

PRODUCT GUIDE

REF615 ANSI 5.0 FP1

Feeder protection and control



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Feeder protection & control

1. Description

REF615 is a dedicated feeder protection and control relay designed for the protection, control, measurement and supervision of utility substations and industrial power systems including radial, looped and meshed distribution networks with or without distributed power generation. REF615 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 designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices.

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

Depending on the chosen standard configuration, the relay is adapted for the protection of overhead line and cable feeders in isolated neutral, resistance grounded, compensated and solidly grounded networks. Once the standard configuration 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, Modbus® and DNP3.

2. Standard configurations

REF615 is available in 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 Relay Manager PCM600. Further, the application configuration functionality of PCM600 supports the creation of multi-layer logic functions using various logical elements, including timers and flip-flops. By combining protection functions with logic function blocks, the relay configuration can be adapted to userspecific 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 REF615 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.

Figure 1. Functionality overview for standard configuration D

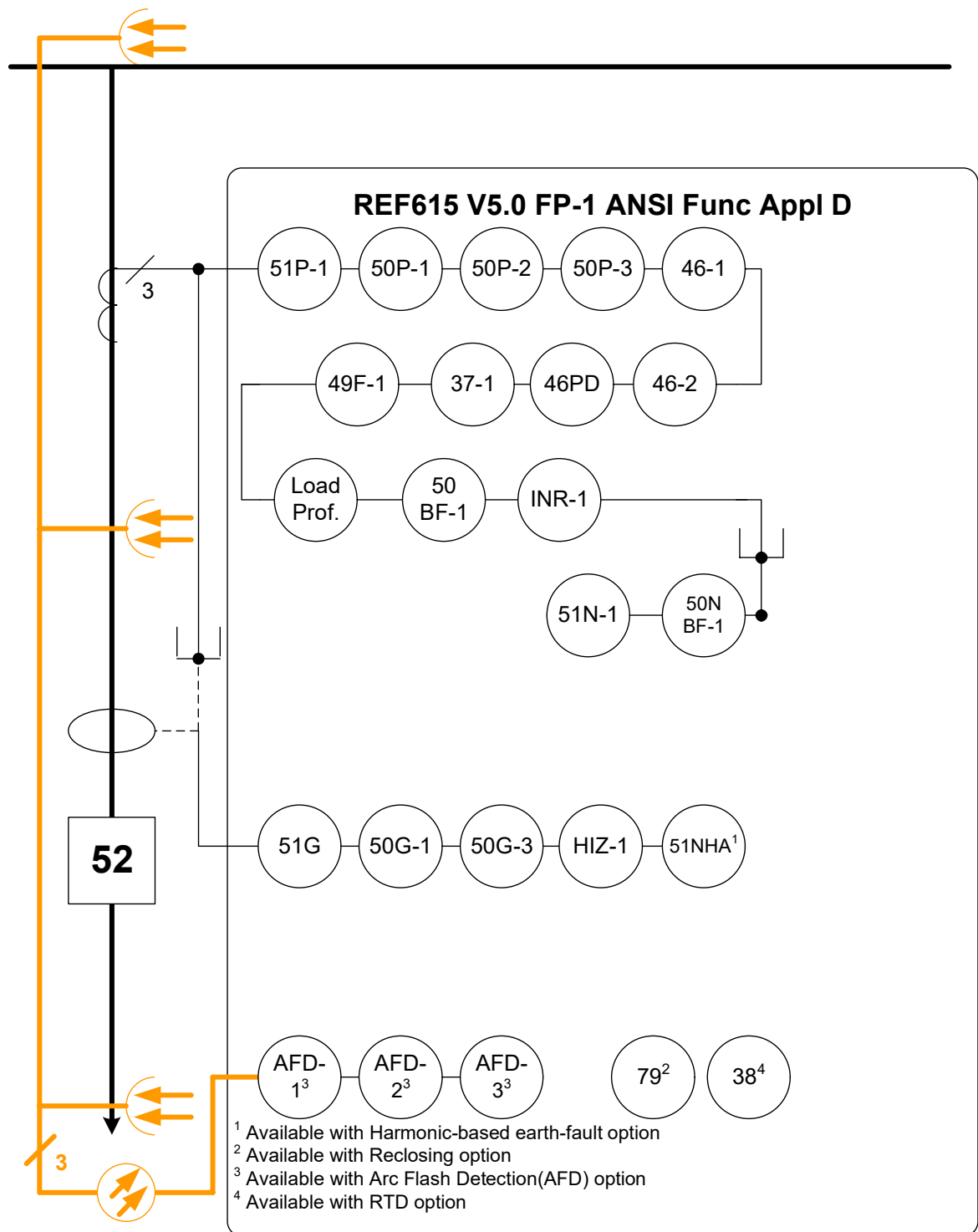


Figure 2. Functionality overview for standard configuration F

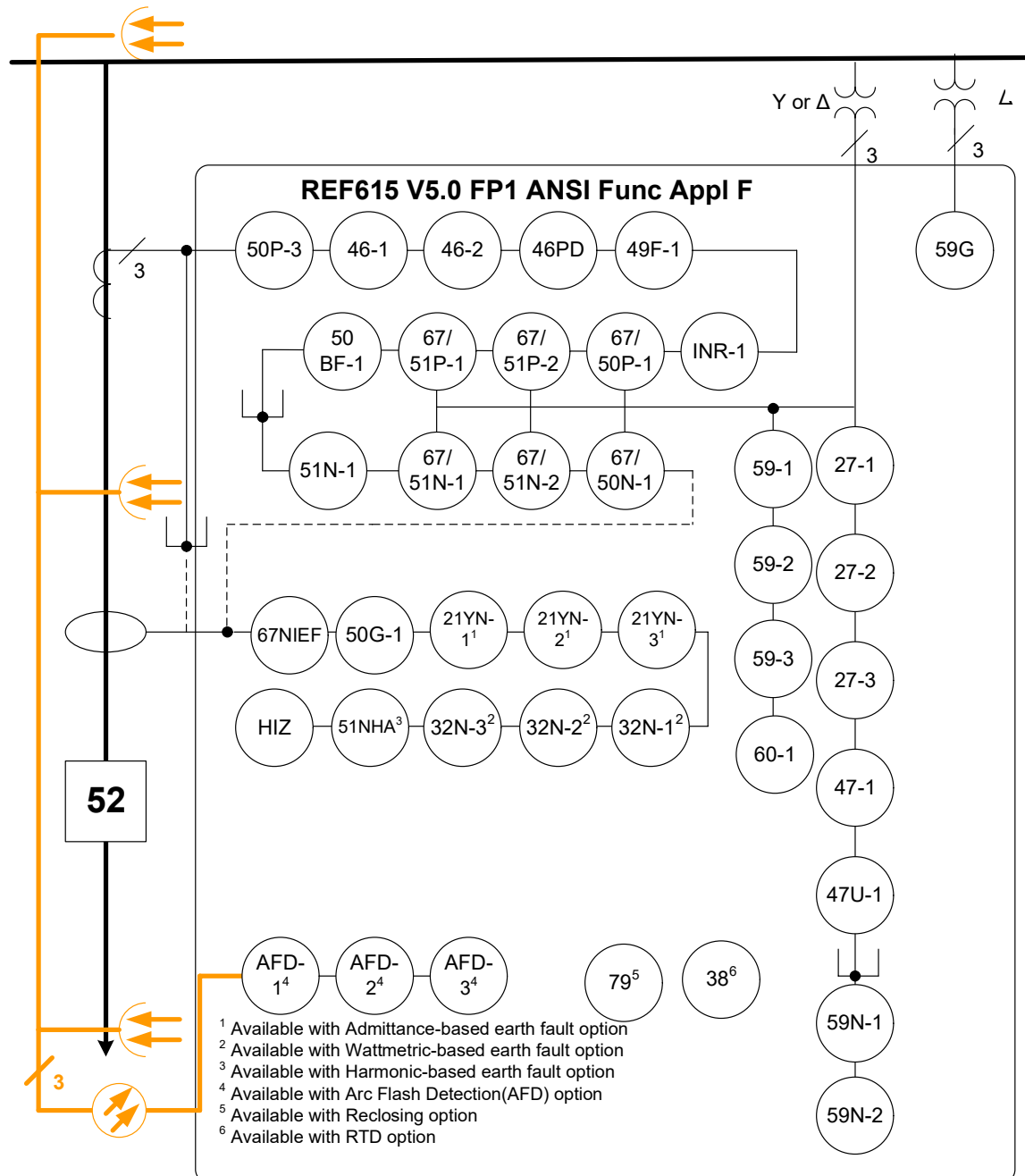


Figure 3. Functionality overview for standard configuration L

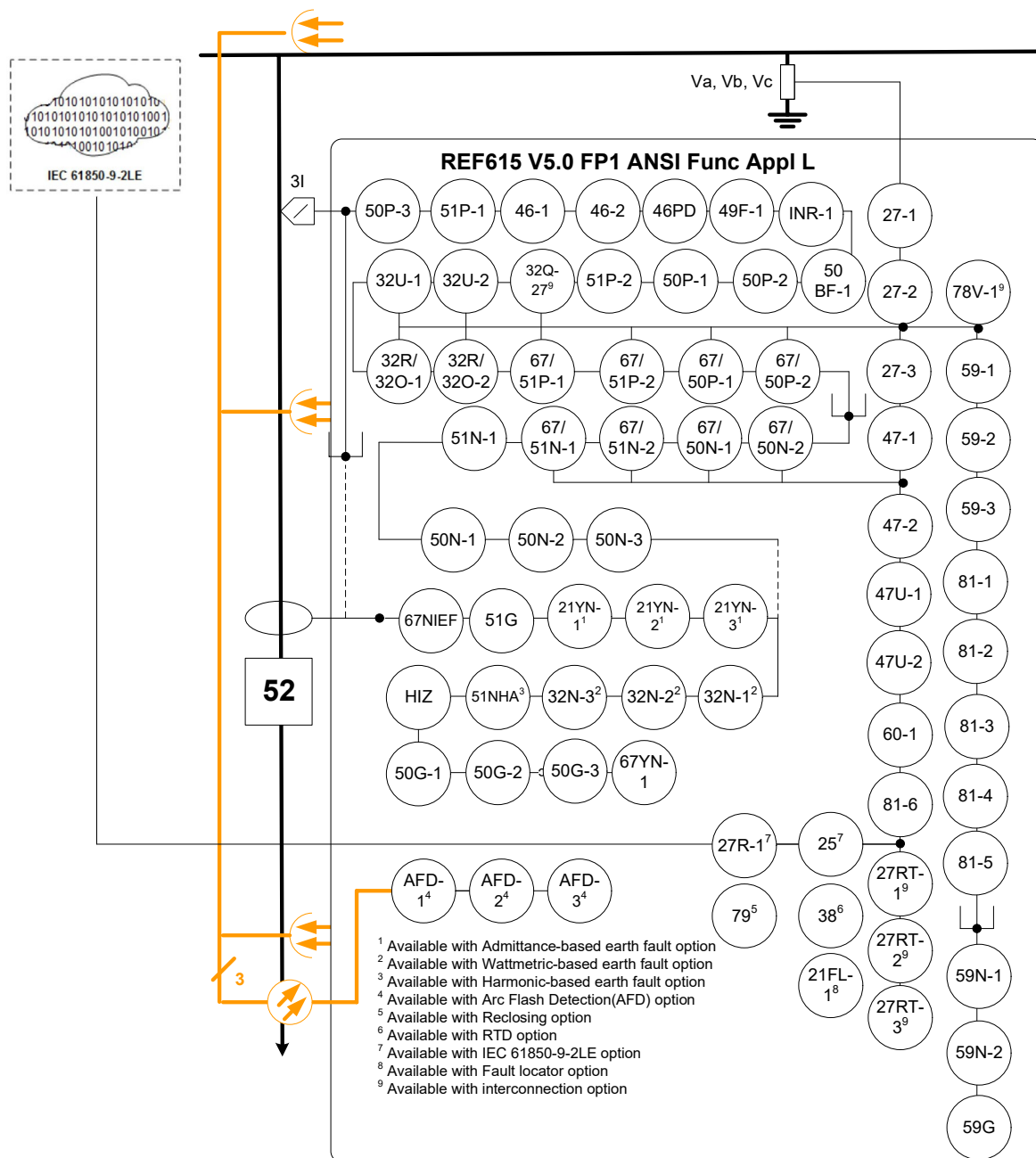


Figure 4. Functionality overview for standard configuration N

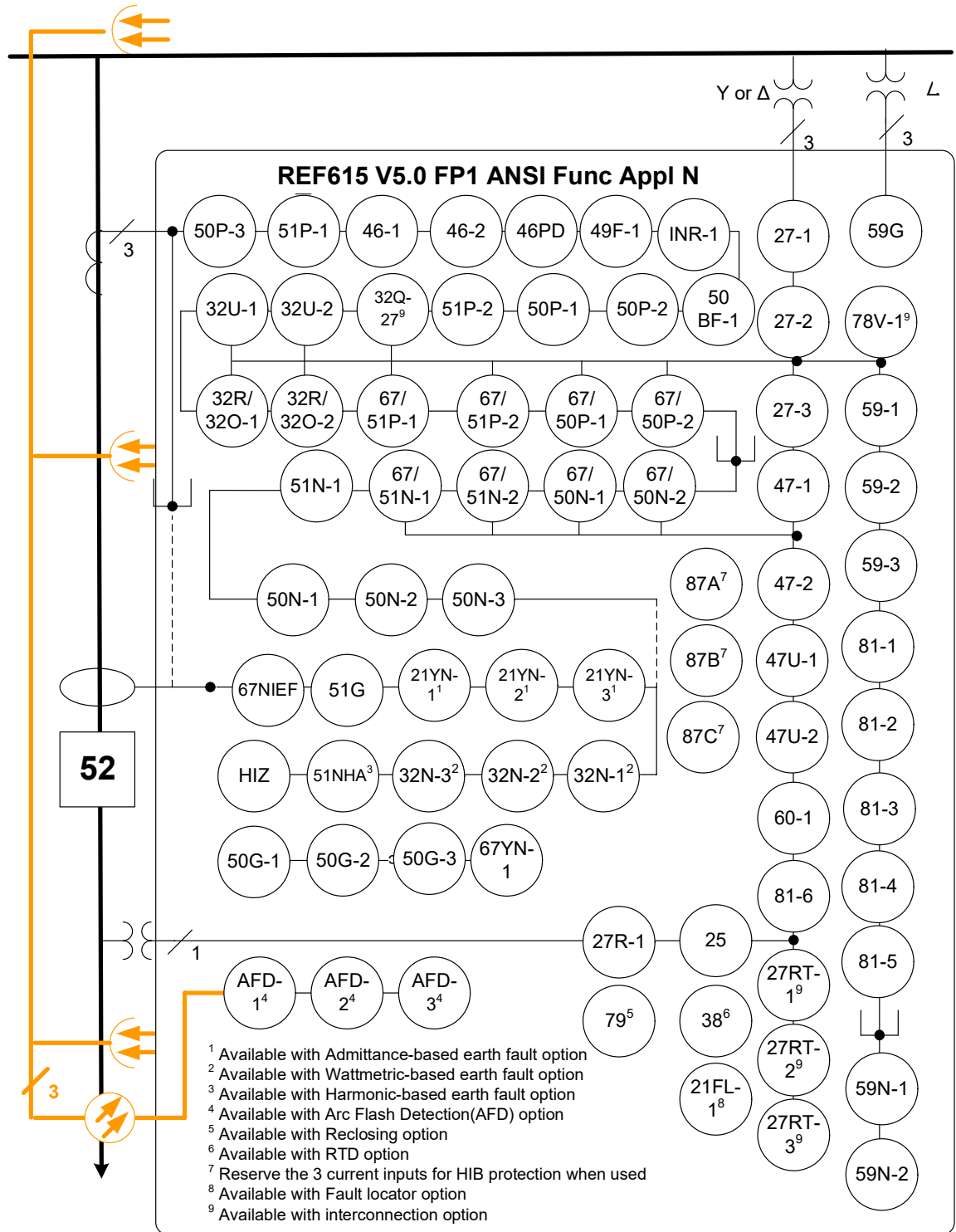


Figure 5. Functionality overview for standard configuration P

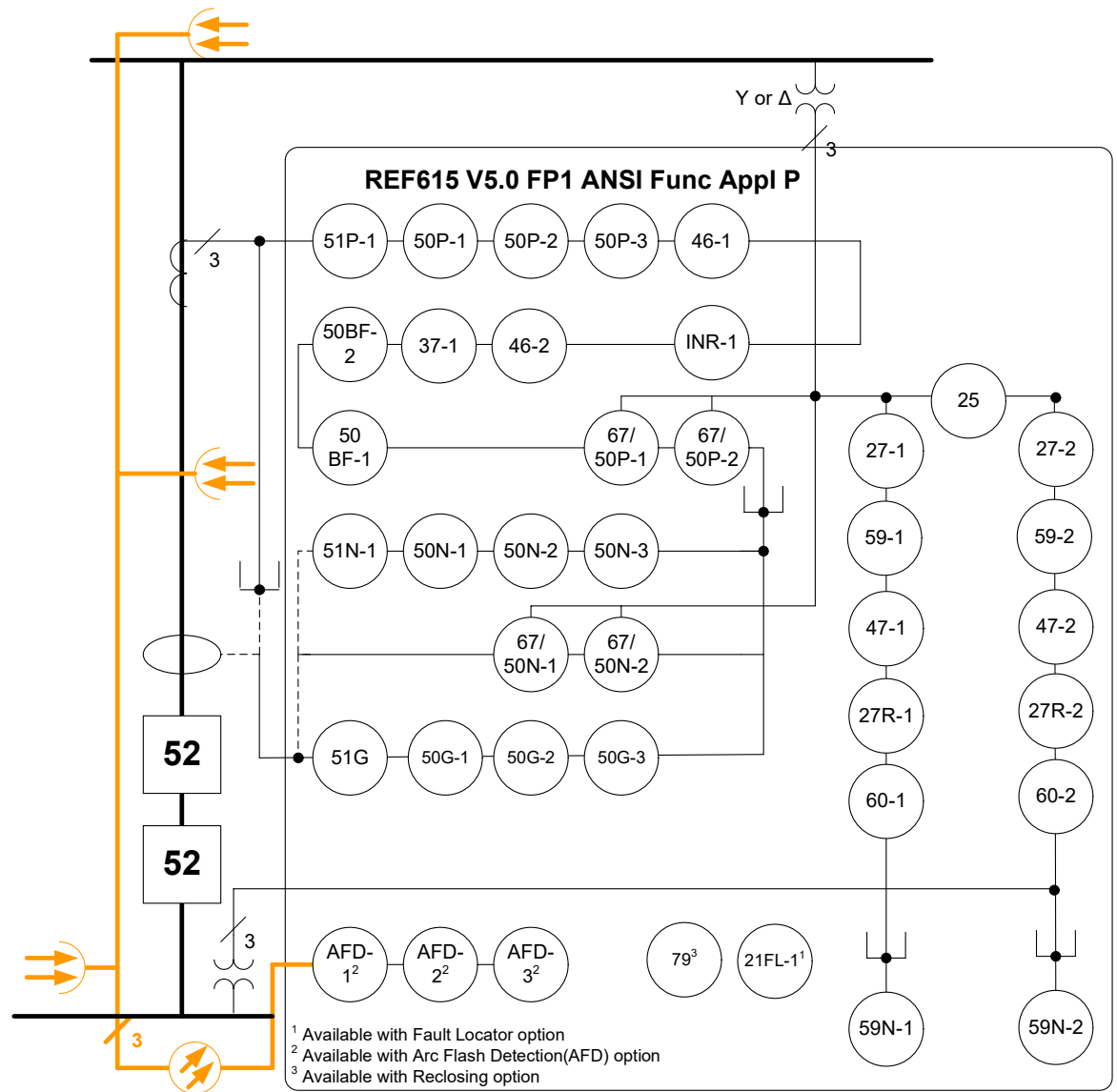


Table 1. Standard configurations

Description	Std. conf.
Non-directional overcurrent and ground fault protection and circuit-breaker condition monitoring (RTD option)	D
Directional overcurrent and ground fault protection, voltage-based protection and measurements, and circuitbreaker condition monitoring (RTD option), and voltage remanent protection	F
Directional and non-directional overcurrent and ground fault protection with multifrequency neutral admittance, voltage, frequency and power based protection and measurements, and circuit-breaker condition monitoring (sensor inputs, optional power quality, fault locator, interconnection protection and synchro-check and voltage remanent protection with IEC 61850-9-2 LE)	L
Directional and non-directional overcurrent and ground fault protection with multifrequency neutral admittance, voltage, frequency and power based protection and measurements, high-impedance differential protection, synchro-check and circuit-breaker condition monitoring (optional power quality, fault locator, interconnection protection and voltage remanent protection)	N
Directional overcurrent and ground fault, voltage and voltage remanent protection and power system metering for two tie breakers with synchro-check	P

Table 2. Supported functions

Function	IEC 61850	ANSI	D	F	L	N	P
Protection							
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	51P	1		2 ⁽¹⁹⁾	2	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	50P	2		1 ⁽¹⁹⁾ 1	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P		2	2	2 ⁽¹⁹⁾	
Three-phase directional overcurrent protection, high stage	DPHHPDOC	67/50P		1	2	1 ⁽¹⁹⁾ 1	2
Non-directional earth-fault protection, low stage	EFLPTOC	51N, 51G	1 ⁽⁵⁾ 1 ⁽⁴⁾		1 ^{(5), (19)} 1 ^{(4), (19)}	1 ⁽⁵⁾ 1 ⁽⁴⁾	1 ⁽⁵⁾ 1 ⁽⁴⁾
Non-directional earth-fault protection, high stage	EFHPTOC	50N, 50G	1 ⁽⁴⁾	1 ⁽⁴⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	50N-3, 50G-3	1 ⁽⁴⁾		1 ^{(5), (19)} 1 ^{(4), (19)}	1 ⁽⁵⁾ 1 ⁽⁴⁾	1 ⁽⁵⁾ 1 ⁽⁴⁾
Directional earth-fault protection, low stage	DEFLPDEF	67/51N		2 ^{(4), (9)}	2 ⁽⁵⁾⁽¹⁰⁾	2 ^{(4), (9), (19)}	
Directional earth-fault protection, high stage	DEFHPDEF	67/50N		1 ^{(4), (9)}	2 ^{(4), (10)}	2 ^{(4), (9), (19)}	2
Admittance-based earth-fault protection 1)	EFPADM	21YN		(3) ^{(1), (4), (9)}	(3) ^{(1), (4), (11)}	(3) ^{(1), (4), (9)}	
Wattmetric-based earth-fault protection 1)	WPWDE	32N		(3) ^{(1), (4), (9)}	(3) ^{(1), (4), (11)}	(3) ^{(1), (4), (9)}	
Transient/intermittent earth-fault protection	INTRPTEF	67NIEF		1 ^{(9), (15)}	1 ^{(11), (15)}	1 ^{(9), (15), (19)}	
Harmonics-based earth-fault protection 1)	HAEFPTOC	51NHA	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	
Negative-sequence overcurrent protection	NSPTOC	46	1	1	1	1	1
Phase discontinuity protection	PDNSPTOC	46PD	1	1	1	1	
Residual overvoltage protection	ROVPTOV	59N/59G		3 ⁽⁹⁾	3 ⁽¹¹⁾	3 ^{(9), (19)}	1 ^(B1) 1 ^(B2)
Three-phase undervoltage protection	PHPTUV	27		3	3	3 ⁽¹⁹⁾	1 ^(B1) 1 ^(B2)
Three-phase overvoltage protection	PHPTOV	59		3	3	3 ⁽¹⁹⁾	1 ^(B1) 1 ^(B2)

Table 2. Supported functions, continued

Function	IEC 61850	ANSI	D	F	L	N	P
Protection							
Three-phase non-directional overcurrent protection, low stage	PHLPTOC	51P	1		2 ⁽¹⁹⁾	2	1
Three-phase non-directional overcurrent protection, high stage	PHHPTOC	50P	2		1 ⁽¹⁹⁾ 1	2	2
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC	50P-3	1	1	1	1	1
Three-phase directional overcurrent protection, low stage	DPHLPDOC	67/51P		2	2	2 ⁽¹⁹⁾	
Three-phase directional overcurrent protection, high stage	DPHHPDOC	67/50P		1	2	1 ⁽¹⁹⁾ 1	2
Non-directional earth-fault protection, low stage	EFLPTOC	51N, 51G	1 ⁽⁵⁾ 1 ⁽⁴⁾		1 ^{(5), (19)} 1 ^{(4), (19)}	1 ⁽⁵⁾ 1 ⁽⁴⁾	1 ⁽⁵⁾ 1 ⁽⁴⁾
Non-directional earth-fault protection, high stage	EFHPTOC	50N, 50G	1 ⁽⁴⁾	1 ⁽⁴⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾	2 ⁽⁴⁾ 2 ⁽⁵⁾
Non-directional earth-fault protection, instantaneous stage	EFIPTOC	50N-3, 50G-3	1 ⁽⁴⁾		1 ^{(5), (19)} 1 ^{(4), (19)}	1 ⁽⁵⁾ 1 ⁽⁴⁾	1 ⁽⁵⁾ 1 ⁽⁴⁾
Directional earth-fault protection, low stage	DEFLPDEF	67/51N		2 ^{(4), (9)}	2 ⁽⁵⁾⁽¹⁰⁾	2 ^{(4), (9), (19)}	
Directional earth-fault protection, high stage	DEFHPDEF	67/50N		1 ^{(4), (9)}	2 ^{(4), (10)}	2 ^{(4), (9), (19)}	2
Admittance-based earth-fault protection 1)	EFPADM	21YN		(3) ^{(1), (4), (9)}	(3) ^{(1), (4), (11)}	(3) ^{(1), (4), (9)}	
Wattmetric-based earth-fault protection 1)	WPWDE	32N		(3) ^{(1), (4), (9)}	(3) ^{(1), (4), (11)}	(3) ^{(1), (4), (9)}	
Transient/intermittent earth-fault protection	INTRPTEF	67NIEF		1 ^{(9), (15)}	1 ^{(11), (15)}	1 ^{(9), (15), (19)}	
Harmonics-based earth-fault protection 1)	HAEPPTOC	51NHA	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	(1) ^{(1), (15), (19)}	
Negative-sequence overcurrent protection	NSPTOC	46	1	1	1	1	1
Phase discontinuity protection	PDNSPTOC	46PD	1	1	1	1	
Residual overvoltage protection	ROVP TOV	59N/59G		3 ⁹⁾	3 ¹¹⁾	3 ^{9), (19)}	1 ^(B1) 1 ^(B2)
Three-phase undervoltage protection	PHPTUV	27		3	3	3 ¹⁹⁾	1 ^(B1) 1 ^(B2)
Three-phase overvoltage protection	PHPTOV	59		3	3	3 ¹⁹⁾	1 ^(B1) 1 ^(B2)
Positive-sequence undervoltage protection	PSPTUV	47U		1	1 ¹⁹⁾	2 ¹⁹⁾	
Negative-sequence overvoltage protection	NSPTOV	47		1	1 ¹⁹⁾	2 ¹⁹⁾	1 ^(B1) 1 ^(B2)
Three-phase remnant undervoltage protection	MSVPR	27R			(1) ^{(19), (26)}	1	1 ^(B1) 1 ^(B2)
Frequency protection	FRPFRQ	81			3 3 ⁽¹⁹⁾	6 ⁽¹⁹⁾	
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR	49F	1	1	1	1	
High-impedance differential protection for phase A	HIAPDIF1	87A				1 ⁽¹⁹⁾	
High-impedance differential protection for phase B	HIBPDIF	87B				1 ⁽¹⁹⁾	

Table 2. Supported functions, continued

Function	IEC 61850	ANSI	D	F	L	N	P
High-impedance differential protection for phase C	HICPDIF	87C				1 ⁽¹⁹⁾	
Circuit breaker failure protection	CCBRBRF	50BF	1	1	1	1	1 ^(B1) 1 ^(B2)
Three-phase inrush detector	INRPHAR	INR	1	1	1	1	1
Switch onto fault	CBPSOF	SOTF	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	
Master trip	TRPPTRC	86/94	2 (3) ⁽²²⁾	2 (3) ⁽²²⁾	2 (3) ⁽²²⁾	2 (3) ⁽²²⁾	2 (3) ⁽²²⁾
Arc protection	ARCSARC	AFD	(3)	(3)	(3)	(3)	(3)
Multipurpose protection	MAPGAPC	MAP	18 ⁽¹⁹⁾	18 ⁽¹⁹⁾	18 ⁽¹⁹⁾	18 ⁽¹⁹⁾	18 ⁽¹⁹⁾
Fault locator	SCEFRFLO	21FL			(1) ⁽¹⁹⁾	(1) ⁽¹⁹⁾	(1) ⁽¹⁹⁾
Loss of phase	PHPTUC1	37					1
High-impedance fault detection	PHIZ	HIZ	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾		1 ⁽¹⁹⁾	
Underpower protection	DUPDPDR	32U			2	2	
Reverse power/ directional overpower protection	DOPDPDR	32R/32O			2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	
Multifrequency admittance-based earth fault protection	MFADPSDE	67YN			1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	
Interconnection functions							
Directional reactive power undervoltage protection	DQPTUV	32Q-27			(1) ⁽¹⁹⁾	(1) ⁽¹⁹⁾	
Low-voltage ride- through protection	LVRTPTUV	27RT			(3) ⁽¹⁹⁾	(3) ⁽¹⁹⁾	
Voltage vector shift protection	VVSPAM	78V			(1) ⁽¹⁹⁾	(1) ⁽¹⁹⁾	
Power quality							
Current total demand distortion	CMHAI	PQI			(1) ^{(17), (19)}	(1) ^{(17), (19)}	(1) ^{(17), (19)}
Voltage total harmonic distortion	VMHAI	PQVPH			(1) ^{(17), (19)}	(1) ^{(17), (19)}	(1) ^{(17), (19), (B1)} (1) ^{(17), (19), (B2)}
Voltage variation	PHQVVR	PQSS			(1) ^{(17), (19)}	(1) ^{(17), (19)}	(1) ^{(17), (19), (B1)} (1) ^{(17), (19), (B2)}
Voltage unbalance	VSQVUB	PQVUB			(1) ^{(17), (19)}	(1) ^{(17), (19)}	(1) ^{(17), (19)}
Control							
Circuit breaker control	CBXCBR	52	1	1	1	1	2
Disconnecter control	DCXSWI	29DS	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾
Earthing switch control	ESXSWI	29GS	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾
Disconnecter position indication	DCSXSWI	52-TOC, 29DS	1 2 ⁽¹⁹⁾	1 2 ⁽¹⁹⁾	1 2 ⁽¹⁹⁾	1 2 ⁽¹⁹⁾	1 2 ⁽¹⁹⁾
Earthing switch indication	ESSXSWI	29GS	1 1 ⁽¹⁹⁾	1 1 ⁽¹⁹⁾	1 1 ⁽¹⁹⁾	1 1 ⁽¹⁹⁾	1 1 ⁽¹⁹⁾
Autoreclosing	DARREC	79	(1)	(1)	(1)	(1)	(1)
Synchronism and energizing check	SECRSYN	25			(1) ^{(19), (26)}	1 ⁽¹⁹⁾	1
Conditioning monitoring and supervision							
Circuit breaker condition monitoring	SSCBR	52CM	1	1	1	1	1 ^(B1) 1 ^(B2)
Trip circuit supervision	TCSSCBR	TCM	2	2	2	2	2
Current circuit supervision	CCSPVC	CCM		1	1	1 ⁽¹⁹⁾	1
"Current transformer supervision for highimpedance protection scheme for phase A"	HZCCASPVC	MCS				1 ⁽¹⁹⁾	

Table 2. Supported functions, continued

Function	IEC 61850	ANSI	D	F	L	N	P
"Current transformer supervision for highimpedance protection scheme for phase B"	HZCCBSPVC	MCS				1 ⁽¹⁹⁾	
"Current transformer supervision for highimpedance protection scheme for phase C"	HZCCCSPVC	MCS				1 ⁽¹⁹⁾	
Fuse failure supervision	SEQSPVC	60		1	1	1 ⁽¹⁹⁾	1 ^(B1) 1 ^(B2)
Runtime counter for machines and devices	MDSOPT	OPTM	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾
Measurement							
Load profile record	LDPRLC	LOADPROF	1	1	1	1	1
Three-phase current measurement	CMMXU	IA, IB, IC	1	1	1	1	1
Sequence current measurement	CSMSQI	I1, I2, I0	1	1	1	1	1
Residual current measurement	RESCMMXU	IG	1	1	1	1	1
Three-phase voltage measurement	VMMXU	VA, VB, VC		1	1 (1) ^{(19), (26)}	2	2
Residual voltage measurement	RESVMMXU	VG		1		1	1
Sequence voltage measurement	VSMSQI	V1, V2, V0					1
Single-phase power and energy measurement	SPEMMXU	SP, SE		1	1	1	1
Three-phase power and energy measurement	PEMMXU	P, E		1	1	1	1
RTD/mA measurement	XRGGIO130	X130 (RTD)	(1)	(1)		(1)	
Frequency measurement	FMMXU	f		1	1	1	1
"IEC 61850-9-2 LE sampled value sending (23), (26)"	SMVSENDER	SMVSENDER		(1)	(1)	(1)	(1)
"IEC 61850-9-2 LE sampled value receiving (voltage sharing) (23), (26)"	SMVRCV	SMVRECEIVER		(1)	(1)	(1)	(1)
Other							
"Minimum pulse timer (2 pcs)"	TPGAPC	62TP	2 2 ⁽¹⁹⁾	3 1 ⁽¹⁹⁾	3 1 ⁽¹⁹⁾	2 2 ⁽¹⁹⁾	2 2 ⁽¹⁹⁾
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC	62TPS	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC	62TPM	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾
Pulse timer (8 pcs)	PTGAPC	62PT	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾
Time delay off (8 pcs)	TOFGAPC	62TOF	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾
Time delay on (8 pcs)	TONGAPC	G2TON	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾
Set-reset (8 pcs)	SRGAPC	SR	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾
Move (8 pcs)	MVGAPC	MV	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾
"Generic control point (16 pcs)"	SPCGAPC	SPC	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾	2 ⁽¹⁹⁾
"Analog value scaling (4 pcs)"	SCA4GAPC	SCA4	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾
"Integer value move (4 pcs)"	MVI4GAPC	MVI4	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾	1 ⁽¹⁹⁾
Generic up-down counters	UDFCNT	CTR	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾	4 ⁽¹⁹⁾

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Table 2. Supported functions, continued

() = optional

- 1) One of the following can be ordered as an option; Admittance based E/F, Wattmetric based E/F or Harmonics based E/F. The option is an addition to the existing E/F of the original configuration. The optional E/F has also a predefined configuration in the relay. The optional E/F can be set on or off.
- 2) Multi-purpose protection is used for, for example, RTD/mA based protection, or Analogue Goose
- 3) Light only
- 4) Io selectable by parameter, Io measured as default
- 5) Io selectable by parameter, Io calculated as default
- 6) Io calculated is always used
- 7) IoB calculated is always used
- 8) IoB calculated and 3IB are always used
- 9) Uo selectable by parameter, Uo measured as default
- 10) Uo calculated and negative sequence voltage selectable by parameter, Uo calculated as default
- 11) Uo calculated is always used
- 12) Uo measured is always used
- 13) IoB measured is always used
- 14) IoB measured and 3IB are always used
- 15) Io measured is always used
- 16) IoB selectable by parameter, IoB measured as default
- 17) Power quality option includes Current total demand distortion, Voltage total harmonic distortion and Voltage variation.
- 18) Available in IED and SMT but not connected to anything in logic.
- 19) Must be added with ACT to be available in SMT and in IED.
- 20) Uob measured is always used for unbalance protection with unearthed single Y connected capacitor bank.
- 21) The Iunb measurements values will be taken from this block and put in Measurent view.
- 22) Master Trip included and connected to corresponding HSO in the configuration only when BIO0007 module is used. If additionally the ARC option is selected, then ARCSARC is connected in the configuration to the corresponding Master Trip input.
- 23) Only available with COM0031-0037
- 24) Power quality option includes only Current total demand distortion
- 25) Unbalance voltage measurement for capacitor bank for REV615
- 26) Only available with IEC 61850-9-2
- LV) The function block is to be used on the low voltage side in the application
- HV) The function block is to be used on the high voltage side in the application
- NT) The function block is to be used on the neutral side in the application
- TR) The function block is to be used on the terminal side in the application
- BS) The function block is to be used on the bus side in the application
- EX) This function to be excluded from the Integration Test Data generation

3. Protection functions

The relay offers directional and non-directional overcurrent and thermal overload protection as well as directional and nondirectional ground-fault protection. Some standard configurations allow as an option admittance-based, harmonics-based or wattmetric-based ground-fault protection to be used in addition to directional earth-fault protection. Further, the relay features sensitive earth-fault protection, phase discontinuity protection, transient/intermittent earth-fault protection, overvoltage and undervoltage protection, residual overvoltage protection, positive-sequence undervoltage and negative-sequence overvoltage protection. Frequency protection, including overfrequency, underfrequency and frequency rate-of-change protection, is offered in relays with standard configurations L and N. The relay also incorporates optional three-pole multishot autoreclosing functions for overhead line feeders.

The standard configurations L and N additionally offer multifrequency admittance-based earth-fault protection providing selective directional earth-fault protection for high-impedance grounded networks. The operation is based on multifrequency neutral admittance measurement utilizing fundamental frequency and harmonic components in U_0 and I_0 . A special filtering algorithm enables dependable and secure fault direction also during intermittent/restriking earth faults. It provides a very good combination of reliability and sensitivity of protection with a single function for low ohmic and higher ohmic earth faults and for transient and intermittent or restriking earth faults.

Enhanced with optional hardware and software, the relay also features three light detection channels for arc fault protection of the circuit breaker, busbar and cable compartment of metal-clad indoor switchgear.

The arc-fault protection sensor interface is available on the optional communication module. Fast tripping increases staff safety and security and limits material damage in an arc fault situation. A binary input and output module can be selected as an option - having three high speed binary outputs (HSO) it further decreases the total operate time with typically 4...6 ms compared to the normal power outputs.

4. Application

The feeder protection relay can be supplied either with directional or non-directional ground-fault protection. Directional ground-fault protection is mainly used in isolated neutral or compensated networks, whereas non-directional ground-fault protection is intended for directly or low impedance grounded neutral networks. The relay can also be used for protection of ring-type and meshed distribution networks as well of radial networks containing distributed power generation.

The standard configuration D offer non-directional ground-fault protection for outgoing feeders equipped with phase current transformers. The residual current for the ground-fault protection is derived from the phase currents. When applicable, the core-balance current transformers can be used for measuring the residual current, especially when sensitive earth-fault protection is required. The standard configuration F offer directional ground-fault protection with phase voltage and residual voltage measurement. Furthermore, the standard configuration F include current circuit supervision and fuse failure supervision for incoming feeders provided with busbar voltage measurement. In addition, the standard configuration F offers directional overcurrent protection, overvoltage and undervoltage protection, positive-sequence undervoltage and negative sequence overvoltage protection and residual voltage protection.

The standard configuration L include 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 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 ReliaGear® ND Digital, Advance® Digital, and SafeGear® Digital, eliminating the need of dedicated PT compartments. Further, the adapters also enable the use of sensors with Twin-BNC connectors.

The standard configuration L includes directional overcurrent and directional ground-fault protection, phase-voltage and frequency based protection and measurement functions. The analog measurements include one conventional residual current (Io) input and three combi-sensor inputs for phase currents and phase voltages. The provided functionality supports the use of the standard configuration in power systems, where power is generated in the plant itself and/or derived from the distribution network. The standard configuration L includes an optional power quality function which enables monitoring and detecting current and voltage harmonics and short duration system disturbances. The standard configuration L also features an optional impedance-measuring fault location function suitable for locating shortcircuits in radial distribution systems and ground-faults in effectively and low-resistance earthed networks. The standard configuration L has been pre-configured especially for ABB switchgear; for example, ReliaGear ND Digital. The use of standard configuration L is however not restricted for switchgears only but provides the highest functionality level with sensor inputs for phase currents and phase voltages. Standard configuration L is not designed for using all the available functionality content in one relay at the same time. In order to ensure the performance of the relay, the user specific configuration load is verified with the Application Configuration tool in PCM600.

Completed with the optional synchrocheck function, voltage remnant protection, and process bus with sampled values of analog phase voltages, relays with standard config. L ensure a safe interconnection of two networks.

The standard configuration N provides the highest functionality level of all standard configurations. It is delivered as preconfigured, in the same way as other 615 standard configurations. It is typically reconfigured when taken into use. This allows flexibility in standardizing one type of REF615. Depending on the specific feeder application the appropriate functionality can be selected and own configurations can be created with the Application Configuration tool in PCM600. Standard configuration N is not designed for using all the available functionality content in one relay at the same time. In order to ensure the performance of the relay the user specific configuration load is verified with Application Configuration tool of PCM600.

In addition to directional ground-fault protection, one of these three functions can be ordered as an option: admittance-based, harmonics-based or wattmetric-based earth-fault protection. Admittance- and wattmetric-based earth-fault protection functions are available for standard configurations L and N. Harmonics-based earth-fault protection is available for standard configurations D, F, L and N. The admittance-based earth-fault protection ensures a correct operation of the protection even though the connection status information of the Petersen coil is missing. The standard configurations L and N additionally offer multifrequency admittance-based ground-fault protection.

The configuration P provides the ideal functionality for the implementation of Main-Tie-Main and Main-Tie-Tie-Main Automatic Transfer Schemes. With Directional and non-directional overcurrent protection, for one breaker, and six voltage inputs for undervoltage, overvoltage, negative-sequence voltage, and voltage remnant protection. The voltage remnant protection is ideal for the implementation Automatic Transfer schemes with motor loads connected to the bus, where supervision is required to prevent re-energizing the motors, before the power is at an acceptable level. The configuration P is completed with synchro-check functionality for the implementation of Automatic Transfer Schemes where the incoming sources would be paralleled momentarily to increase reliability.

Figure 6. Substation example with overcurrent and ground-fault protection using the standard configuration D.

Figure 6 shows a substation example with overcurrent and ground-fault protection using the standard configuration D. Additionally voltage and frequency based protection is used with standard configuration F. The relays are equipped with optional arc protection function enabling fast and selective arc protection throughout the switchgear. Additionally for the feeder with overhead line the optional autoreclosing function is used.

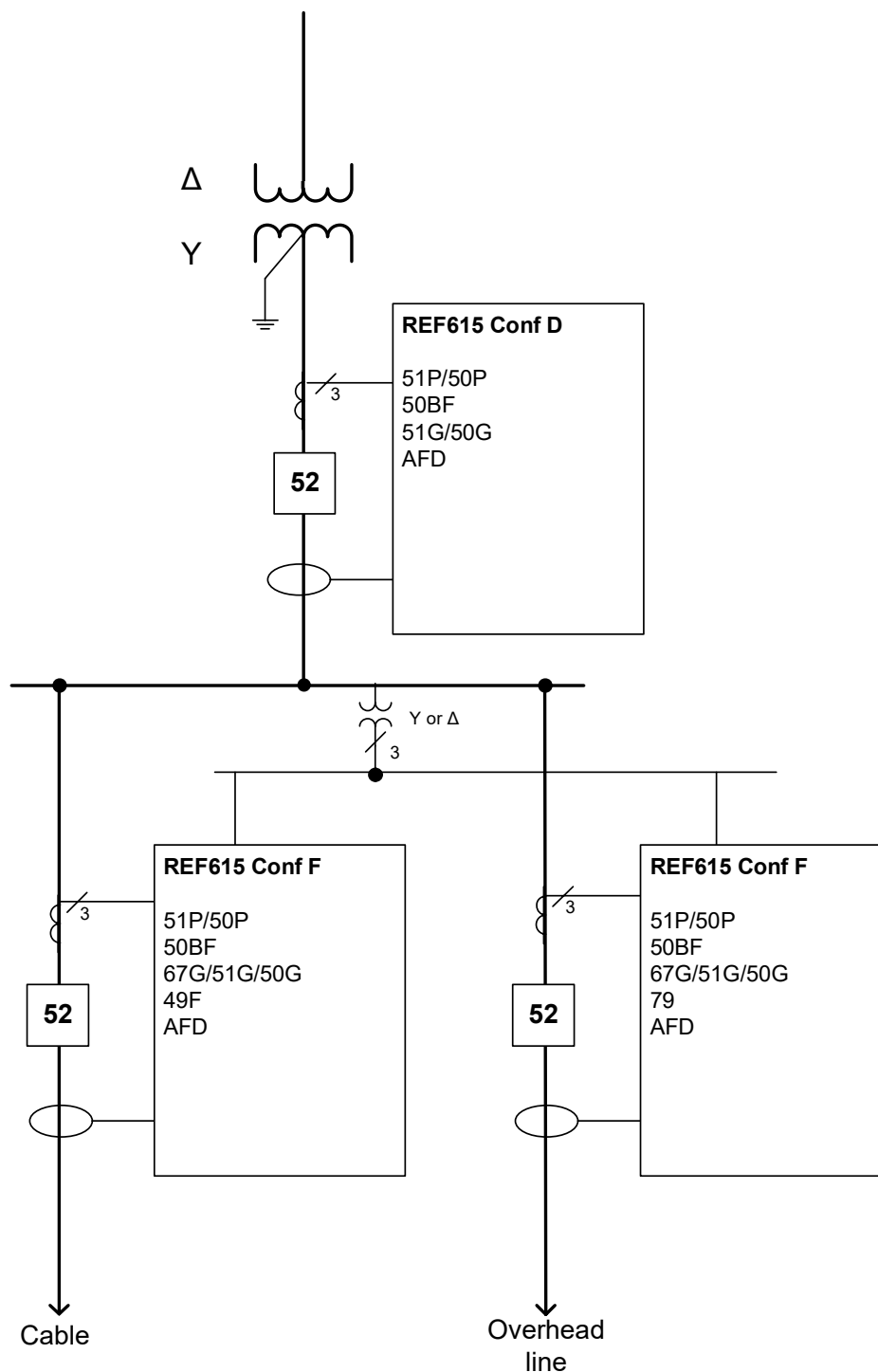


Figure 7. Substation example in low impedance grounded network using the D and N standard configurations with overcurrent, ground-fault and thermal protection for the outgoing feeder cables

Figure 7 illustrates a substation example in low impedance grounded network using the D and N standard configurations with overcurrent, ground-fault and thermal protection for the outgoing feeder cables. The relays are equipped with optional arc protection function enabling fast and selective arc protection throughout the switchgear. Additionally the optional fault locator function is used in standard configuration N for the calculation of fault distance from the substation.

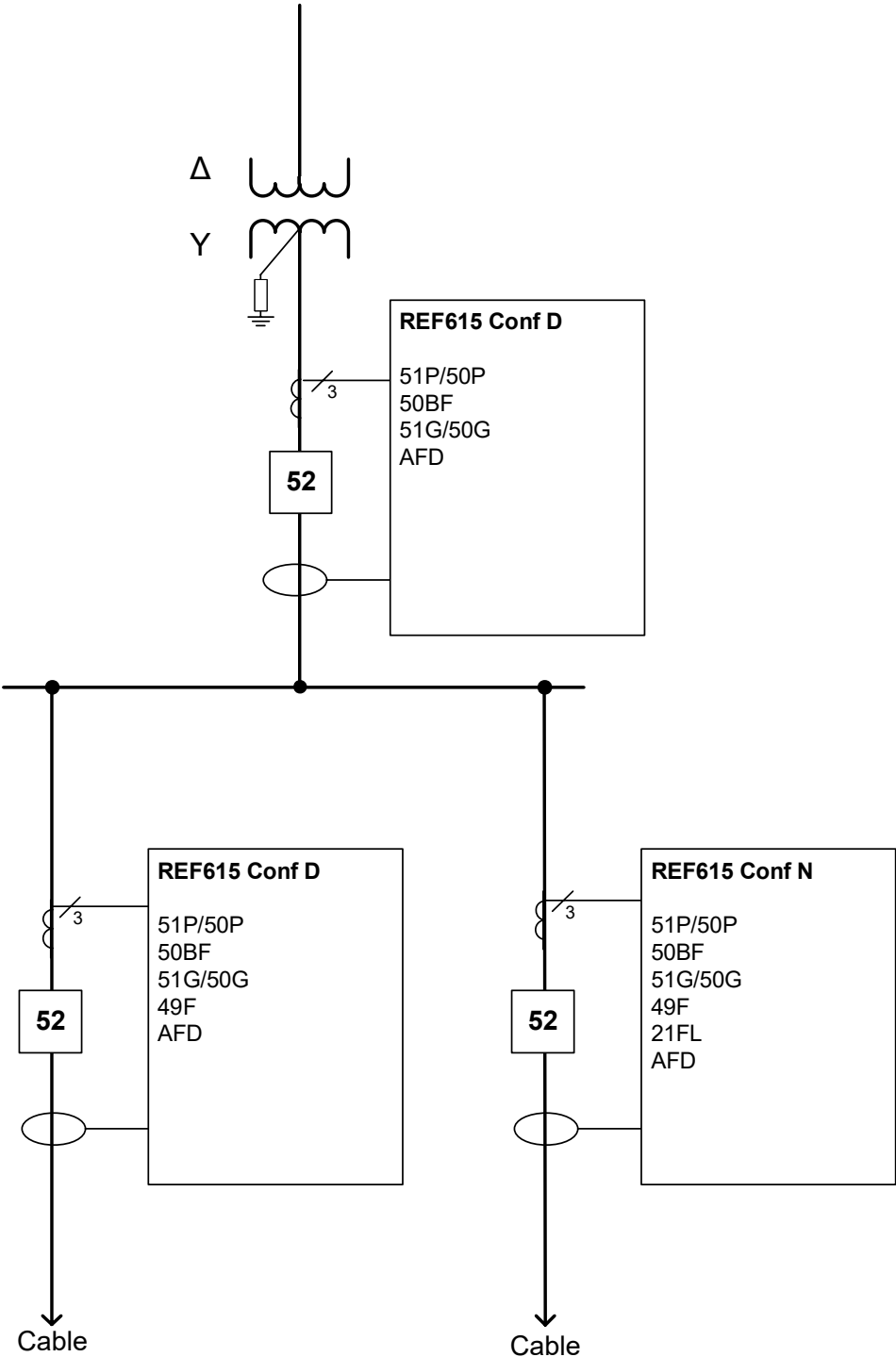


Figure 8. Application example with single busbar switchgear arrangement

Application example with single busbar switchgear arrangement is shown in Figure 8. Current sensors (Rogowski coil) and voltage sensors (voltage divider) are used for the measurements in standard configurations L. The used main protection functions are overcurrent, ground-fault and voltage based protection. 27R and 25 functions are provided via IEC 61850-9-2LE for the implementation of automatic transfer schemes in mains and tie relays.

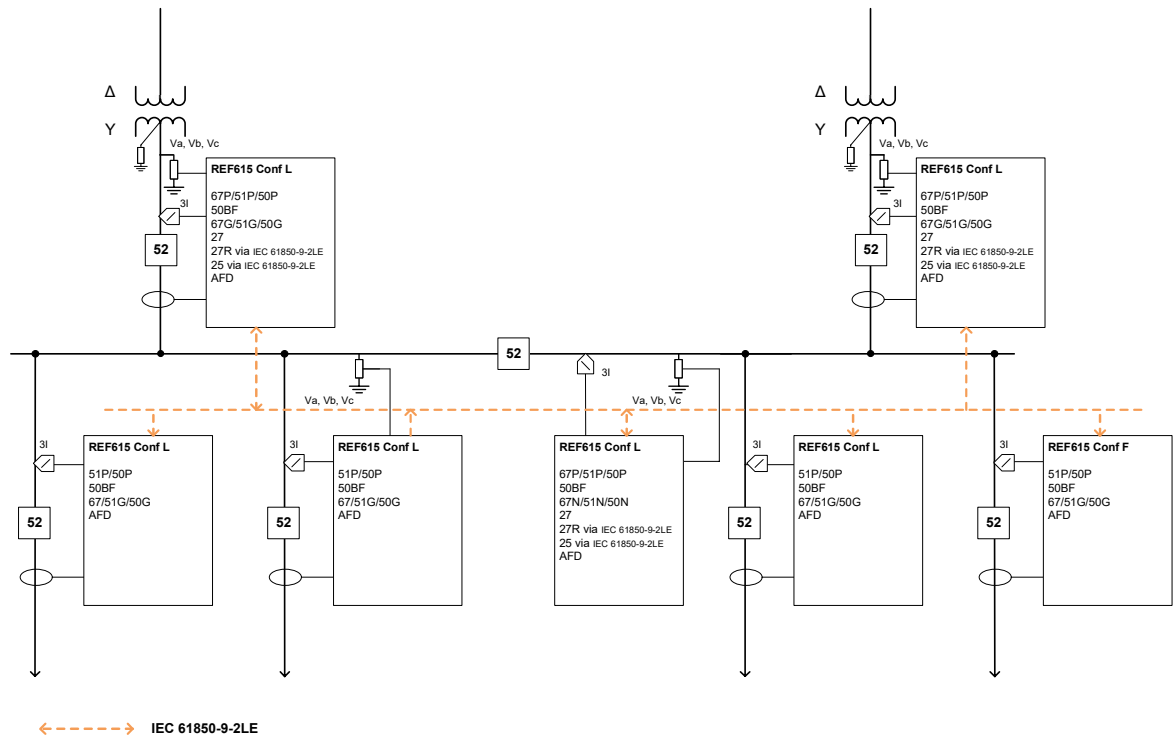


Figure 9. Application example with single busbar switchgear arranged into two bus sections separated with bus coupler. Standard configuration F is used in the outgoing feeders with optional Arc Flash detection for increased safety. The synchro-check and voltage remnant functions are used in standard configuration N in the incoming feeders, and configuration P in the tie breaker. Standard configuration P has 6 voltage inputs to be able to monitor decaying voltage in the buses for the implementation of Automatic Transfer Schemes.

In the application example in Figure 9, a single busbar switchgear is arranged into two bus sections separated with bus coupler. Standard configuration F is used in the outgoing feeders with optional Arc Flash detection for increased safety. The synchro-check and voltage remnant functions are used in standard configuration N in the incoming feeders, and configuration P in the tie breaker. Standard configuration P has 6 voltage inputs to be able to monitor decaying voltage in the buses for the implementation of Automatic Transfer Schemes.

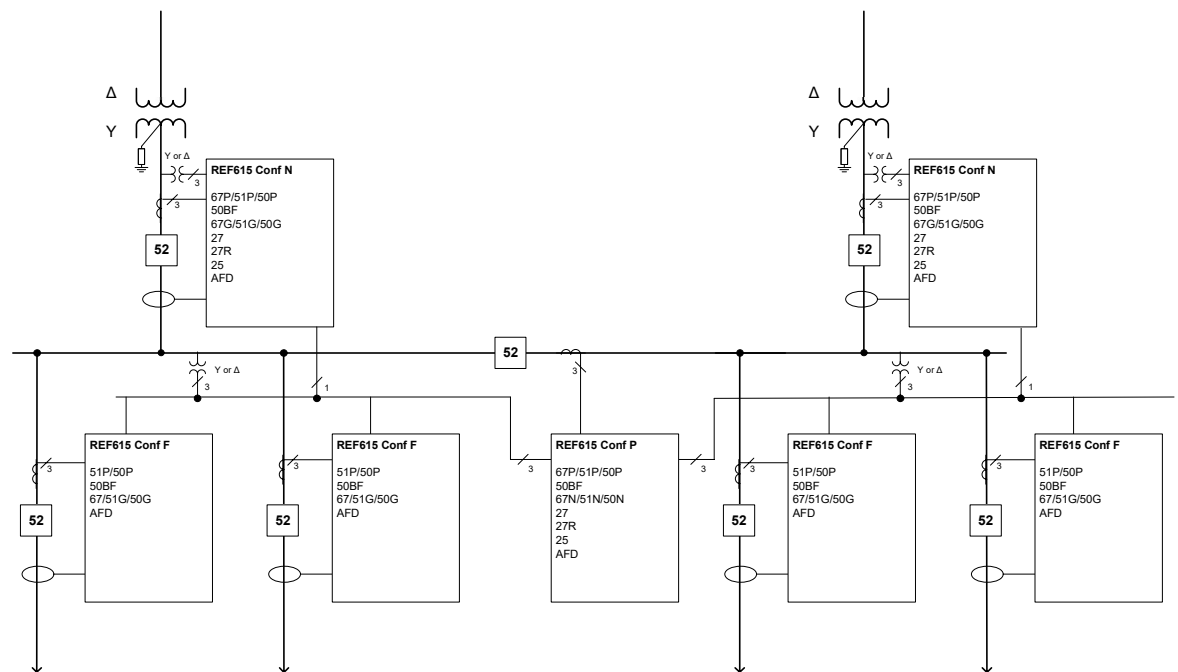


Figure 10. Application example of single busbar switchgear using the most comprehensive standard configuration N and standard configuration P

Figure 10 illustrates an application example of single busbar switchgear using the most comprehensive standard configuration N and P. The used main protection functions overcurrent, ground-fault and voltage based protection. Also thermal protection is used for the protection of the outgoing feeder

cables. Additionally, an optional autoreclosing function is used for the feeders with overhead line. The relays are equipped with optional arc protection function enabling fast and selective arc protection throughout the switchgear. Standard configuration P in the tie breaker is used for the implementation of automatic transfer schemes.

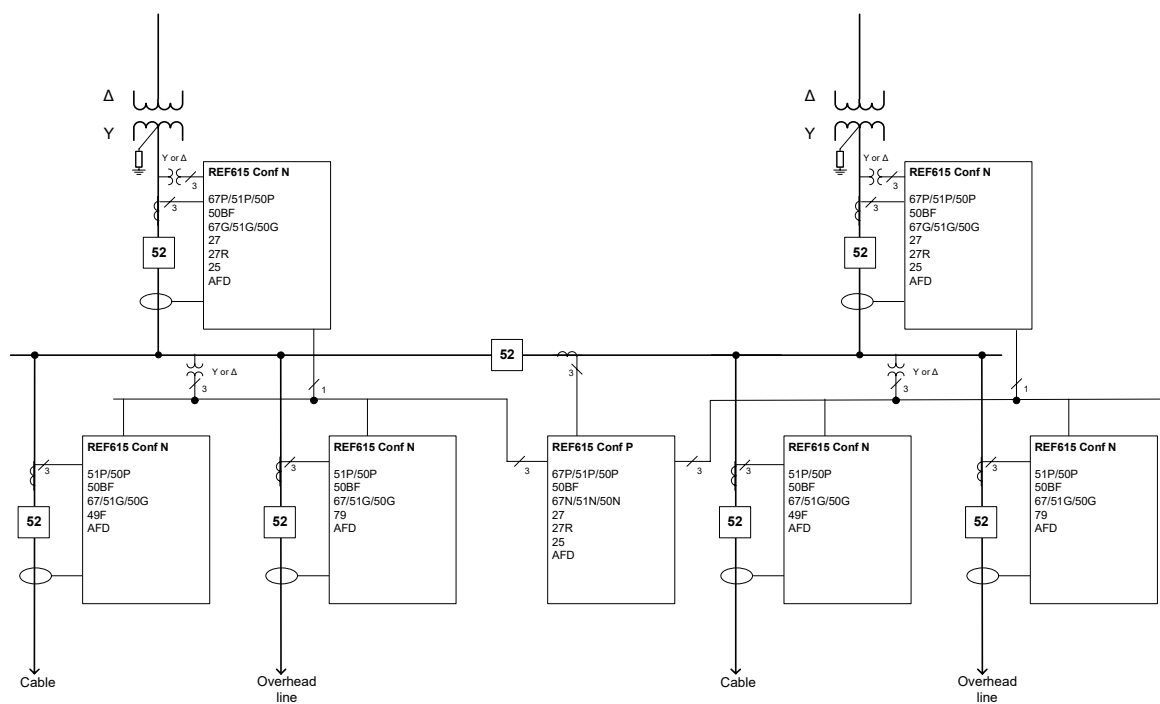


Figure 11. Protection and control of outgoing feeder with standard configuration F

Figure 11 illustrates the protection and control of the point of close coupling between the utility and distributed generation with standard configuration N.

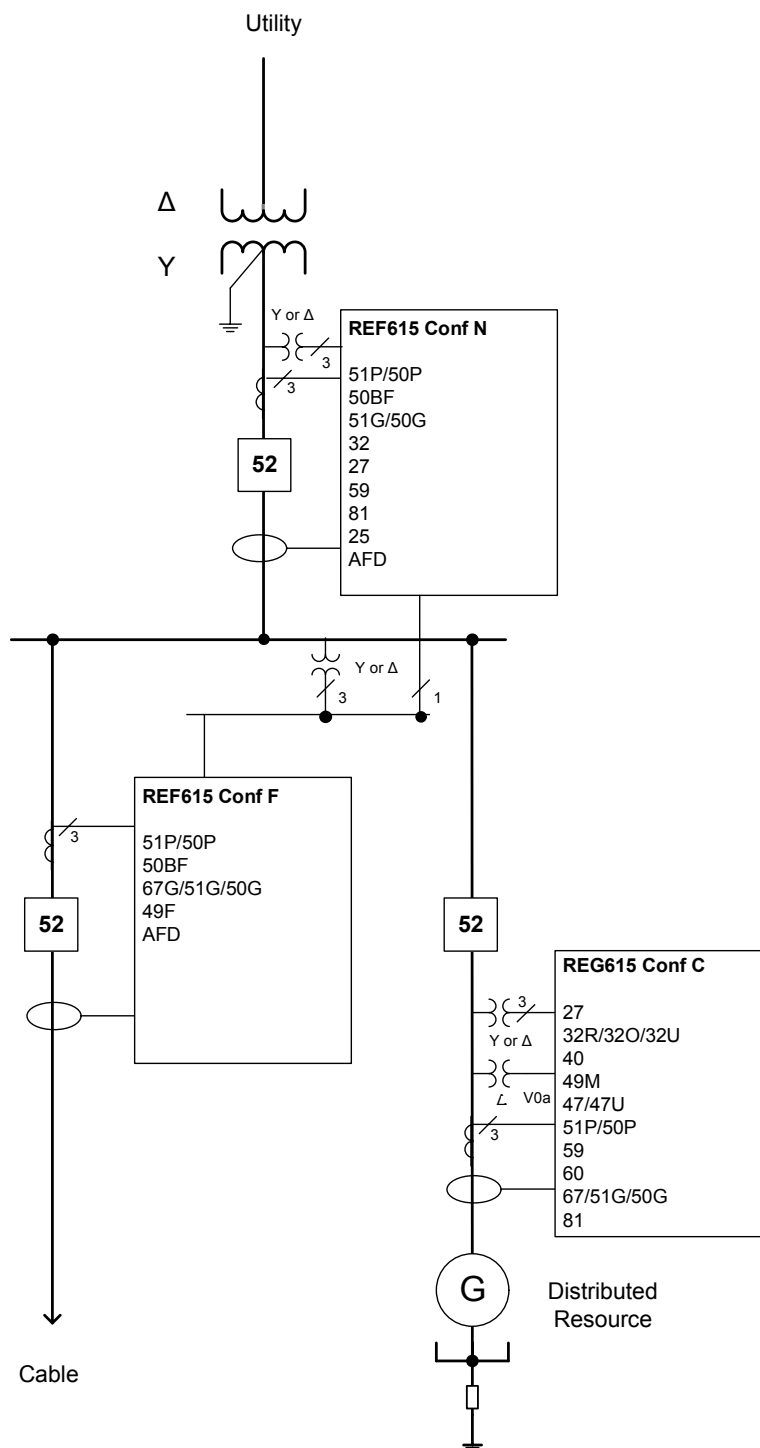
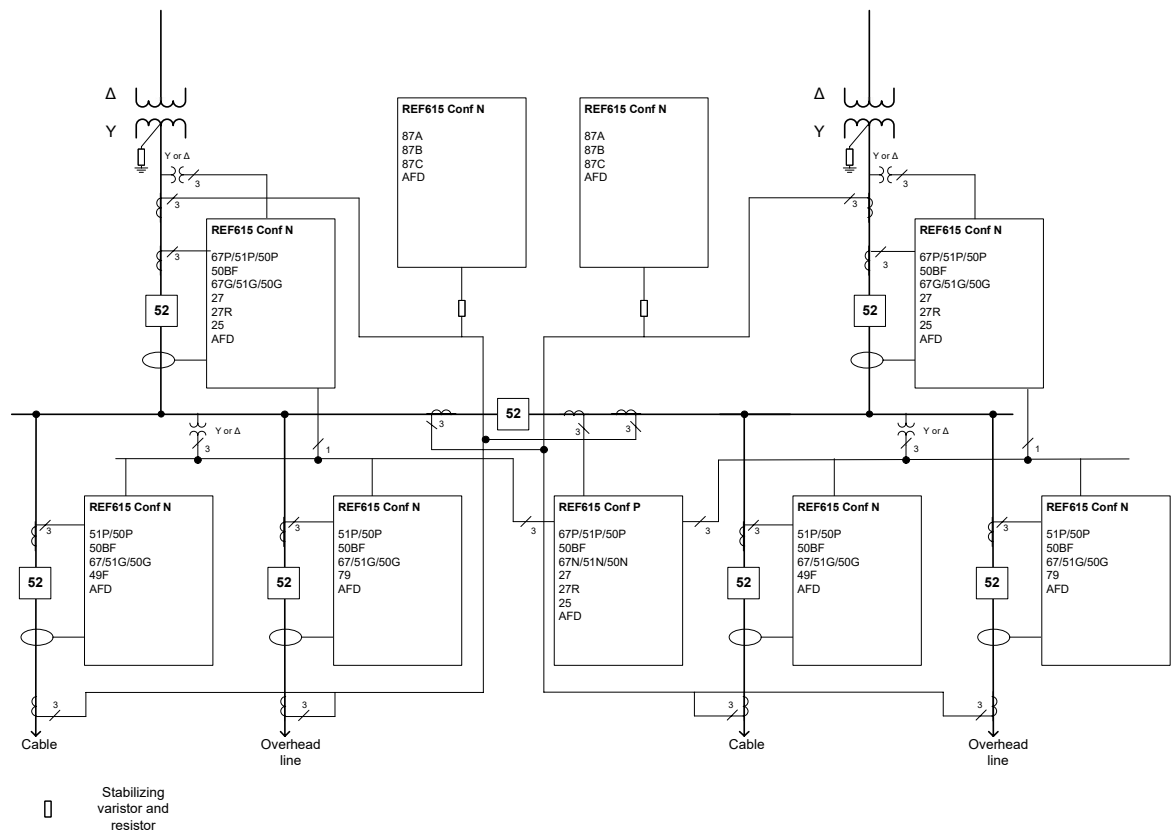


Figure 12. Application example of busbar differential protection covering two zones using standard configuration N

In the application example in Figure 12, single busbar switchgear has been arranged into two bus sections separated with bus coupler. Standard configuration N is used with high-impedance differential protection for busbar and covering two zones with two protection relays.



5. Supported ABB solutions

The 615 series protection relays together with the Substation Management Unit COM600F 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 COM600F 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, COM600F uses the data content of the baylevel devices to enhance substation level functionality. COM600F 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 COM600F 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, COM600F 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

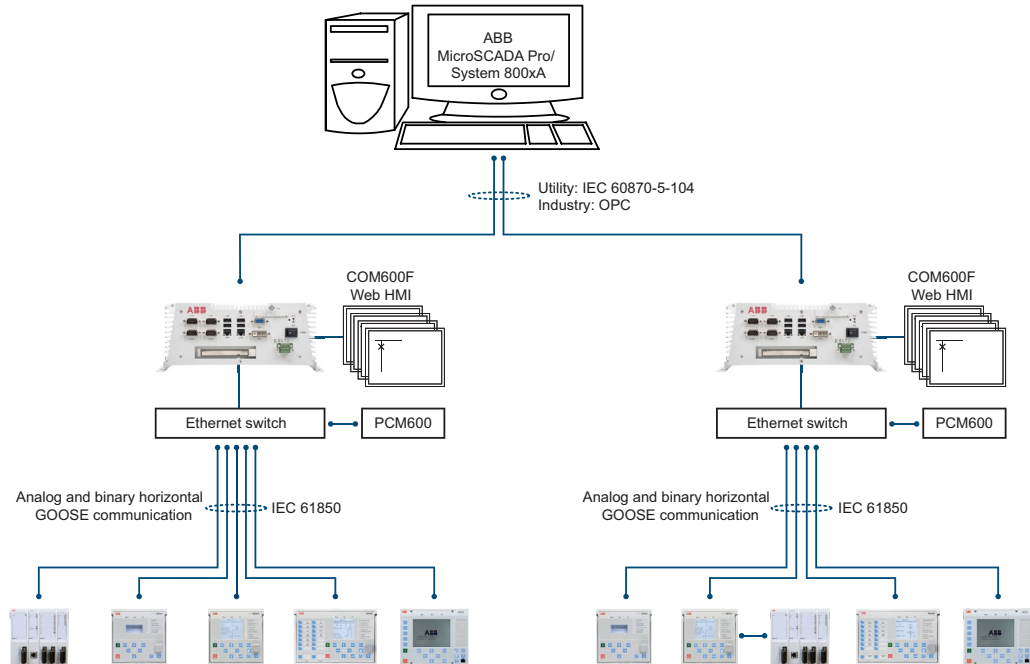
situations by using the data historian and event handling features of COM600S. The historical data can be used for accurate monitoring of process and equipment performance, using calculations based on both real-time and historical values. A better understanding of the process dynamics is achieved by combining time-based process measurements with production and maintenance events.

COM600F 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 COM600F	4.0 SP1 or later
	4.1 or later (Edition 2)
	9.3 FP2 or later
MicroSCADA Pro SYS 600	9.4 or later (Edition 2)
	5.1 or later
System 800xA	

Figure 13. ABB power system example using Relion relays, COM600S and MicroSCADA Pro/ System 800xA



6. Control

REF615 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. Depending on the chosen standard configuration of the relay the number of unused binary inputs and binary outputs varies. 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, for example, 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 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 large graphical LCD of the relay's local 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. Depending on the standard configuration, the relay also incorporates a synchrocheck function to ensure that the voltage, phase angle and frequency on either side of an open circuit breaker satisfy the conditions for safe interconnection of two networks.

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 phase voltages and the voltage sequence components. Depending on the standard configuration the relay additionally offers frequency measurement. 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 negative-sequence and positive-sequence current.

Furthermore, the relay offers three-phase power and energy measurement including power factor.

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 provides a short-term three-second average and a long-term demand for total demand distortion TDD and total harmonic distortion THD.

9. Fault location

The relay 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 non-volatile 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, current, voltage and angle 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.

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.

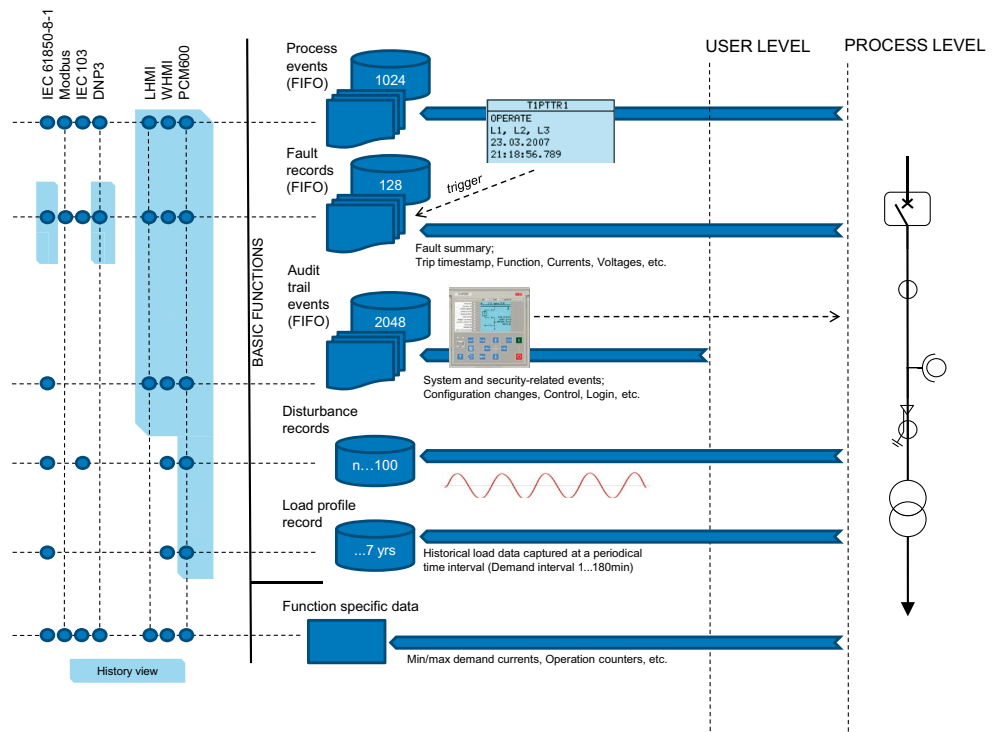
The monitoring functions provide operational circuit breaker history data, which can be used for scheduling preventive circuit breaker maintenance.

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 open-circuit monitoring both when the circuit breaker is in its closed and in its open position. It also detects loss of circuit-breaker control voltage.

Figure 14. Recording and event capabilities overview



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. Fuse failure supervision

Depending on the chosen standard configuration, the relay includes fuse failure supervision functionality. The fuse failure supervision detects failures between the voltage measurement circuit and the relay. The failures are detected either by the negative sequence-based algorithm or by the delta voltage and delta current algorithm. Upon the detection of a failure, the fuse failure supervision function activates an alarm and blocks voltage-dependent protection functions from unintended operation.

17. Current circuit supervision

Depending on the chosen standard configuration, 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 certain 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.

18. Access control

To protect the relay from unauthorized access and to maintain information integrity, the relay is provided with a four-level, rolebased 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 residualcurrent input for non-directional earth-fault protection, or three phase-current inputs, one residual-current input and one residual voltage input for directional earth-fault protection or three phase-current inputs, one residual-current input, three phase-voltage inputs and one residual voltage input for directional earth-fault protection and directional overcurrent protection. Standard configuration L 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 three phase-voltage inputs and the residual-voltage input covers the rated voltages 60...210 V. Both phase-to-phase voltages and phase-to-earth voltages can be connected.

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 inputs and outputs 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.

Optionally, a binary input and output module can be selected. It has three high speed binary outputs (HSO) and it decreases the total operate time with typically 4...6 ms compared to the normal power 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
D	AC/AD	AF	4	-	-	18	4 PO + 9 SO	-
		FB	4	-	-	18	4 PO + 5 SO + 3 HSO	-
	FC/FD	AD	4	-	-	12	4 PO + 6 SO	
		FE	4	-	-	12	4 PO + 2 SO + 3 HSO	6
		AG	4	5	-	16	4 PO + 6 SO	-
F N	AE/AF	FC	4	5	-	16	4 PO + 2 SO + 3 HSO	-
		AG	4	5	-	12	4 PO + 6 SO	2
	FE/FF	FC	4	5	-	12	4 PO + 2 SO + 3 HSO	2
		FD	1	-	3	8	4 PO + 6 SO	1
L	DA	FD	1	-	3	8	4 PO + 2 SO + 3 HSO	
		AK	4	5	-	15	4 PO + 6 SO	
P	AK	FH	4	5	-	15	4 PO + 2 SO + 3 HSO	

20. Station communication

The relay supports a range of communication protocols including IEC 61850 Edition 2, IEC 61850-9-2 LE, Modbus® and DNP3. Operational information and controls are available through these protocols. However, some communication functionality, for example, horizontal communication between the 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 sam-

pled 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 either two optical or two galvanic Ethernet network interfaces. A third port with galvanic Ethernet network interface is also available. The third Ethernet interface provides connectivity for any other Ethernet device to an IEC 61850 station bus inside a switchgear bay, for example connection of a Remote I/O. 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.

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 15. 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.

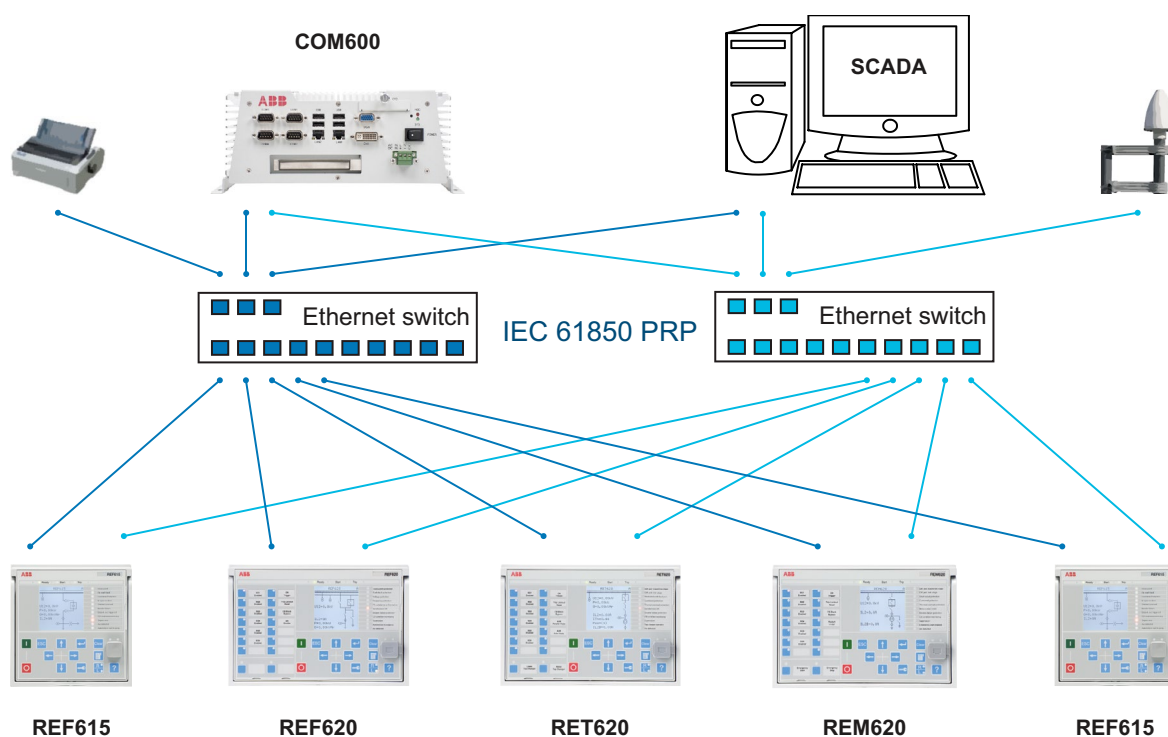
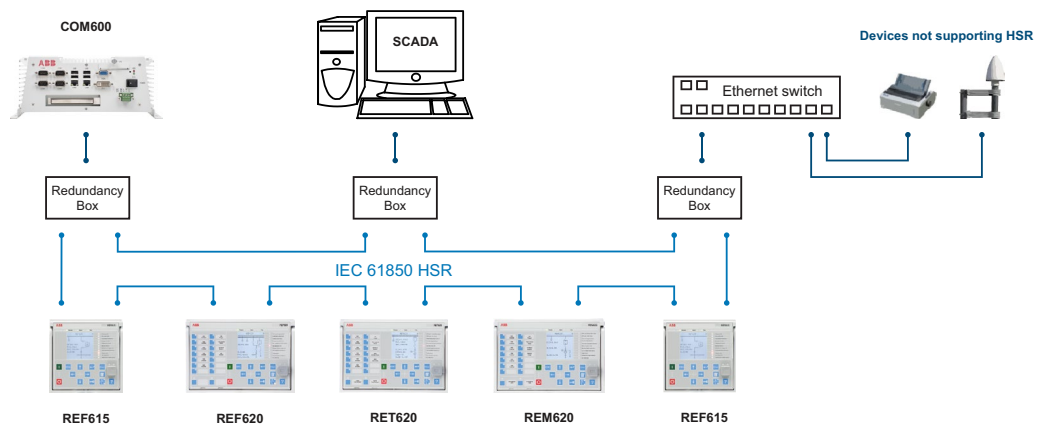


Figure 16. High availability seamless redundancy (HSR) solution

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.



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). If connection to serial bus is required, the 9-pin RS-485 screw-terminal can be used. An optional serial interface is available for RS-232 communication.

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.

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.

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.

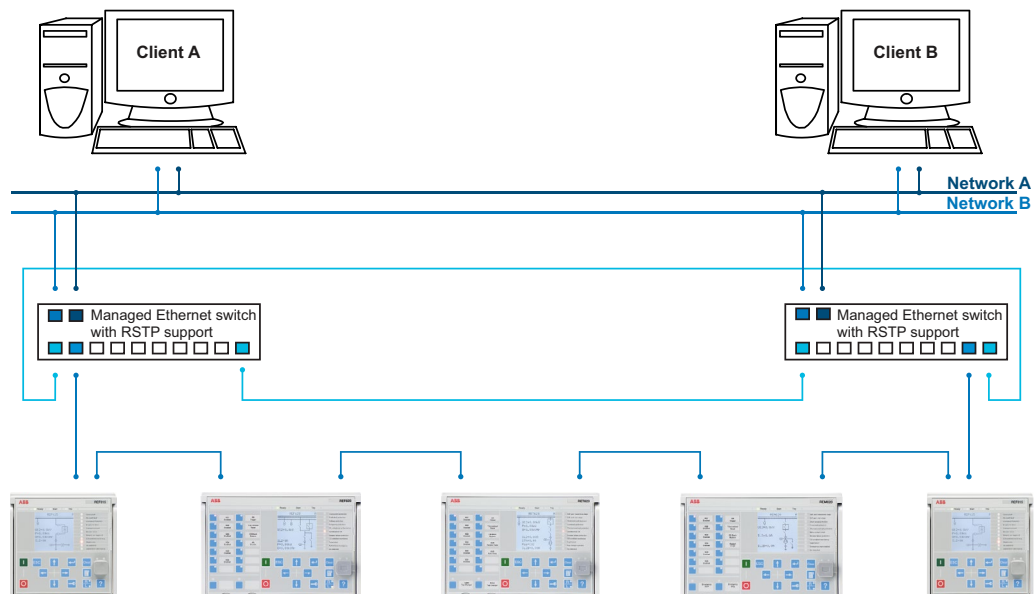
Ethernet-based

- SNTP (Simple Network Time Protocol)

With special time synchronization wiring

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

Figure 17. Self-healing Ethernet ring solution



The relay supports the following high accuracy time synchronization method with a time-stamping resolution of 4 μ s 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 $\pm 1 \mu$ s. 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, and DNP3 serial communication protocols.

Table 5. Supported station communication interfaces and protocols

Interfaces/protocols	Ethernet		Serial	
	100BASE-TX RJ-45	100BASE-FX LC	RS-232/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	•	•	—	—

• = Supported

20. Technical data

Table 6. Dimensions

Description	Value	
Width	frame	177 mm
	case	164 mm
Height	frame	177 mm (4U)
	case	160 mm
Depth	case	201 mm (153 + 48mm)
Weight	complete protection relay	4.1 kg
	plug-in unit only	2.1 kg

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 48, 60, 110, 125, 220, 250 V DC	24, 30, 48, 60 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.) AC <16.0 W (nominal)/<21.0 W (max.)	DC <13.0 W (nominal)/<18.0 W (max.)
Ripple in the DC auxiliary voltage	Max 15% of the DC value (at frequency of 100 Hz)	
Fuse type	T4A/250 V	

Table 8. Energizing inputs

Description	Value	
Rated frequency	50/60 Hz ± 5 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:	
Voltage input	- Half-wave value	250 A 1250 A
	Input impedance	<100 mΩ <20 mΩ
	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

1) Ordering option for ground current input

2) Ground current and/or phase current

Table 9. Energizing input (sensors)

Description	Value	
Current sensor input	Rated current voltage (in secondary slide)	75 mV...9000 mV ¹⁾
	Continuous voltage withstand	125 V
	Input impedance at 50/60 Hz	2...3 MΩ ²⁾
Voltage sensor input	Rated voltage	6 kV...30 kV ³⁾
	Continuous voltage withstand	50 V
	Input impedance at 50/60 Hz	3 MΩ

1) Equals the current range of 40...4000 A with a 80 A, 3 mV/Hz Rogowski

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

3) This range is covered (up to 2*rated) with sensor division ratio of 10 000:1

—
Table 10. 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

—
Table 11. 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)	2 kV (inputs to protective earth)
	Response time	<4 s
	RTD/resistance sensing current	Maximum 0.33 mA rms
	Operation accuracy	Resistance
		± 2.0% or ±1 Ω
		Temperature
		±1°C 10 Ω copper: ±2°C
	Supported current range	0...20 mA
	Current input impedance	44 Ω ± 0.1%
	Operation accuracy	±0.5% or ±0.01 mA

—
Table 12. 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	1 A/0.25 A/0.15 A
Minimum contact load	100 mA at 24 V AC/DC

—
Table 13. 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	15 A
Make and carry for 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

Table 14. 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)

Table 15. 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

Table 16. 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
Operate time	<1 ms
Reset	<20 ms, resistive load

Table 17. 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

Table 18. Station communication link, fiber optic

Connector	Fiber type ¹⁾	Wave length	Typical max. length ²⁾	Permitted path attenuation ³⁾
LC	MM 62.5/125 or 50/125 μ m glass fiber core	1300 nm	2 km	<8 dB
ST	MM 62.5/125 or 50/125 μ m glass fiber core	820...900 nm	1 km	<11 dB

1) (MM) multi-mode fiber, (SM) single-mode fiber

2) Maximum length depends on the cable attenuation and quality, the amount of splices and connectors in the path.

3) Maximum allowed attenuation caused by connectors and cable together

Table 19. 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

1) According to the 200-04 IRIG standard

Table 20. Lens sensor and optical fiber for arc protection

Description	Value
Fiber optic cable including lens	1.5 m, 3.0 m or 5.0 m
Normal service temperature range of the lens	-40...+100°C
Maximum service temperature range of the lens, max 1 h	+140°C
Minimum permissible bending radius of the connection fiber	100 mm

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

Description	Value
Front side	IP 54
Rear side, connection terminals	IP 10
Left and right side	IP 20
Top and bottom	IP 20

Table 22. Environmental conditions

Description	Value
Operating temperature range	-25...+55°C (continuous)
Short-time service temperature range	-40...+85°C (<16h) ^{1), 2)}
Relative humidity	<93%, non-condensing
Atmospheric pressure	86...106 kPa
Altitude	Up to 2000 m
Transport and storage temperature range	-40...+85°C

1) Degradation in MTBF and HMI performance outside the temperature range of -25...+55 °C

2) For relays with an LC communication interface the maximum operating temperature is +70 °C

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 • Differential mode	2.5 kV 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 • Air discharge	8 kV 15 kV	

Table 23. Electromagnetic compatibility tests (continued)

Description	Type test value	Reference
Radio frequency interference test	10 V (rms) f = 150 kHz...80 MHz	IEC 61000-4-6 IEC 60255-26, class III
	10 V/m (rms) f = 80...2700 MHz	IEC 61000-4-3 IEC 60255-26, class III
	10 V/m f = 900 MHz	ENV 50204 IEC 60255-26, class III
	20 V/m (rms) f = 80...1000 MHz	IEEE C37.90.2-2004
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	300 A/m	
Pulse magnetic field immunity test	1000 A/m 6.4/16 µs	IEC 61000-4-9
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 60%/100 ms 60%/1000 ms >95%/5000 ms	IEC 61000-4-11
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 Test level 3 (10/1/10 V rms)	IEC 61000-4-16
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	

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	IEEE C37.90-2005
Impulse voltage test	5 kV, 1.2/50 μ s, 0.5 J	IEC 60255-27
	1 kV, 1.2/50 μ s, 0.5 J, communication	IEEE C37.90-2005
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

Table 25. Mechanical tests

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

Table 26. Environmental tests

Description	Type test value	Reference
Dry heat test	• 96 h at +55°C	IEEE C37.90-2005
	• 16 h at +85°C1)	IEC 60068-2-2
Dry cold test	• 96 h at -25°C	IEEE C37.90-2005
	• 16 h at -40°C	IEC 60068-2-1
Damp heat test	• 6 cycles (12 h + 12 h) at +25°C...+55°C, humidity >93%	IEEE C37.90-2005
		IEC 60068-2-30
Change of temperature test	• 5 cycles (3 h + 3 h) at -25°C...+55°C	IEEE C37.90-2005
		IEC 60068-2-14
Storage test	• 96 h at -40°C	IEEE C37.90-2005
	• 96 h at +85°C	IEC 60068-2-1
		IEC 60068-2-2

1) For relays with an LC communication interface the maximum operating temperature is +70°C

Table 27. Product safety

Description	Value
LV directive	2006/95/EC
Standard	EN 60255-27 (2013)
	EN 60255-1 (2009)

Table 28. EMC compliance

Description	Value
EMC directive	2004/108/EC
Standard	EN 60255-26 (2013)

Table 29. RoHS compliance

Description	Value
Complies with RoHS directive 2002/95/EC	

Protection functions

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

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: $f_n \pm 2$ Hz		
	PHLPTOC	$\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
	PHHPTOC and PHIPTOC	$\pm 1.5\%$ of set value or $\pm 0.002 \times I_n$ (at currents in the range of $0.1 \dots 10 \times I_n$) $\pm 5.0\%$ of the set value (at currents in the range of $10 \dots 40 \times I_n$)		
Start time ^{1) 2)}		Minimum	Typical	Maximum
	PHIPTOC:			
	$I_{Fault} = 2 \times \text{set Start value}$	16 ms	19 ms	23 ms
	$I_{Fault} = 10 \times \text{set Start value}$	11 ms	12 ms	14 ms
	PHHPTOC and PHLPTOC:			
	$I_{Fault} = 2 \times \text{set Start value}$	23 ms	26 ms	29 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		< 30 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 ³⁾		
Suppression of harmonics		RMS: No suppression DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$ Peak-to-Peak: No suppression P-to-P+backup: No suppression		

1) Set Operate delay time = 0,02 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, fault current in one phase

with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Includes the delay of the heavy-duty output contact

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

Parameter	Function	Value (range)	Step
Start value	PHLPTOC	$0.05 \dots 5.00 \times I_n$	0.01
	PHHPTOC	$0.10 \dots 40.00 \times I_n$	0.01
	PHIPTOC	$1.00 \dots 40.00 \times I_n$	0.01
Time multiplier	PHIPTOC	0.05...15.00	0.01
Operate delay time	PHLPTOC and PHHPTOC	40...200000 ms	10
	PHIPTOC	20...200000 ms	10
Operating curve type ¹⁾	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	

1) For further reference, see the Operation characteristics table

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

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: $f_n \pm 2$ Hz		
	DPHLPDOC	$\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
		$\pm 1.5\%$ of set value or $\pm 0.002 \times I_n$ (at currents in the range of $0.1 \dots 10 \times I_n$)		
	DPHHPDOC	$\pm 5.0\%$ of the set value (at currents in the range of $10 \dots 40 \times I_n$)		
Start time ^{1) 2)}		Minimum	Typical	Maximum
	$I_{Fault} = 2.0 \times \text{set Start value}$	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		$\pm 1.0\%$ of the set value or ± 20 ms		
Operate time accuracy in inverse time mode		$\pm 5.0\%$ of the theoretical value or ± 20 ms ³⁾		
Suppression of harmonics		DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$		

1) Measurement mode and Pol quantity = default, current before fault = $0.0 \times I_n$, voltage before fault = $1.0 \times U_n$, $f_n = 50$ Hz, fault current in one phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Maximum Start value = $2.5 \times I_n$, Start value multiples in range of 1.5...20

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

Parameter	Function	Value (range)	Step
Start value	DPHLPDOC	$0.05 \dots 5.00 \times I_n$	0.01
	DPHHPDOC	$0.10 \dots 40.00 \times I_n$	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°	
Operating curve type ¹⁾	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	

1) For further reference, see the Operation characteristics table

Table 34. Three-phase non-directional overcurrent protection (PHxPTOC)

Characteristic		Value		
		Depending on the frequency of the measured current: $f_n \pm 2 \text{ Hz}$		
Operation accuracy	EFLPTOC	$\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
	EFHPTOC and EFIPTOC	$\pm 1.5\%$ of set value or $\pm 0.002 \times I_n$ (at currents in the range of $0.1 \dots 10 \times I_n$) $\pm 5.0\%$ of the set value (at currents in the range of $10 \dots 40 \times I_n$)		
		Minimum	Typical	Maximum
Start time ^{1) 2)}	EFIPTOC:			
	$I_{\text{Fault}} = 2 \times \text{set Start value}$	16 ms	19 ms	23 ms
	$I_{\text{Fault}} = 10 \times \text{set Start value}$	11 ms	12 ms	14 ms
	EFHPTOC and EFLPTOC:			
	$I_{\text{Fault}} = 2 \times \text{set Start value}$	23 ms	26 ms	29 ms
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		
Retardation time		< 30 ms		
Operate time accuracy in definite time mode		$\pm 1.0\%$ of the set value or $\pm 20 \text{ ms}$		
Operate time accuracy in inverse time mode		$\pm 5.0\%$ of the theoretical value or $\pm 20 \text{ ms}$ ³⁾		
Suppression of harmonics		RMS: No suppression		
		DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$		
		Peak-to-Peak: No suppression		

1) Measurement mode = default (depends on stage), current before fault = $0.0 \times I_n$, $f_n = 50 \text{ Hz}$, earth-fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Maximum Start value = $2.5 \times I_n$, Start value multiples in range of $1.5 \dots 20$

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

Parameter	Function	Value (range)	Step
Start value	EFLPTOC	$0.010 \dots 5.000 \times I_n$	0.005
	EFHPTOC	$0.10 \dots 40.00 \times I_n$	0.01
	EFIPTOC	$1.00 \dots 40.00 \times I_n$	0.01
Time multiplier	EFLPTOC and EFHPTOC	$0.05 \dots 15.00$	0.01
Operate delay time	EFLPTOC and EFHPTOC	40...200000 ms	10
	EFIPTOC	20...200000 ms	10
Operating curve type ¹⁾	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	

1) For further reference, see the Operation characteristics table

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	$\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
		$\pm 1.5\%$ of set value or $\pm 0.002 \times I_n$ (at currents in the range of $0.1 \dots 10 \times I_n$)		
	DEFHPDEF	$\pm 5.0\%$ of the set value (at currents in the range of $10 \dots 40 \times I_n$)		
Start time ^{1) 2)}		Minimum	Typical	Maximum
	DEFHPDEF $I_{Fault} = 2 \times \text{set Start value}$	42 ms	46 ms	49 ms
	DEFLPDEF $I_{Fault} = 2 \times \text{set Start value}$	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		$\pm 1.0\%$ of the set value or ± 20 ms		
Operate time accuracy in inverse time mode		$\pm 5.0\%$ of the theoretical value or ± 20 ms ³⁾		
Suppression of harmonics		RMS: No suppression		
		DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$		
		Peak-to-Peak: No suppression		

1) 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

2) Includes the delay of the signal output contact

3) Maximum Start value = $2.5 \times I_n$, Start value multiples in range of 1.5...20

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

Parameter	Function	Value (range)	Step
Start value	DEFLPDEF	$0.010 \dots 5.000 \times I_n$	0.005
	DEFLPDEF	$0.10 \dots 40.00 \times I_n$	0.01
Directional mode	DEFLPDEF and DEFHPDEF	1 = Non-directional	0.01
		2 = Forward	
Time multiplier	DEFLPDEF	0.05...15.00	10
	DEFHPDEF	0.05...15.00	10
Operate delay time	DEFLPDEF	50...200000 ms	40...200000 ms
	DEFHPDEF	40...200000 ms	
Operating curve type ¹⁾	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	1 = Phase angle 2 = IoSin 3 = IoCos 4 = Phase angle 80 5 = Phase angle 88
	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	

1) For further reference, see the Operation characteristics table

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

Characteristic	Value		
Operation accuracy	At the frequency $f = f_n$		
	$\pm 1.0\%$ or ± 0.01 mS (In range of 0.5...100 mS)		
Start time ^{1) 2)}	Minimum	Typical	Maximum
	56 ms	60 ms	64 ms
Reset time	40 ms		
Operate time accuracy i	$\pm 1.0\%$ of the set value or ± 20 ms		
Suppression of harmonics	-50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$		

1) $U_0 = 1.0 \times U_n$

2) Includes the delay of the signal output contact, results based on statistical distribution of 1000 measurements

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

Parameter	Function	Value (range)	Step
Voltage start value	EFPADM	$0.01 \dots 2.00 \times U_n$	0.01
Directional mode	EFPADM	1 = Non-directional 2 = Forward 3 = Reverse	-
		1 = Yo 2 = Go 3 = Bo 4 = Yo, Go 5 = Yo, Bo 6 = Go, Bo 7 = Yo, Go, Bo	
Operation mode	EFPADM		-
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

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

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz
	Current and voltage: $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$
	Power: $\pm 3\%$ of the set value or $\pm 0.002 \times P_n$
Start time ^{1), 2)}	Typically 63 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Operate time accuracy in definite time mode	$\pm 1.0\%$ of the set value or ± 20 ms
Operate time accuracy in IDMT mode	$\pm 5.0\%$ of the set value or ± 20 ms
Suppression of harmonics	-50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) I_0 varied during the test, $U_0 = 1.0 \times U_n$ = phase to earth voltage during earth fault in compensated or un-earthed network, the residual power value before fault = 0.0 pu, $f_n = 50$ Hz, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

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	$0.010...5.000 \times I_n$	0.001
Voltage start value	WPWDE	$0.010...1.000 \times U_n$	0.001
Power start value	WPWDE	$0.003...1.000 \times P_n$	0.001
Reference power	WPWDE	$0.050...1.000 \times P_n$	0.001
Characteristic angle	WPWDE	-179...180°	1
Time multiplier	WPWDE	0.05...2.00	0.01
Operating curve type ¹⁾	WPWDE	Definite or inverse time Curve type: 5, 15, 20	
Operate delay time	WPWDE	60...200000 ms	10
Min operate current	WPWDE	$0.010...1.000 \times I_n$	0.001
Min operate voltage	WPWDE	$0.01...1.00 \times U_n$	0.01

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

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_o$
Operate time accuracy	$\pm 1.0\%$ of the set value or ± 20 ms
Suppression of harmonics	-50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

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	$0.05...0.50 \times U_n$	0.01
Operation mode	INTRPTEF	1 = Intermittent EF 2 = Transient EF	-
Peak counter limit	INTRPTEF	2...20	1
Min operate current	INTRPTEF	$0.01...1.00 \times I_n$	0.01

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

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 5\%$ of the set value or $\pm 0.004 \times I_n$
Start time ^{1), 2)}	Typically 77 ms
Reset time	Typically 40 ms
Reset ratio	Typically 0.96
Operate time accuracy in definite time mode	$\pm 1.0\%$ of the set value or ± 20 ms
Operate time accuracy in IDMT mode ³⁾	$\pm 5.0\%$ of the set value or ± 20 ms
Suppression of harmonics	-50 dB at $f = f_n$ -3 dB at $f = 13 \times f_n$

1) Fundamental frequency current = $1.0 \times I_n$, harmonics current before fault = $0.0 \times I_n$, harmonics fault current $2.0 \times$ Start value, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Maximum Start value = $2.5 \times I_n$, Start value multiples in range of 2...20

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 ¹⁾	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

1) For further reference, see the Operation characteristics table

Table 46. Negative-sequence overcurrent protection (NSPTOC)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$
Start time ^{1) 2)}	Minimum Typical Maximum
$I_{Fault} = 2 \times \text{set Start value}$	23 ms 26 ms 28 ms
$I_{Fault} = 10 \times \text{set Start value}$	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	$\pm 1.0\%$ of the set value or ± 20 ms
Operate time accuracy in inverse time mode	$\pm 5.0\%$ of the theoretical value or ± 20 ms ³⁾
Suppression of harmonics	DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Negative sequence current before fault = 0.0, $f_n = 50$ Hz, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Maximum Start value = $2.5 \times I_n$, Start value multiples in range of 1.5...20

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 ¹⁾	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	

1) For further reference, see the Operation characteristics table

Table 48. Remnant undervoltage protection (MSVPR)

Characteristic	Value
Operation accuracy	$\pm 4\%$ of setting or $\pm 0.01 \times V_n$ ($70 \text{ Hz} > f > 20 \text{ Hz}$) $\pm 10\%$ of setting ($20 \text{ Hz} > f \geq 10 \text{ Hz}$)
Pickup time ¹⁾	Minimum Typical Maximum
	30 ms 75 ms 140 ms
Reset time	< 180 ms
Reset ratio	Depends on the relative hysteresis setting
Retardation time	< 45 ms
Trip time accuracy	$\pm 1.0\%$ of the set value or ± 20 ms
Suppression of harmonics	Operates only in RMS mode

1) Includes the delay of the signal output contact

2) Operate time delays do not account for variation due to pickup delay

Table 49. Phase discontinuity protection (PDNSPTOC)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 2\%$ 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	$\pm 1.0\%$ of the set value or ± 20 ms
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

Table 50. 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	$0.05 \dots 0.30 \times I_n$	0.01

Table 51. Residual overvoltage protection (ROVPTOV)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ^{1) 2)}	Minimum Typical Maximum
$U_{Fault} = 2 \times \text{set Start value}$	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	$\pm 1.0\%$ of the set value or ± 20 ms
Suppression of harmonics	DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) 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

2) Includes the delay of the signal output contact

Table 52. Residual overvoltage protection (ROVPTOV) main settings

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

Table 53. Three-phase undervoltage protection (PHPTUV)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ^{1) 2)}	Minimum Typical Maximum
$U_{\text{Fault}} = 0.9 \times \text{set Start value}$	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 ³⁾
Suppression of harmonics	DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) 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

2) Includes the delay of the signal output contact

3) Minimum Start value = 0.50, Start value multiples in range of 0.90...0.20

Table 54. Three-phase undervoltage protection (PHPTUV) main settings

Parameter	Function	Value (range)	Step
Start value	PHPTUV	$0.05 \dots 1.20 \times U_n$	0.01
Time multiplier	PHPTUV	$0.05 \dots 15.00$	0.01
Operate delay time	PHPTUV	$60 \dots 300000$ ms	10
Operating curve type ¹⁾	PHPTUV	Definite or inverse time Curve type: 5, 15, 21, 22, 23	

1) For further reference, see the Operation characteristics table

Table 55. Three-phase overvoltage protection (PHPTOV)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ^{1) 2)}	Minimum Typical Maximum
$U_{\text{Fault}} = 1.1 \times \text{set Start value}$	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	$\pm 1.0\%$ of the set value or ± 20 ms
Operate time accuracy in inverse time mode	$\pm 5.0\%$ of the theoretical value or ± 20 ms ³⁾
Suppression of harmonics	DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Start value = $1.0 \times U_n$, Voltage before fault = $0.9 \times U_n$, $f_n = 50$ Hz, overvoltage in one phase-to-phase with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

3) Maximum Start value = $1.20 \times U_n$, Start value multiples in range of 1.10...2.00

Table 56. Three-phase overvoltage protection (PHPTOV) main settings

Parameter	Function	Value (range)	Step
Start value	PHPTOV	$0.05 \dots 1.60 \times U_n$	0.01
Time multiplier	PHPTOV	$0.05 \dots 15.00$	0.01
Operate delay time	PHPTOV	$40 \dots 300000$ ms	10
Operating curve type ¹⁾	PHPTOV	Definite or inverse time Curve type: 5, 15, 17, 18, 19, 20	

1) For further reference, see the Operation characteristics table

Table 57. Positive-sequence undervoltage protection (PSPTUV)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: $f_n \pm 2$ Hz		
		$\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
Start time ^{1) 2)}	$U_{Fault} = 0.99 \times \text{set Start value}$ $U_{Fault} = 0.9 \times \text{set Start value}$	Minimum	Typical	Maximum
		52 ms	55 ms	58 ms
		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		$\pm 1.0\%$ of the set value or ± 20 ms		
Suppression of harmonics		DFT: -50dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$		

1) Start value = $1.0 \times U_n$, positive-sequence voltage before fault = $1.1 \times U_n$, $f_n = 50$ Hz, positive sequence undervoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

Table 58. Positive-sequence undervoltage protection (PSPTUV) main settings

Parameter	Function	Value (range)	Step
Start value	PSPTUV	$0.010 \dots 1.200 \times U_n$	0.001
Operate delay time	PSPTUV	40...120000 ms	10
Voltage block value	PSPTUV	$0.01 \dots 1.00 \times U_n$	0.01

Table 59. Negative-sequence overvoltage protection (NSPTOV)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f _n ±1.5% of the set value or ±0.002 × U _n		
Start time ^{1) 2)}	U _{Fault} = 1.1 x set Start value U _{Fault} = 2.0 x set Start value	Minimum	Typical	Maximum
		33 ms	35 ms	37 ms
		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: -50dB at f = n x f _n , where n = 2, 3, 4, 5,...		

1) Negative-sequence voltage before fault = $0.0 \times U_n$, $f_n = 50$ Hz, negative-sequence overvoltage with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

Table 60. Negative-sequence overvoltage protection (NSPTOV) main settings

Parameter	Function	Value (range)	Step
Start value	NSPTOV	$0.010 \dots 1.000 \times U_n$	0.001
Operate delay time	NSPTOV	40...120000 ms	1

Table 61. Frequency protection (FRPFRQ)

Characteristic		Value
Operation accuracy	$f > / f <$	± 5 mHz
	df/dt	± 50 mHz/s (in range $ df/dt < 5$ Hz/s)
		$\pm 2.0\%$ of the set value (in range $5 \text{ Hz/s} < df/dt < 15 \text{ Hz/s}$)
Start time ^{1) 2)}	$f > / f <$	<80 ms
	df/dt	<120 ms
Reset time		<150 ms
Operate time accuracy		$\pm 1.0\%$ of the set value or ± 30 ms

Table 62. 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

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

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current: $f_n \pm 2$ Hz Current measurement: $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$ (at currents in the range of $0.01...4.00 \times I_n$)
Operate time accuracy ¹⁾	$\pm 2.0\%$ of the theoretical value or ± 0.50 s

1) Overload current > $1.2 \times$ Operate level temperature

Table 64. 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	$0.05...4.00 \times I_n$	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

Table 65. High-impedance differential protection (HIXPDIF)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$		
		Minimum	Typical	Maximum
Start time ^{1) 2)}	$I_{Fault} = 2.0 \times \text{set Start value}$	12 ms	16 ms	24 ms
	$I_{Fault} = 10.0 \times \text{set Start value}$	10 ms	12 ms	14 ms
Reset time		< 40 ms		
Reset ratio		Typically 0.96		
Retardation time		< 35 ms		
Operate time accuracy in definite time mode		$\pm 1.0\%$ of the set value or ± 20 ms		

1) Measurement mode = default (depends on stage), current before fault = $0.0 \times I_n$, $f_n = 50$ Hz, fault current with nominal frequency injected from random phase angle, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

Table 66. High-impedance differential protection (HlXPDIF) main settings

Parameter	Function	Value (range)	Step
Operate value	HREFPDIF	1.0...50.0% I_n	0.1
Minimum operate time	HREFPDIF	40...300000 ms	1

Table 67. Circuit breaker failure protection (CCBRBRF)

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

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

Parameter	Function	Value (range)	Step
Current value	CCBRBRF	0.05...2.00 $\times I_n$	0.05
Current value Res	CCBRBRF	0.05...2.00 $\times I_n$	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

Table 69. Three-phase inrush detector (INRPHAR)

Characteristic	Value
Operation accuracy	At the frequency $f = f_n$ Current measurement: $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$ Ratio I_{2f}/I_{1f} measurement: $\pm 5.0\%$ of the set value
Reset time	+35 ms / -0 ms
Reset ratio	Typically 0.96
Operate time accuracy	+35 ms / -0 ms

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

Table 71. Switch onto fault (CBPSOF)

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

Table 72. Switch onto fault (CBPSOF) main settings

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

Table 73. Arc protection (ARCSARC)

Characteristic		Value		
Operation accuracy		Depending on the frequency of the measured current: f _n ±2 Hz		
		Minimum	Typical	Maximum
Operate time	Operation mode = "Light +current" ^{1), 2)}	9 ms ³⁾	12 ms ³⁾	15 ms ³⁾
		4 ms ⁴⁾	6 ms ⁴⁾	9 ms ⁴⁾
	Operation mode = "Light only" ²⁾	9 ms ³⁾	10 ms ³⁾	12 ms ³⁾
		4 ms ⁴⁾	6 ms ⁴⁾	7 ms ⁴⁾
Reset time		Typically 40 ms		
Reset ratio		Typically 0.96		

1) Phase start value = $1.0 \times I_n$, current before fault = $2.0 \times$ set Phase start value, $f_n = 50$ Hz, fault with nominal frequency, results based on statistical distribution of 200 measurements

2) Includes the delay of the heavy-duty output contact

3) Normal power output

4) High-speed output

Table 74. Arc protection (ARCSARC) main settings

Parameter	Function	Value (range)	Step
Phase start value	ARCSARC	$0.50...40.00 \times I_n$	0.01
Ground start value	ARCSARC	$0.05...8.00 \times I_n$	0.01
Operation mode	ARCSARC	1 = Light+current 2 = Light only 3 = BI controlled	-

Table 75. Multipurpose protection (MAPGAPC)

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

Table 76. 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	-

Table 77. Fault locator (SCEFRFLO)

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

Table 78. 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

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	-

Table 80. Reverse power/directional overpower protection (DOPPDPR)

Characteristic	Value
Operation accuracy ¹⁾	Depending on the frequency of the measured current and voltage: $f = f_n \pm 2$ Hz Power measurement accuracy $\pm 3\%$ of the set value or $\pm 0.002 \times S_n$ Phase angle: $\pm 2^\circ$
Start time ^{2), 3)}	Typically 45 ms
Reset time	Typically 30 ms
Reset ratio	Typically 0.94
Operate time accuracy	$\pm 1.0\%$ of the set value of ± 20 ms
Suppression of harmonics	-50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Measurement mode = "Pos Seq" (default)

2) $U = U_n$, $f_n = 50$ Hz, results based on statistical distribution of 1000 measurements

3) Includes the delay of the signal output contact

Table 81. Reverse power/directional overpower protection (DOPPDPR) main settings

Parameter	Function	Value (range)	Step
Start value	DOPPDPR	$0.01 \dots 2.00 \times S_n$	0.01
Operate delay time	DOPPDPR	40...300000 ms	10
Directional mode	DOPPDPR	2 = Forward 3 = Reverse	-
Power angle	DOPPDPR	-90...90°	1

Table 82. Underpower protection (DUPPDPR)

Characteristic	Value
Operation accuracy ¹⁾	Depending on the frequency of the measured current and voltage: $f_n \pm 2$ Hz Power measurement accuracy $\pm 3\%$ of the set value or $\pm 0.002 \times S_n$ Phase angle: $\pm 2^\circ$
Start time ^{2), 3)}	Typically 45 ms
Reset time	Typically 30 ms
Reset ratio	Typically 1.04
Operate time accuracy	$\pm 1.0\%$ of the set value of ± 20 ms
Suppression of harmonics	-50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Measurement mode = "Pos Seq" (default)

2) $V = V_n$, $f_n = 50$ Hz, results based on statistical distribution of 1000 measurements

3) Includes the delay of the signal output contact

Table 83. Multifrequency admittance-based earth-fault protection (MFADPSDE)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: $f_n \pm 2 \text{ Hz}$ $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ¹⁾	Typically 35 ms
Reset time	Typically 40 ms
Operate time accuracy	$\pm 1.0\%$ of the set value of $\pm 20 \text{ ms}$

1) Includes the delay of the signal output contact, results based on statistical distribution of 1000 measurements

Table 84. Multifrequency admittance-based earth-fault protection (MFADPSDE) main settings

Parameter	Function	Value (range)	Step
Directional mode	MFADPSDE	2 = Forward 3 = Reverse	-
Voltage start value	MFADPSDE	$0.01 \dots 1.00 \times U_n$	0.01
Operate delay time	MFADPSDE	60...1200000	10
Operating quantity	MFADPSDE	1 = Adaptive 2 = Amplitude	-
Min operate current	MFADPSDE	$0.005 \dots 5.000 \times I_n$	0.001
Operation mode	MFADPSDE	1 = Intermittent EF 3 = General EF 4 = Alarming EF	-
Peak counter limit	MFADPSDE	2...20	1

Table 85. Operation characteristics

Characteristic	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

Interconnection functions

Table 86. Directional reactive power undervoltage protection (DQPTUV)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured current and voltage: $f_n \pm 2$ Hz Reactive power range $ PF < 0.71$
	Power: $\pm 3.0\%$ or $\pm 0.002 \times Q_n$ Voltage: $\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ^{1) 2)}	Typically 46 ms
Reset time	< 50 ms
Reset ratio	Typically 0.96
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Start value = $0.05 \times S_n$, reactive power before fault = $0.8 \times$ Start value, reactive power overshoot 2 times, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

Table 87. Directional reactive power undervoltage protection (DQPTUV) main settings

Parameter	Function	Value (range)	Step
Voltage start value	DQPTUV	$0.20 \dots 1.20 \times U_n$	0.01
Operate delay time	DQPTUV	100...300000 ms	10
Min reactive power	DQPTUV	$0.01 \dots 0.50 \times S_n$	0.01
Min Ps Seq current	DQPTUV	$0.02 \dots 0.20 \times I_n$	0.01
Pwr sector reduction	DQPTUV	$0 \dots 10^\circ$	1

Table 88. Low-voltage ride-through protection (LVRTPTUV)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: $f_n \pm 2$ Hz
	$\pm 1.5\%$ of the set value or $\pm 0.002 \times U_n$
Start time ^{1) 2)}	Typically 40 ms
Reset time	Based on maximum value of Recovery time setting
Operate time accuracy	$\pm 1.0\%$ of the set value or ± 20 ms
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

1) Tested for Number of Start phases = 1 out of 3, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

—
Table 89. Low-voltage ride-through protection (LVRTPTUV) main settings

Parameter	Function	Value (range)	Step
Voltage start value	LVRTPTUV	$0.05...1.20 \times U_n$	0.01
Num of start phases	LVRTPTUV	4 = Exactly 1 of 3 5 = Exactly 2 of 3 6 = Exactly 3 of 3	-
Voltage selection	LVRTPTUV	1 = Highest Ph-to-E 2 = Lowest Ph-to-E 3 = Highest Ph-to-Ph 4 = Lowest Ph-to-Ph 5 = Positive Seq	-
Active coordinates	LVRTPTUV	1...10	1
Voltage level 1	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 2	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 3	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 4	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 5	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 6	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 7	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 8	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 9	LVRTPTUV	0.00...1.20 ms	0.01
Voltage level 10	LVRTPTUV	0.00...1.20 ms	0.01
Recovery time 1	LVRTPTUV	0...300000 ms	1
Recovery time 2	LVRTPTUV	0...300000 ms	1
Recovery time 3	LVRTPTUV	0...300000 ms	1
Recovery time 4	LVRTPTUV	0...300000 ms	1
Recovery time 5	LVRTPTUV	0...300000 ms	1
Recovery time 6	LVRTPTUV	0...300000 ms	1
Recovery time 7	LVRTPTUV	0...300000 ms	1
Recovery time 8	LVRTPTUV	0...300000 ms	1
Recovery time 9	LVRTPTUV	0...300000 ms	1
Recovery time 10	LVRTPTUV	0...300000 ms	1

—
Table 90. Voltage vector shift protection (VVSPAM)

Characteristic	Value
Operation accuracy	Depending on the frequency of the measured voltage: $f_n \pm 1$ Hz $\pm 1^\circ$
Operate time ^{1) 2)}	Typically 53 ms

1) $f_n = 50$ Hz, results based on statistical distribution of 1000 measurements

2) Includes the delay of the signal output contact

—
Table 91. Voltage vector shift protection (VVSPAM) main settings

Parameter	Function	Value (range)	Step
Start value	VVSPAM	$2.0...30.0^\circ$	0.1
Over Volt Blk value	VVSPAM	$0.40...1.50 \times U_n$	0.01
Under Volt Blk value	VVSPAM	$0.15...1.00 \times U_n$	0.01
Phase supervision	VVSPAM	7 = Ph A + B + C 8 = Pos sequence	-

Power quality functions

Table 92. 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)

Table 93. Voltage unbalance (VSQVUB)

Characteristic	Value
Operation accuracy	±1.5% of the set value or $\pm 0.002 \times U_n$
Reset ratio	Typically 0.96

Control functions

Table 94. Autoreclosing (DARREC)

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

Table 95. Synchronism and energizing check (SECRSYN)

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

Table 96. 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	$0.01 \dots 0.50 \times U_n$	0.01
Difference frequency	SECRSYN	$0.001 \dots 0.100 \times f_n$	0.001
Difference angle	SECRSYN	$5 \dots 90^\circ$	1
Synchrocheck mode	SECRSYN	1 = Off 2 = Synchronous 3 = Asynchronous	-
Dead line value	SECRSYN	$0.1 \dots 0.8 \times U_n$	0.1
Live line value	SECRSYN	$0.2 \dots 1.0 \times U_n$	0.1
Max energizing V	SECRSYN	$0.50 \dots 1.15 \times U_n$	0.01
Control mode	SECRSYN	1 = Continuous 2 = Command	-
Close pulse	SECRSYN	200...60000 ms	10
Phase shift	SECRSYN	$-180 \dots 180^\circ$	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

Condition monitoring and supervision functions

Table 97. Circuit-breaker condition monitoring (SSCBR)

Characteristic	Value
Current measuring accuracy	$\pm 1.5\%$ or $\pm 0.002 \times I_n$ (at currents in the range of $0.1 \dots 10 \times I_n$) $\pm 5.0\%$ (at currents in the range of $10 \dots 40 \times I_n$)
Operate time accuracy	$\pm 1.0\%$ of the set value or ± 20 ms
Travelling time measurement	$+10$ ms / -0 ms

Table 98. Current circuit supervision (CCSPVC)

Characteristic	Value
Operate time ¹⁾	< 30 ms

1) Including the delay of the output contact

Table 99. Current circuit supervision (CCSPVC) main settings

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

Table 100. Current transformer supervision for high-impedance protection scheme (HZCCxSPVC)

Characteristic	Value
Operation accuracy	Depending on the frequency of the current measured: $f_n \pm 2$ Hz $\pm 1.5\%$ of the set value or $\pm 0.002 \times I_n$
Reset time	< 40 ms
Reset ratio	Typically 0.96
Retardation time	< 35 ms
Operate time accuracy in definite time mode	$\pm 1.0\%$ of the set value or ± 20 ms

Table 101. CT supervision for high-impedance protection scheme (HZCSPVC) main settings

Parameter	Function	Value (range)	Step
Start value	HZCCASPVC HZCCBSPVC HZCCCSPVC	$1.0 \dots 100.0 \% I_n$	0.1
Alarm delay time	HZCCASPVC HZCCBSPVC HZCCCSPVC	$100 \dots 300000$ ms	10
Alarm output mode	HZCCASPVC HZCCBSPVC HZCCCSPVC	1=Non-latched 3=Lockout	-

Table 102. Fuse failure supervision (SEQSPVC)

Characteristic		Value	
Operate time ¹⁾	NPS function	$U_{\text{Fault Lev}} = 1.1 \times \text{set Neg Seq voltage}$	<33 ms
		$U_{\text{Fault Lev}} = 5.0 \times \text{set Neg Seq voltage}$	<18 ms
	Delta function	$\Delta U = 1.1 \times \text{set Voltage change rate}$	<33 ms
		$\Delta U = 2.0 \times \text{set Voltage change rate}$	<24 ms

1) 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

Table 103. Runtime counter for machines and devices (MDSOPT)

Description	Value
Motor runtime measurement accuracy ¹⁾	$\pm 0.5\%$

1) Of the reading, for a stand-alone relay, without time synchronization

Measurement functions

Table 104. 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 $0.01 \dots 4.00 \times I_n$)
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$ RMS: No suppression

Table 105. 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 $0.01 \dots 4.00 \times I_n$
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$

Table 106. 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 $0.01 \dots 4.00 \times I_n$
Suppression of harmonics	DFT: -50 dB at $f = n \times f_n$, where $n = 2, 3, 4, 5, \dots$ RMS: No suppression

Table 107. Three-phase voltage measurement (VMMXU)

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

Table 108. Residual voltage measurement (RESVMMXU)

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

Table 109. Sequence voltage measurement (VSMSQI)

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

Table 110. Three-page power and energy measurements (SPEMMXU and PEMMXU)

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

1) $|PF| > 0.5$ which equals $|\cos\phi| > 0.5$

2) $|PF| < 0.86$ which equals $|\sin\phi| > 0.5$

Table 111. RTD/mA measurement (XRGGIO130)

Parameter	Value (range)	
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 k Ω
	Maximum lead resistance (threewire measurement)	25 Ω per lead
	Isolation	2 kV (inputs to protective earth)
	Response time	<4 s
mA inputs	RTD/resistance sensing current	Maximum 0.33 mA rms
	Operation accuracy	Resistance
		Temperature
		$\pm 2.0\%$ or $\pm 1 \Omega$
		$\pm 1^\circ\text{C}$ 10 Ω copper: $\pm 2^\circ\text{C}$
	Supported current range	0...20 mA
mA inputs	Current input impedance	44 $\Omega \pm 0.1\%$
	Operation accuracy	$\pm 0.5\%$ or ± 0.01 mA

Table 112. Frequency measurement (FMMXU)

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

Other functions

—
Table 113. Pulse timer (PTGAPC)

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

—
Table 114. Time delay off (8 pcs) (TOFPAGC)

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

—
Table 115. Time delay on (8 pcs) (TONGAPC)

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

21. 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.

The LCD display offers front-panel user interface functionality with menu navigation and menu views. The display also 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.

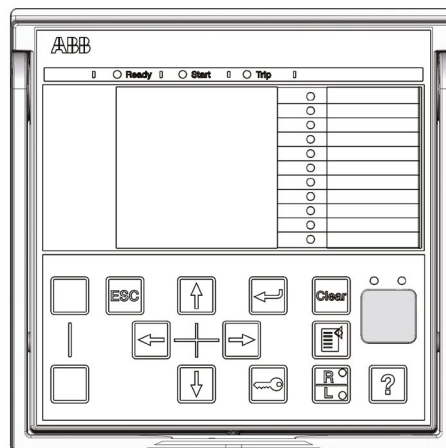
The local HMI includes a push button (L/R) for local/remote operation of the relay. When the relay is in the local mode, it can be operated only by using the local front panel user interface. When the relay is in the remote mode, it can execute commands sent from a remote location. The relay supports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

Table 114. Large display

Character size ⁽¹⁾	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

1) Depending on the selected language

Figure 18. Large display



22. 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.

Mounting methods

- Flush mounting
- Semi-flush mounting
- Semi-flush mounting in a 25° tilt
- Rack mounting
- Wall mounting
- Mounting to a 19" equipment frame

Panel cut-out for flush mounting

- Height: 161.5 ±1 mm
- Width: 165.5 ±1 mm

Figure 19. Flush mounting

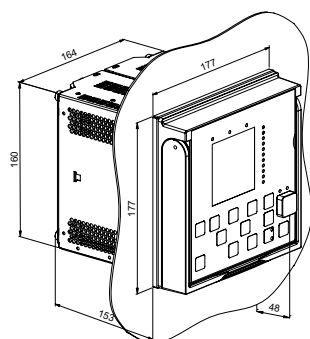


Figure 20. Semi-flush mounting

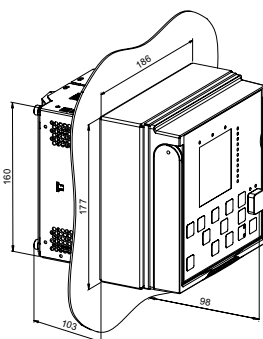
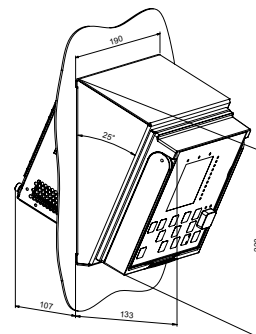


Figure 21. Semi-flush mounting in a 25° tilt



23. 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.

24. 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.

A link to the tool can be found [here](#).

25. Accessories and ordering data

Table 115. Cables

Item	Order number
Optical sensor for arc protection, cable length 1.5 m	1MRS120534-1.5
Optical sensor for arc protection, cable length 3.0 m	1MRS120534-3
Optical sensor for arc protection, cable length 5.0 m	1MRS120534-5
Optical sensor for arc protection, cable length 7.0 m	1MRS120534-7
Optical sensor for arc protection, cable length 10.0 m	1MRS120534-10
Optical sensor for arc protection, cable length 15.0 m	1MRS120534-15
Optical sensor for arc protection, cable length 20.0 m	1MRS120534-20
Optical sensor for arc protection, cable length 25.0 m	1MRS120534-25
Optical sensor for arc protection, cable length 30.0 m	1MRS120534-30

Table 116. 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

1) Cannot be used when the protection relay is mounted with the Combiflex 19" equipment frame (2RCA032826A0001)

26. 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 117. Tools

Description	Version
PCM600	2.8 or later
Web browser	IE 10.0 or IE 11.0
REF615 Connectivity Package	5.1 or later

Table 118. 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)	-	•
Saving of relay parameter settings in the tool	-	•
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

27. 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.

28. Terminal diagrams

Figure 22. Terminal diagram of standard configuration D

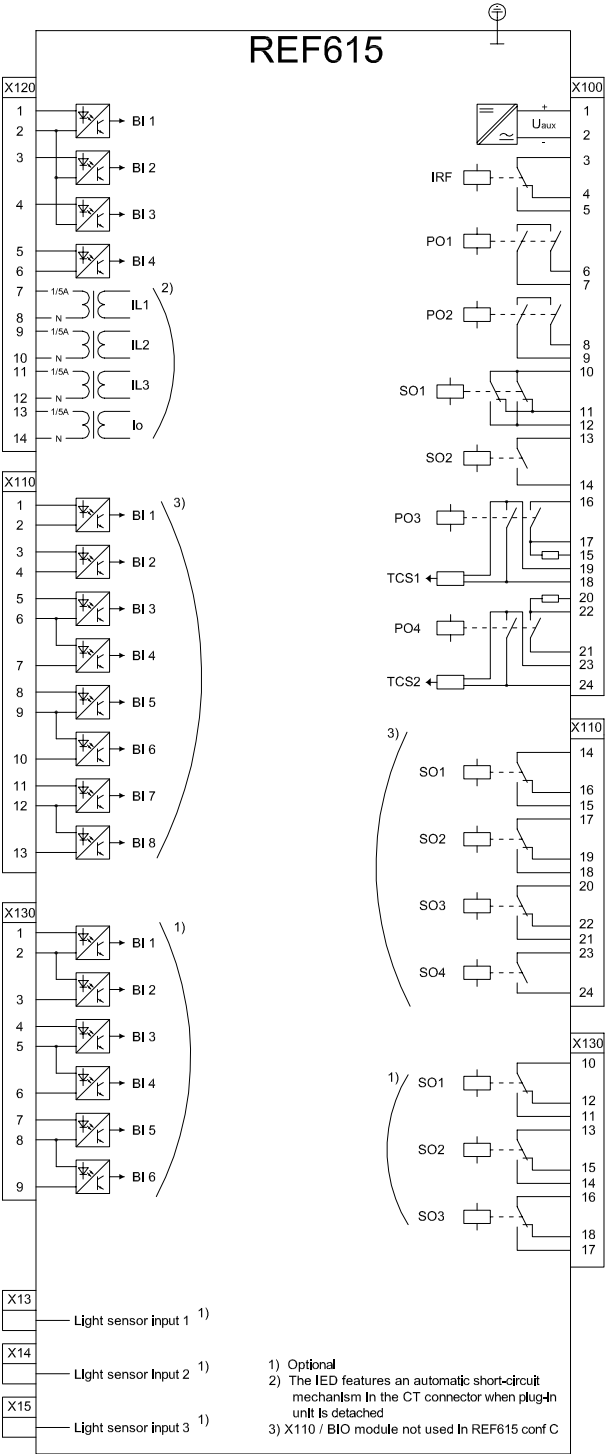


Figure 23. Terminal diagram of standard configuration F

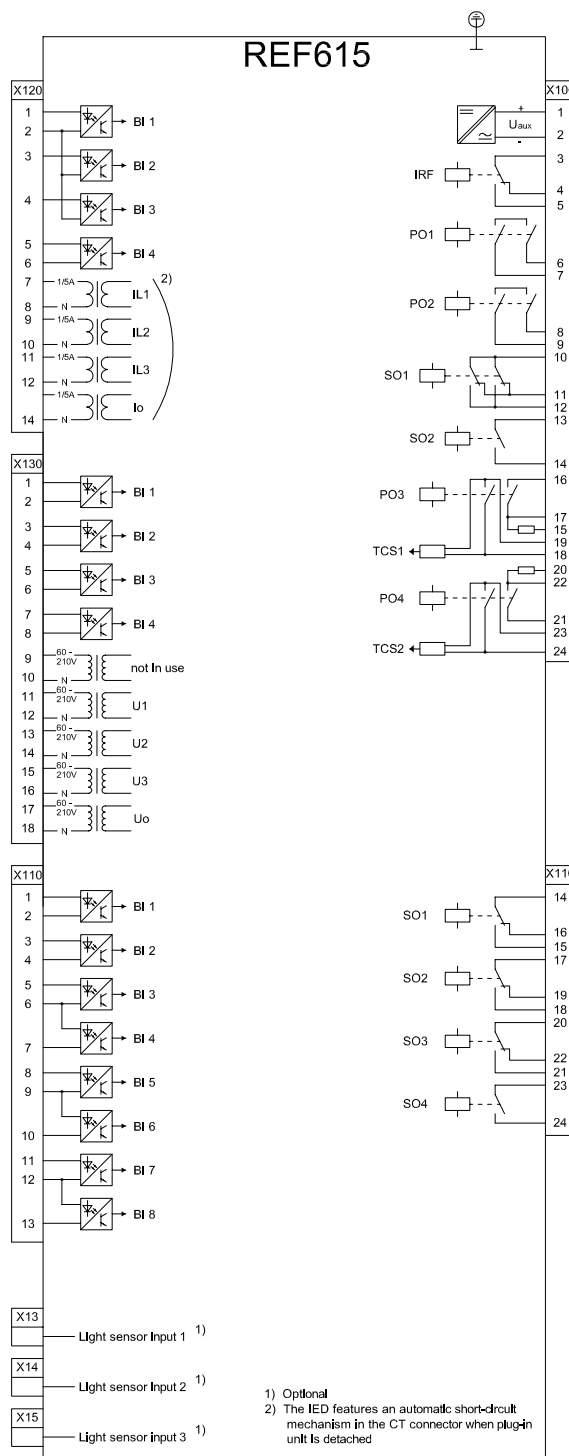


Figure 24. Terminal diagram of standard configuration L

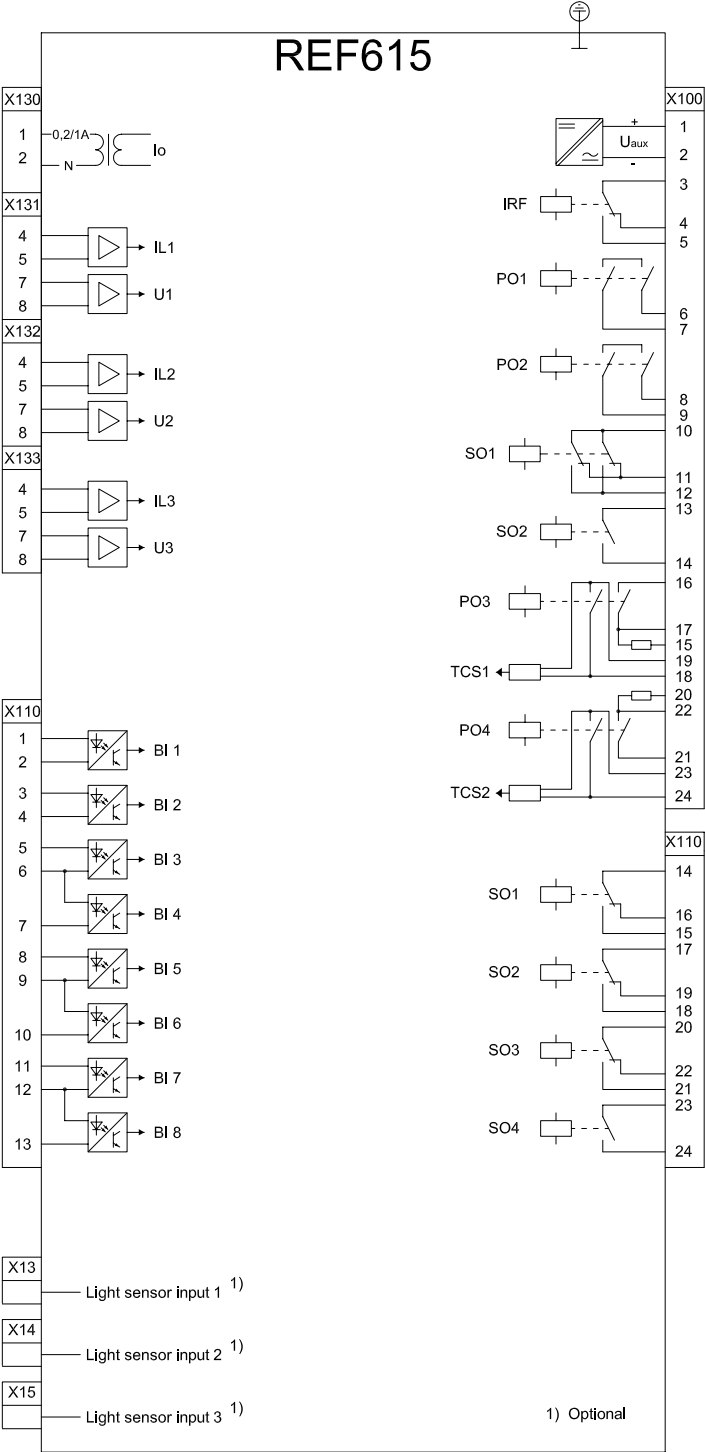


Figure 25. Terminal diagram of standard configuration N

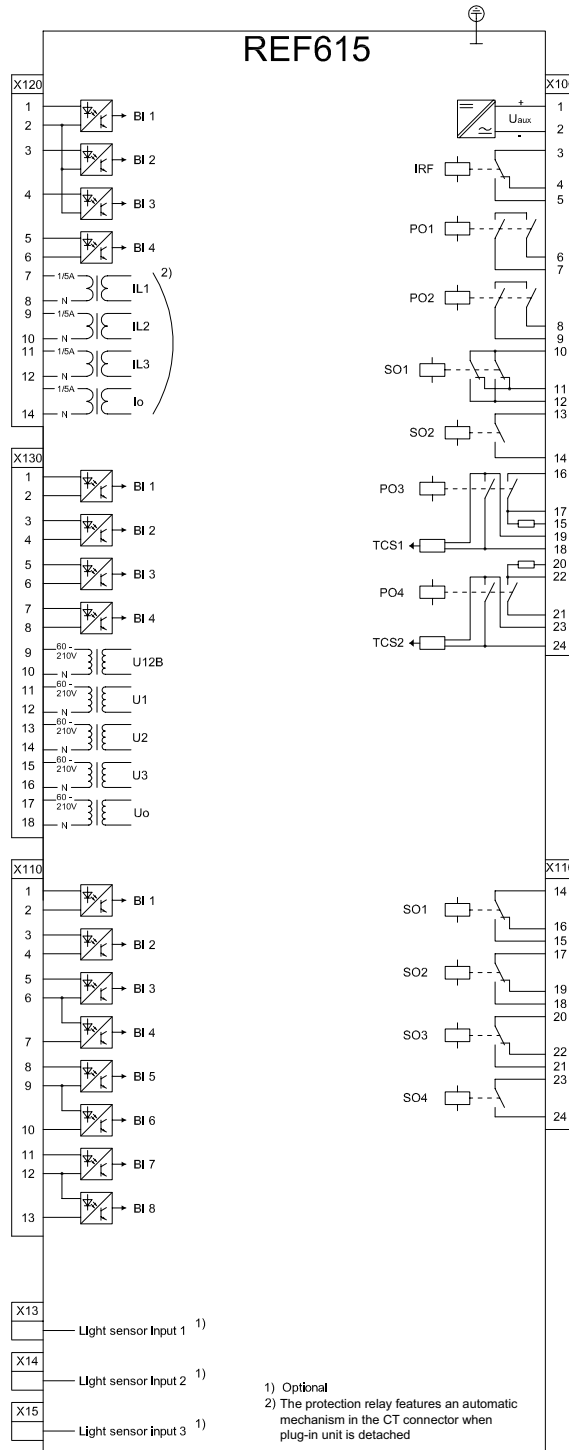
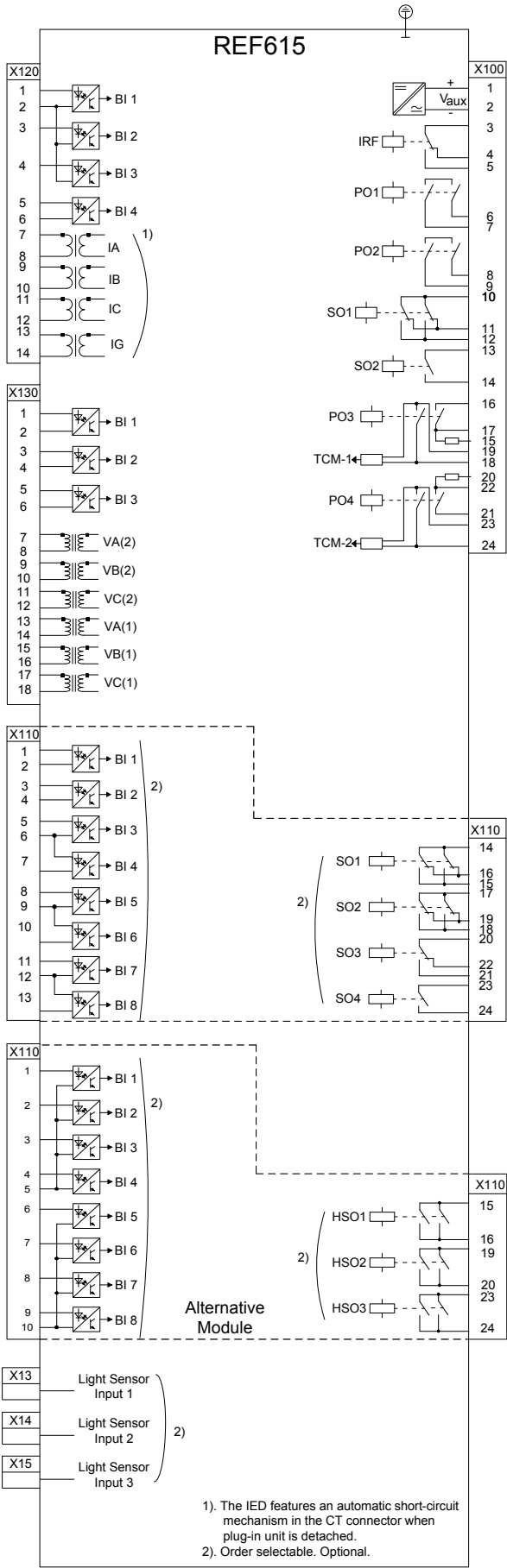


Figure 26. Terminal diagram of standard configuration P



29. Certificates

DNV GL has issued an IEC 61850 Edition 2 Certificate Level A1 for Relion® 615 series. Certificate number: 74105701-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.

Additional certificates can be found on the product page.

30. Inspection reports

KEMA has issued an Inspection report for REF615, “Comparison between hardwired and GOOSE performance of UniGear switchgear panels with REF615 and REF630 Feeder Protection and Control IEDs based on IEC 62271-3”. Report number: 70972064-TDT 09-1398. The Inspection report concludes in its summary, apart from the performance comparisons, that “both the REF630 and REF615 comply to the performance class P1 message type 1A “Trip” for distribution bays (transfer time <10 msec) as defined in IEC 61850-5”.

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 REF615 protection and control relay is found on the product page. Scroll down the page to find and download the related documentation.

32. Functions, codes and symbols

Table 119. Functions included in the relay

Function	IEC 61850	ANSI
Protection		
Three-phase non-directional overcurrent protection, low stage	PHLPTOC1	51P-1 (1)
	PHLPTOC2	51P-1 (2)
Three-phase non-directional overcurrent protection, high stage	PHHPTOC1	51P-2 (1)
	PHHPTOC2	51P-2 (2)
Three-phase non-directional overcurrent protection, instantaneous stage	PHIPTOC1	50P/51P (1)
Three-phase directional overcurrent protection, low stage	DPHLPDOC1	67-1 (1)
	DPHLPDOC2	67-1 (2)
Three-phase directional overcurrent protection, high stage	DPHHPDOC1	67-2 (1)
Non-directional earth-fault protection, low stage	EFLPTOC1	51N-1 (1)
	EFLPTOC2	51N-1 (2)
Non-directional earth-fault protection, high stage	EFHPTOC1	51N-2 (1)
Non-directional earth-fault protection, instantaneous stage	EFIPTOC1	50N/51N (1)
Directional earth-fault protection, low stage	DEFLPDEF1	67N-1 (1)
	DEFLPDEF2	67N-1 (2)
Directional earth-fault protection, high stage	DEFHPDEF1	67N-2 (1)
Admittance-based earth-fault protection	EFPADM1	21YN (1)
	EFPADM2	21YN (2)
	EFPADM3	21YN (3)
Wattmetric-based earth-fault protection	WPWDE1	32N (1)
	WPWDE2	32N (2)
	WPWDE3	32N (3)
Transient/intermittent earth-fault protection	INTRPTEF1	67NIEF (1)
Harmonics-based earth-fault protection	HAEFPTOC1	51NHA (1)
Non-directional (cross-country) earth-fault protection, using calculated I_0	EFHPTOC1	51N-2 (1)
Negative-sequence overcurrent protection	NSPTOC1	46 (1)
	NSPTOC2	46 (2)
Phase discontinuity protection	PDNSPTOC1	46PD (1)
Residual overvoltage protection	ROVPTOV1	59G (1)
	ROVPTOV2	59G (2)
	ROVPTOV3	59G (3)
Three-phase undervoltage protection	PHPTUV1	27 (1)
	PHPTUV2	27 (2)
	PHPTUV3	27 (3)
Three-phase overvoltage protection	PHPTOV1	59 (1)
	PHPTOV2	59 (2)
	PHPTOV3	59 (3)
Positive-sequence undervoltage protection	PSPTUV1	47U+ (1)
	PSPTUV2	47U+ (2)
Negative-sequence overvoltage protection	NSPTOV1	47O- (1)
	NSPTOV2	47O- (2)

Table 119. Functions included in the relay (continued)

Function	IEC 61850	ANSI
Frequency protection	FRPFRQ1	81 (1)
	FRPFRQ2	81 (2)
	FRPFRQ3	81 (3)
	FRPFRQ4	81 (4)
	FRPFRQ5	81 (5)
	FRPFRQ6	81 (6)
Three-phase thermal protection for feeders, cables and distribution transformers	T1PTTR1	49F (1)
High-impedance based restricted earth-fault protection	HREFPDIF1	87NH (1)
High-impedance differential protection for phase A	HIAPDIF1	87A(1)
High-impedance differential protection for phase B	HIBPDIF1	87B(1)
High-impedance differential protection for phase C	HICPDIF1	87C(1)
Circuit breaker failure protection	CCBRBRF1	51BF/51NBF (1)
Three-phase inrush detector	INRPHAR1	68 (1)
Switch onto fault	CBPSOF1	SOTF (1)
Master trip	TRPPTRC1	94/86 (1)
	TRPPTRC2	94/86 (2)
	TRPPTRC3	94/86 (3)
	TRPPTRC4	94/86 (4)
	TRPPTRC5	94/86 (5)
Arc protection	ARCSARC1	50L/50NL (1)
	ARCSARC2	50L/50NL (2)
	ARCSARC3	50L/50NL (3)
Multipurpose protection	MAPGAPC1	MAP (1)
	MAPGAPC2	MAP (2)
	MAPGAPC3	MAP (3)
	MAPGAPC4	MAP (4)
	MAPGAPC5	MAP (5)
	MAPGAPC6	MAP (6)
	MAPGAPC7	MAP (7)
	MAPGAPC8	MAP (8)
	MAPGAPC9	MAP (9)
	MAPGAPC10	MAP (10)
	MAPGAPC11	MAP (11)
	MAPGAPC12	MAP (12)
	MAPGAPC13	MAP (13)
	MAPGAPC14	MAP (14)
	MAPGAPC15	MAP (15)
	MAPGAPC16	MAP (16)
	MAPGAPC17	MAP (17)
	MAPGAPC18	MAP (18)
Fault locator	SCEFRFLO1	21FL (1)
High-impedance fault detection	PHIZ1	HIZ (1)
Reverse power/directional overpower protection	DOPDPDR1	32R/32O (1)
	DOPDPDR2	32R/32O (2)
Multifrequency admittance-based earth-fault protection	MFADPSDE1	67YN (1)

Table 119. Functions included in the relay (continued)

Function	IEC 61850	ANSI
Interconnection functions		
Directional reactive power undervoltage protection	DQPTUV1	32Q,27 (1)
	LVRTPTUV1	27RT (1)
Low-voltage ride-through protection	LVRTPTUV2	27RT (2)
	LVRTPTUV3	27RT (3)
Voltage vector shift protection	VVSPAM1	78V (1)
Power quality		
Current total demand distortion	CMHAI1	PQM3I (1)
Voltage total harmonic distortion	VMHAI1	PQM3V (1)
Voltage variation	PHQVVR1	PQMV (1)
Voltage unbalance	VSQVUB1	PQVUB (1)
Control		
Circuit-breaker control	CBXCBR1	I <-> O CB (1)
Disconnecter control	DCXSWI1	I <-> O DCC (1)
	DCXSWI2	I <-> O DCC (2)
Earthing switch control	ESXSWI1	I <-> O ESC (1)
	DCSXSWI1	I <-> O DC (1)
Disconnecter position indication	DCSXSWI2	I <-> O DC (2)
	DCSXSWI3	I <-> O DC (3)
Earthing switch indication	ESSXSWI1	I <-> O ES (1)
	ESSXSWI2	I <-> O ES (2)
Autoreclosing	DARREC1	79 (1)
Synchronism and energizing check	SECRSYN1	25 (1)
Condition monitoring and supervision		
Circuit-breaker condition monitoring	SSCBR1	CBCM (1)
Trip circuit supervision	TCSSCBR1	TCM (1)
	TCSSCBR2	TCM (2)
Current circuit supervision	CCSPVC1	MCS 3I (1)
Current transformer supervision for high-impedance protection scheme for phase A	HZCCASPVC1	MCS I_A(1)
Current transformer supervision for high-impedance protection scheme for phase B	HZCCBSPVC1	MCS I_B(1)
Current transformer supervision for high-impedance protection scheme for phase C	HZCCCSPVC1	MCS I_C(1)
Fuse failure supervision	SEQSPVC1	60 (1)
Runtime counter for machines and devices	MDSOPT1	OPTM (1)
Measurement		
Disturbance recorder	RDRE1	DFR (1)
Load profile record	LDPRLRC1	LOADPROF (1)
Fault record	FLTRFRC1	FAULTREC (1)
Three-phase current measurement	CMMXU1	3I (1)
Sequence current measurement	CSMSQI1	I1, I2, I0 (1)
Residual current measurement	RESCMMXU1	In (1)
	RESCMMXU2	In (2)
Three-phase voltage measurement	VMMXU1	3V (1)
	VMMXU2	3V (2)
Residual voltage measurement	RESVMMXU1	Vn (1)
Sequence voltage measurement	VSMSQI1	V1, V2, V0 (1)
Three-phase power and energy measurement	PEMMXU1	P, E (1)
RTD/mA measurement	XRGGIO130	X130 (RTD) (1)
Frequency measurement	FMMXU1	f (1)
IEC 61850-9-2 LE sampled value sending	SMVSENDER	SMVSENDER

Function	IEC 61850	ANSI
Measurement		
IEC 61850-9-2 LE sampled value receiving (voltage sharing)	SMVRCV	SMVRCV
Other		
Minimum pulse timer (2 pcs)	TPGAPC1	TP (1)
	TPGAPC2	TP (2)
	TPGAPC3	TP (3)
	TPGAPC4	TP (4)
Minimum pulse timer (2 pcs, second resolution)	TPSGAPC1	TPS (1)
Minimum pulse timer (2 pcs, minute resolution)	TPMGAPC1	TPM (1)
Pulse timer (8 pcs)	PTGAPC1	PT (1)
	PTGAPC2	PT (2)
Time delay off (8 pcs)	TOFGAPC1	TOF (1)
	TOFGAPC2	TOF (2)
	TOFGAPC3	TOF (3)
	TOFGAPC4	TOF (4)
Time delay on (8 pcs)	TONGAPC1	TON (1)
	TONGAPC2	TON (2)
	TONGAPC3	TON (3)
	TONGAPC4	TON (4)
Set-reset (8 pcs)	SRGAPC1	SR (1)
	SRGAPC2	SR (2)
	SRGAPC3	SR (3)
	SRGAPC4	SR (4)
Move (8 pcs)	MVGAPC1	MV (1)
	MVGAPC2	MV (2)
Generic control point (16 pcs)	SPCGAPC1	SPC (1)
	SPCGAPC2	SPC (2)
Analog value scaling	SCA4GAPC1	SCA4 (1)
	SCA4GAPC2	SCA4 (2)
	SCA4GAPC3	SCA4 (3)
	SCA4GAPC4	SCA4 (4)
Integer value move	MVI4GAPC1	MVI4 (1)

33. Document revision history

Table 120. Functions included in the relay

Document revision/date	Product version	History
A/Aug. 2017	5.0 FP1	First release



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