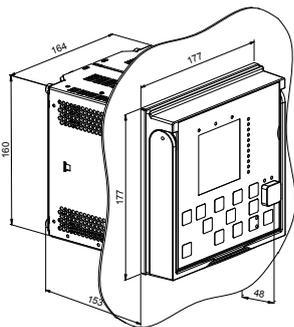
- Height: 161.5 ±1 mm
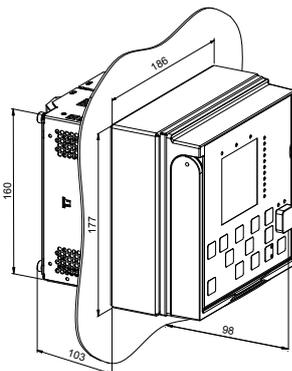- Width: 165.5 ±1 mm

Figure 18: Flush mounting
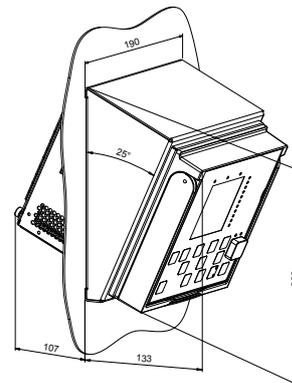

Figure 19: Semi-flush mounting

Figure 20: Semi-flush mounting in a 25º tilt

24. Relay case and plug-in unit

The relay cases are assigned to a certain type of plug-in unit. For safety reasons, the relay cases for current measuring relays are provided with automatically operating contacts for shortcircuiting the CT secondary circuits when a relay unit is withdrawn from its case. The relay case is further provided with a mechanical coding system preventing the current measuring relay units from being inserted into relay cases intended for voltage measuring relay units.

25. Selection and ordering data

Use *ABB Library* to access the selection and ordering information and to generate the order number.

Product Selection Tool (PST), a Next-Generation Order Number Tool, supports order code creation for ABB Distribution Automation IEC products with emphasis on, but not exclusively for, the Relion product family. PST is an easy-to-use, online tool always containing the latest product information. The complete order code can be created with detailed specification and the result can be printed and mailed. Registration is required.

26. Accessories and ordering data

Table 107: Pilot wire communication

Item	Order Number
Pilot Wire communication package including two Pilot Wire modems: RPW600AM (master) and RPW600AF (follower)	RPW600AMF
Diagnostics kit including the RPW-diagnostic tool, a diagnostic cable and a CD with necessary drivers and information	RPW600ADP
3.0 meter LC-LC single-mode fiber-optic patch cable for connecting one Pilot Wire modem to the RED615 relay[69]	1MRS120547-3

Table 108: Mounting accessories

Item	Order number
Semi-flush mounting kit	1MRS050696
Wall mounting kit	1MRS050697
Inclined semi-flush mounting kit	1MRS050831
19" rack mounting kit with cut-out for one relay	1MRS050694
19" rack mounting kit with cut-out for two relays	1MRS050695
Mounting bracket for one relay with test switch RTXP in 4U Combiflex (RHGT 19" variant C)	2RCA022642P0001
Mounting bracket for one relay in 4U Combiflex (RHGT 19" variant C)	2RCA022643P0001
19" rack mounting kit for one relay and one RTXP18 test switch (the test switch is not included in the delivery)	2RCA021952A0003
19" rack mounting kit for one relay and one RTXP24 test switch (the test switch is not included in the delivery)	2RCA022561A0003
Functional earthing flange for RTD modules[70]	2RCA036978A0001
Replacement kit for a Strömberg SP_J40 series relay (cut-out in the center of the installation plate)	2RCA027871A0001
Replacement kit for a Strömberg SP_J40 series relay (cut-out on the left or the right of the installation plate)	2RCA027874A0001
Replacement kit for two Strömberg SP_J3 series relays	2RCA027880A0001
19" rack replacement kit for Strömberg SP_J3/J6 series relays (one cut-out)	2RCA027894A0001
19" rack replacement kit for Strömberg SP_J3/J6 series relays (two cut-outs)	2RCA027897A0001
Replacement kit for a Strömberg SP_J6 series relay	2RCA027881A0001
Replacement kit for three BBC S_ series relays	2RCA027882A0001
Replacement kit for a SPA 300 series relay	2RCA027885A0001

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[69] Two patch cables are required for connecting the Pilot Wire communication package (RPW600AMF).
[70] Cannot be used when the protection relay is mounted with the Combiflex 19" equipment frame (2RCA032826A0001)

27. Tools

The protection relay is delivered as a preconfigured unit. The default parameter setting values can be changed from the frontpanel user interface (local HMI), the Web browser-based user interface (Web HMI) or Protection and Control IED Manager PCM600 in combination with the relay-specific connectivity package.

PCM600 offers extensive relay configuration functions. For example, depending on the protection relay, the relay signals, application, graphical display and single-line diagram, and IEC 61850 communication, including horizontal GOOSE communication, can be modified with PCM600.

When the Web HMI is used, the protection relay can be accessed either locally or remotely using a Web browser (Internet Explorer). For security reasons, the Web HMI is disabled by default but it can be enabled via the local HMI. The Web HMI functionality can be limited to read-only access.

The relay connectivity package is a collection of software and specific relay information, which enables system products and tools to connect and interact with the protection relay. The connectivity packages reduce the risk of errors in system integration, minimizing device configuration and setup times. Further, the connectivity packages for protection relays of this product series include a flexible update tool for adding one additional local HMI language to the protection relay. The update tool is activated using PCM600, and it enables multiple updates of the additional HMI language, thus offering flexible means for possible future language updates.

Table 109: Tools

Description	Version
PCM600	2.6 (Rollup 20150626) or later
Web browser	IE 8.0, IE 9.0, IE 10.0 or IE 11.0
RED615 Connectivity Package	5.1 or later

Table 110: Supported functions

Function	Web HMI	PCM600
Relay parameter setting	●	●
Saving of relay parameter settings in the relay	●	●
Signal monitoring	●	●
Disturbance recorder handling	●	●
Alarm LED viewing	●	●
Access control management	●	●
Relay signal configuration (Signal Matrix)	–	●
Modbus® communication configuration (communication management)	–	●
DNP3 communication configuration (communication management)	–	●
IEC 60870-5-103 communication configuration (communication management)	–	●
Saving of relay parameter settings in the tool	–	●

Table continues on the next page

Function	Web HMI	PCM600
Disturbance record analysis	–	●
XRIO parameter export/import	●	●
Graphical display configuration	–	●
Application configuration	–	●
IEC 61850 communication configuration, GOOSE (communication configuration)	–	●
Phasor diagram viewing	●	–
Event viewing	●	●
Saving of event data on the user's PC	●	●
Online monitoring	–	●

● = Supported

28. Cyber security

The relay supports role based user authentication and authorization. It can store 2048 audit trail events to a nonvolatile memory. The non-volatile memory is based on a memory type which does not need battery backup or regular component exchange to maintain the memory storage. FTP and Web HMI use TLS encryption with a minimum of 128 bit key length protecting the data in transit. In this case the used communication protocols are FTPS and HTTPS. All rear communication ports and optional protocol services can be deactivated according to the required system setup.
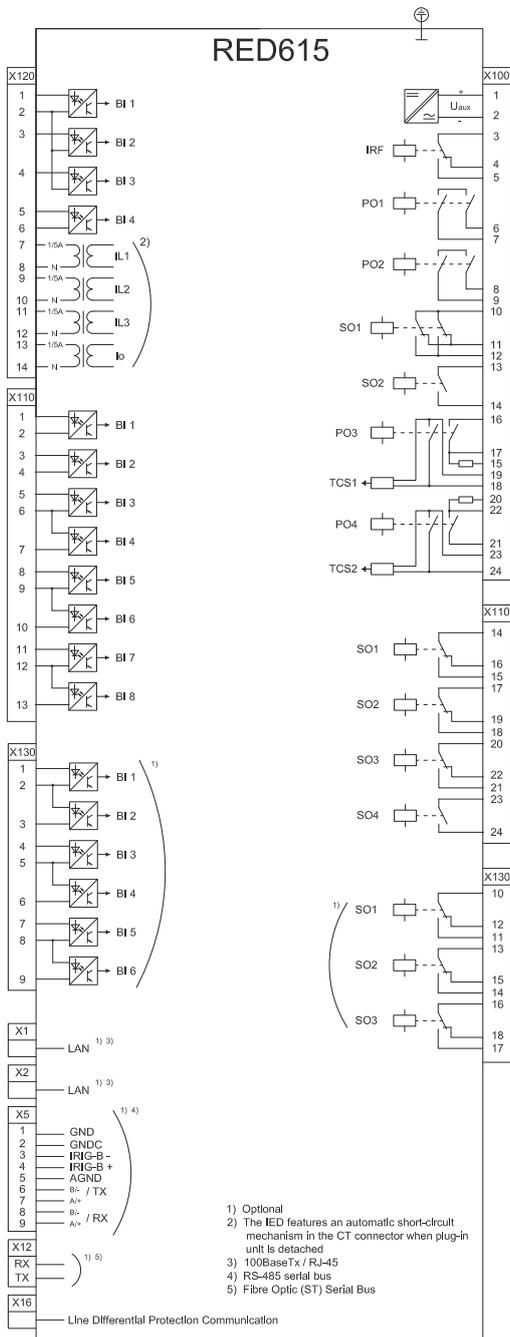
29. Terminal diagrams
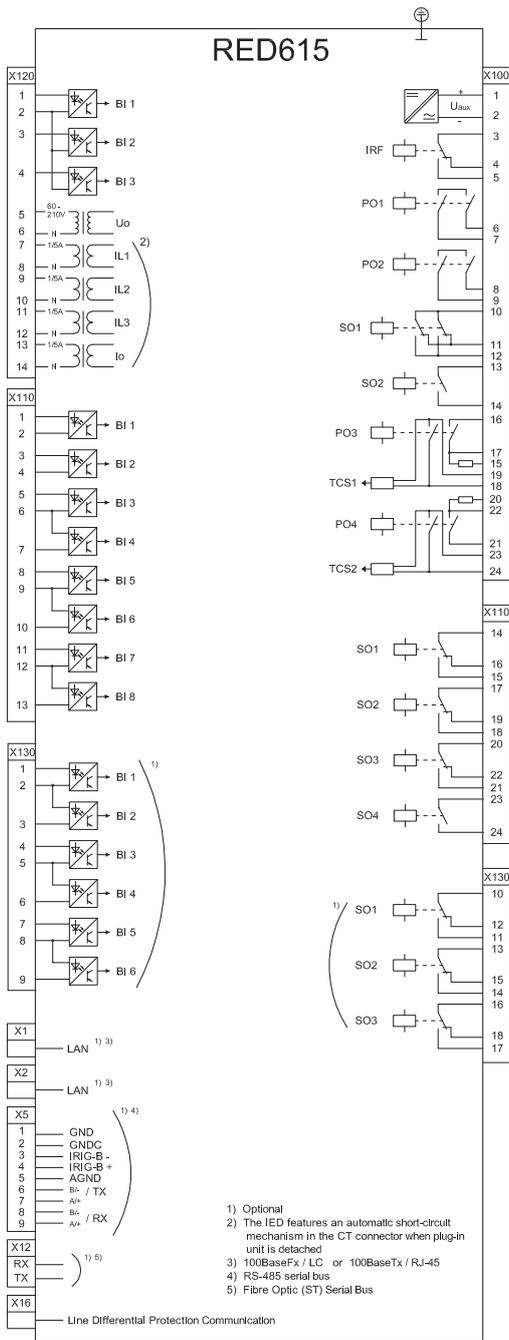

Figure 21: Terminal diagram for configuration A and C

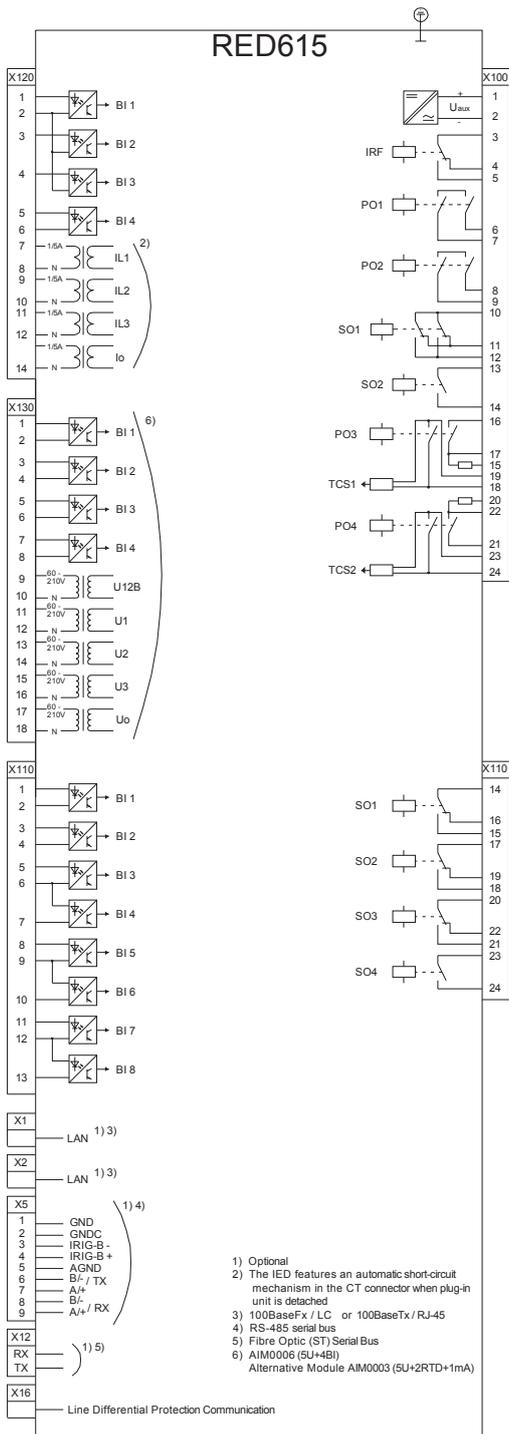*Figure 22: Terminal diagram for configuration B*

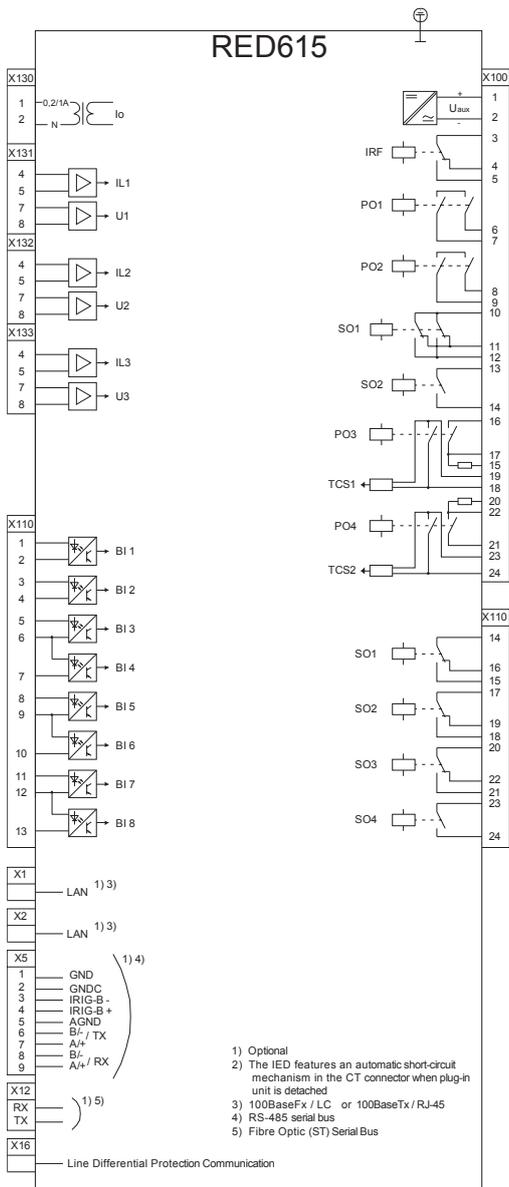*Figure 23: Terminal diagram for configuration D*

Figure 24: Terminal diagram for configuration E

30. Certificates

DNV GL has issued an IEC 61850 Edition 2 Certificate Level A1 for Relion® 615 series. Certificate number: 7410570I-OPE/INC 15-1136.

DNV GL has issued an IEC 61850 Edition 1 Certificate Level A1 for Relion® 615 series. Certificate number: 74105701-OPE/INC 15-1145.

UL 508 and CAN/CSA C22.2 No. 14-13, Industrial Control Equipment.

Additional certificates can be found on the *product page*.

31. References

The *www.abb.com/substationautomation* portal provides information on the entire range of distribution automation products and services.

The latest relevant information on the RED615 protection and control relay is found on the *product page*. Scroll down the page to find and download the related documentation.

For information regarding the RPW600 modems please refer to the RPW600 User's Guide, document id 6621-2260. The document

is available for download on the RED615
product page. Scroll down the page to find and
download the related documentation.

32. Functions, codes and symbols

Table 111: Functions included in the relay

Function	IEC 61850	IEC 60617	IEC-ANSI
Protection			
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	3I> (1)	51P-1 (1)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	3I>> (1)	51P-2 (1)
	PHHPTOC2	3I>> (2)	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	3I>>> (1)	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	3I> -> (1)	67-1 (1)
	DPHLPDOC2	3I> -> (2)	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	3I>> -> (1)	67-2 (1)
Non-directional earth-fault protection, low stage	EFLPTOC1	Io> (1)	51N-1 (1)
	EFLPTOC2	Io> (2)	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	Io>> (1)	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	Io>>> (1)	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	Io> -> (1)	67N-1 (1)
	DEFLPDEF2	Io> -> (2)	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	Io>> -> (1)	67N-2 (1)
Admittance-based earth-fault protection	EFPADM1	Yo> -> (1)	21YN (1)
	EFPADM2	Yo> -> (2)	21YN (2)
	EFPADM3	Yo> -> (3)	21YN (3)
Wattmetric-based earth-fault protection	WPWDE1	Po> -> (1)	32N (1)
	WPWDE2	Po> -> (2)	32N (2)
	WPWDE3	Po> -> (3)	32N (3)
Transient/intermittent earth-fault protection	INTRPTEF1	Io> -> IEF (1)	67NIEF (1)
Harmonics-based earth-fault protection	HAEFPTOC1	Io>HA (1)	51NHA (1)
Non-directional (cross-country) earth-fault protection, using calculated Io	EFHPTOC1	Io>> (1)	51N-2 (1)
Negative-sequence overcurrent protection	NSPTOC1	I2> (1)	46 (1)
	NSPTOC2	I2> (2)	46 (2)
Phase discontinuity protection	PDNSPTOC1	I2/I1> (1)	46PD (1)
Residual overvoltage protection	ROVPTOV1	Uo> (1)	59G (1)
	ROVPTOV2	Uo> (2)	59G (2)
	ROVPTOV3	Uo> (3)	59G (3)
Three-phase undervoltage protection	PHPTUV1	3U< (1)	27 (1)
	PHPTUV2	3U< (2)	27 (2)
	PHPTUV3	3U< (3)	27 (3)
Three-phase overvoltage protection	PHPTOV1	3U> (1)	59 (1)
	PHPTOV2	3U> (2)	59 (2)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
	PHPTOV3	3U> (3)	59 (3)
Positive-sequence undervoltage protection	PSPTUV1	U1< (1)	47U+ (1)
Negative-sequence overvoltage protection	NSPTOV1	U2> (1)	47O- (1)
Frequency protection	FRPFRQ1	f>/f<,df/dt (1)	81 (1)
	FRPFRQ2	f>/f<,df/dt (2)	81 (2)
	FRPFRQ3	f>/f<,df/dt (3)	81 (3)
	FRPFRQ4	f>/f<,df/dt (4)	81 (4)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	3Ith>F (1)	49F (1)
Three-phase thermal overload protection, two time constants	T2PTTR1	3Ith>T/G/C (1)	49T/G/C (1)
Binary signal transfer	BSTGGIO1	BST (1)	BST (1)
Circuit breaker failure protection	CCBRBRF1	3I>/Io>BF (1)	51BF/51NBF (1)
Three-phase inrush detector	INRPHAR1	3I2f> (1)	68 (1)
Switch onto fault	CBPSOF1	SOTF (1)	SOTF (1)
Master trip	TRPPTRC1	Master Trip (1)	94/86 (1)
	TRPPTRC2	Master Trip (2)	94/86 (2)
Multipurpose protection	MAPGAPC1	MAP (1)	MAP (1)
	MAPGAPC2	MAP (2)	MAP (2)
	MAPGAPC3	MAP (3)	MAP (3)
	MAPGAPC4	MAP (4)	MAP (4)
	MAPGAPC5	MAP (5)	MAP (5)
	MAPGAPC6	MAP (6)	MAP (6)
	MAPGAPC7	MAP (7)	MAP (7)
	MAPGAPC8	MAP (8)	MAP (8)
	MAPGAPC9	MAP (9)	MAP (9)
	MAPGAPC10	MAP (10)	MAP (10)
	MAPGAPC11	MAP (11)	MAP (11)
	MAPGAPC12	MAP (12)	MAP (12)
	MAPGAPC13	MAP (13)	MAP (13)
	MAPGAPC14	MAP (14)	MAP (14)
	MAPGAPC15	MAP (15)	MAP (15)
	MAPGAPC16	MAP (16)	MAP (16)
	MAPGAPC17	MAP (17)	MAP (17)
	MAPGAPC18	MAP (18)	MAP (18)
Fault locator	SCEFRFLO1	FLOC (1)	21FL (1)
Line differential protection with in-zone power transformer	LNPLDF1	3Id/I> (1)	87L (1)
High-impedance fault detection	PHIZ1	HIF (1)	HIZ (1)
Power quality			
Current total demand distortion	CMHAI1	PQM3I (1)	PQM3I (1)
Voltage total harmonic distortion	VMHAI1	PQM3U (1)	PQM3V (1)
Voltage variation	PHQVVR1	PQMU (1)	PQMV (1)
Voltage unbalance	VSQVUB1	PQUUB (1)	PQVUB (1)
Control			
Circuit-breaker control	CBXCBR1	I <-> O CB (1)	I <-> O CB (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
Disconnector control	DCXSWI1	I <-> O DCC (1)	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC (1)	I <-> O ESC (1)
Disconnector position indication	DCSXSWI1	I <-> O DC (1)	I <-> O DC (1)
	DCSXSWI2	I <-> O DC (2)	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)	I <-> O ES (2)
Autoreclosing	DARREC1	O -> I (1)	79 (1)
Synchronism and energizing check	SECRSYN1	SYNC (1)	25 (1)
Condition monitoring and supervision			
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCS (1)	TCM (1)
	TCSSCBR2	TCS (2)	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)	MCS 3I (1)
Fuse failure supervision	SEQSPVC1	FUSEF (1)	60 (1)
Protection communication supervision	PCSITPC1	PCS (1)	PCS (1)
Runtime counter for machines and devices	MDSOPT1	OPTS (1)	OPTM (1)
Measurement			
Disturbance recorder	RDRE1	DR (1)	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)	3I (1)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	Io (1)	In (1)
Three-phase voltage measurement	VMMXU1	3U (1)	3V (1)
	VMMXU2	3U (2)	3V (2)
Residual voltage measurement	RESVMMXU1	Uo (1)	Vn (1)
Sequence voltage measurement	VSMSQI1	U1, U2, U0 (1)	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)	P, E (1)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)	f (1)
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER	SMVSENDER
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV	SMVRCV
Other			
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)	TP (1)
	TPGAPC2	TP (2)	TP (2)
	TPGAPC3	TP (3)	TP (3)
	TPGAPC4	TP (4)	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)	PT (1)
	PTGAPC2	PT (2)	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)	TOF (1)

Table continues on the next page

Function	IEC 61850	IEC 60617	IEC-ANSI
	TOFGAPC2	TOF (2)	TOF (2)
	TOFGAPC3	TOF (3)	TOF (3)
	TOFGAPC4	TOF (4)	TOF (4)
Time delay on (8 pcs)	TONGAPC1	TON (1)	TON (1)
	TONGAPC2	TON (2)	TON (2)
	TONGAPC3	TON (3)	TON (3)
	TONGAPC4	TON (4)	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)	SR (1)
	SRGAPC2	SR (2)	SR (2)
	SRGAPC3	SR (3)	SR (3)
	SRGAPC4	SR (4)	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)	MV (1)
	MVGAPC2	MV (2)	MV (2)
Generic control point (16 pcs)	SPCGAPC1	SPC (1)	SPC (1)
	SPCGAPC2	SPC (2)	SPC (2)
Analog value scaling	SCA4GAPC1	SCA4 (1)	SCA4 (1)
	SCA4GAPC2	SCA4 (2)	SCA4 (2)
	SCA4GAPC3	SCA4 (3)	SCA4 (3)
	SCA4GAPC4	SCA4 (4)	SCA4 (4)
Integer value move	MVI4GAPC1	MVI4 (1)	MVI4 (1)

33. Document revision history

Document revision/date	Product version	History
A/2008-10-03	1.1	First release
B/2009-07-03	2.0	Content updated to correspond to the product version
C/2010-06-11	3.0	Content updated to correspond to the product version
D/2010-06-29	3.0	Terminology updated
E/2010-09-07	3.0	Content updated
F/2012-05-11	4.0	Content updated to correspond to the product version
G/2013-02-21	4.0 FP1	Content updated to correspond to the product version
H/2014-01-24	5.0	Content updated to correspond to the product version
K/2015-10-30	5.0 FP1	Content updated to correspond to the product version
L/2016-05-20	5.0 FP1	Content updated
M/2018-12-20	5.0 FP1	Content updated
N/2021-12-30	5.0 FP1	Content updated

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