S24/Fr & S24/G (V2) configuration description

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CONTENTS

S24 RELAY OVERVIEW

The **S24/Fr** and **S24/G** series is member of the ***Smartline*** product line. The ***Smartline*** type complex protection in respect of hardware and software is a modular device. The modules are assembled and configured according to the requirements, and then the software determines the functions. The SMARTLINE S24 series is contain a special selection of the PROTECTA modules, bearing in mind the cost effective realization.

The S24 support a range of communication protocols including the IEC 61850 substation automation standard with horizontal GOOSE communication, IEC 60870-5-101, IEC 60870-5-103 and Modbus® RTU. The SMARTLINE S24 is available in six predefined standard configurations to suit the most common feeder protection and control applications.

The relay is provided with a built-in digital disturbance recorder for up to eight analog signal channels and 32 digital signal channels. The recordings are stored in a non-volatile memory from which data can be uploaded for subsequent fault analysis.

To provide network control and monitoring systems with feeder level event logs, the relay incorporates a non-volatile memory with capacity of storing 1000 event codes including time stamps. The non-volatile memory retains its data also in case the relay temporarily loses its auxiliary supply. The event log facilitates detailed pre- and post-fault analyses of feeder faults and distribution disturbances.

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.

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 will be used for alerting the operator. When a permanent relay fault is detected the protection functions of the relay will be completely blocked to prevent any incorrect relay operation.

CONFIGURATION DESCRIPTION

S24/Fr and S24/G, it is included with the voltage-based functions.

- Especially for those applications where small generators are connected to the network / smart grids.
- Additionally it can be extended with restricted earth fault protection function for simple protection of small transformer.

This chapter describes the specific application of the S24/Fr and S24/G factory configuration.

Protection functions

The **S24/Fr or /G** configuration measures three phase currents, the zero sequence current component and additionally three phase voltages. These measurements allow, in addition to the current- and voltage-based functions, directionality extension of the configured phase and residual overcurrent function. It is intended to protect overhead line or cable networks. The choice of the functions is extended with the automatic reclosing function. The configuration is designed to meet the requirements of a medium voltage field unit.
Based on the voltage measurement also the frequency is evaluated to realize frequency-based protection functions.

The restricted earth fault protection function can be selected optionally for small transformer protection.
The configured protection functions are listed in the Table below.

Protection functions	IEC	ANSI	S24/Fr
Three-phase instantaneous overcurrent protection	I >>>	50	X
Three-phase time overcurrent protection	I >, I >>	51	X
Three-phase directional overcurrent protection	I Dir > >, I Dir >>	67	X
Residual instantaneous overcurrent protection	Io >>>	50N	X
Residual time overcurrent protection	Io >, Io >>	51N	X
Residual directional overcurrent protection	Io Dir > >, Io Dir >>	67N	X
Voltage dependent overcurrent protection	I> U<	51V	X
Negative sequence overcurrent protection	I_2 >	46	X
Inrush detection	I2h >	68	X
Thermal protection	T >	49	X
Definite time overvoltage protection	U >, U >>	59	X
Definite time undervoltage protection	U <, U <<	27	X
Residual overvoltage protection	Uo >, Uo >>	59N	X
Negative sequence overvoltage protection	U_2 >	47	X
Overfrequency protection	f >, f >>	81O	X
Underfrequency protection	f <, f <<	81U	X
Rate of change of frequency protection	df/dt	81R	X
Vector jump protection		78	X
Auto-reclose	0 - > 1	79	X
Breaker failure protection	CBFP	50BF	X
Current unbalance protection		60	X
Restricted earth fault	REF	87N	op.
Loss of excitation		40	S24/G only

Table 1 The protection functions of the S24/Fr or /G configuration

The configured functions are drawn symbolically in the Figure below.

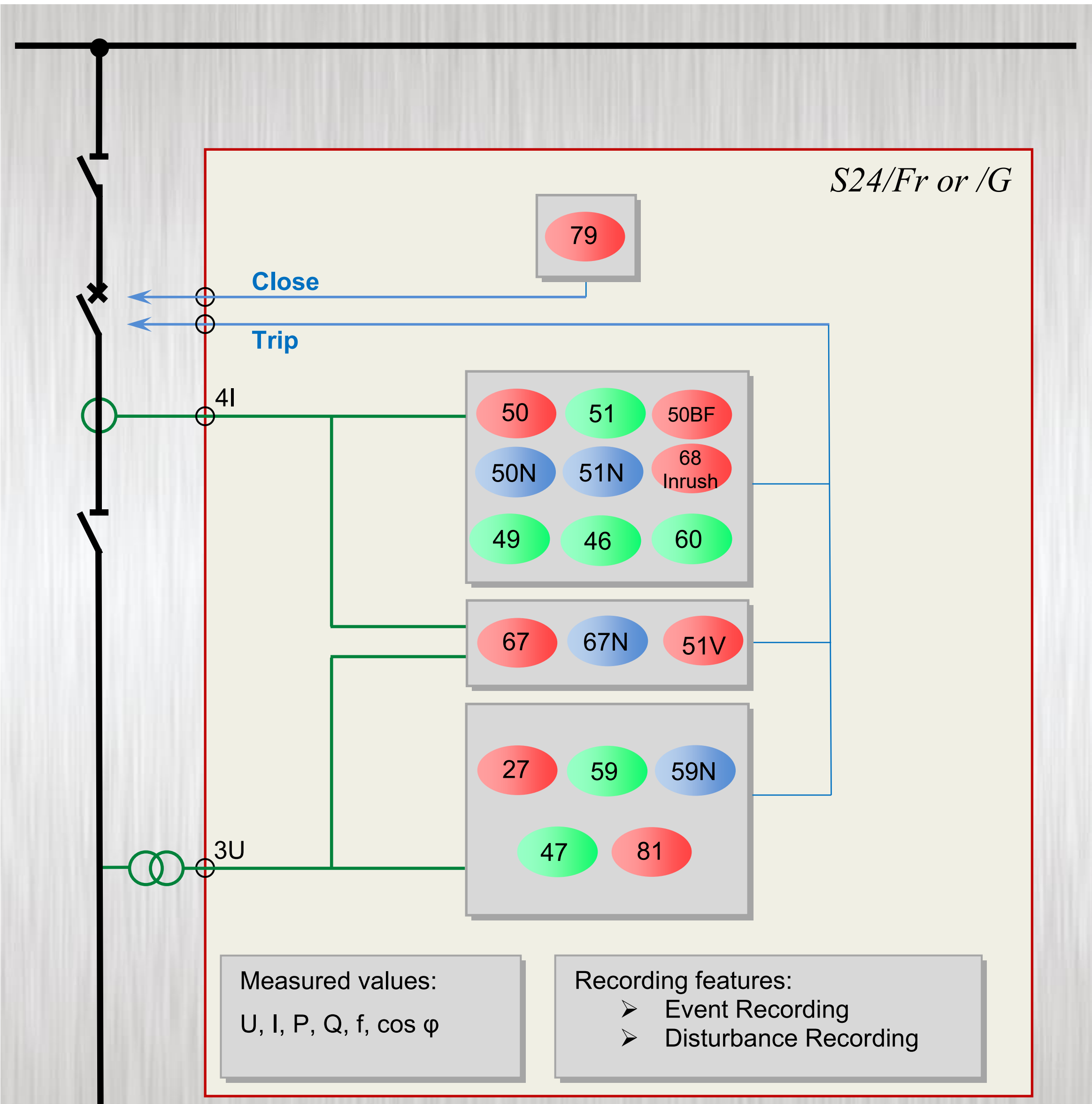


Figure 1 Implemented protection functions

Measurement functions

Based on the hardware inputs the measurements listed in Table below are available.

Measurement functions	S24/Fr or /G
Current (I1, I2, I3, Io)	X
Voltage (U1, U2, U3) and frequency	X
Power (P, Q, S, pf)	X
Circuit breaker wear	X
Supervised trip contacts (TCS)	X

Table 2 The measurement functions of the S24/Fr or /G configuration

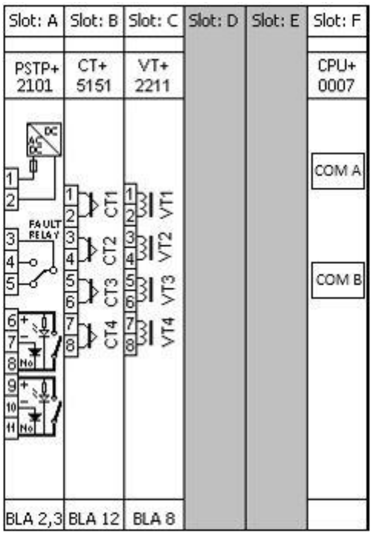
The minimum number of inputs and outputs are listed in the Table below.

Hardware configuration	**S24/Fr or /G**
Housing	Panel instrument enclosure (24 HP size)
Current inputs (4th channel can be sensitive)	4 (3x 1/5 A and 1x 1/5/0,2A)
Voltage inputs	4
Digital inputs	6*
Digital outputs	5*
Fast trip outputs	2 (4 A)
IRF contact	1

* as standard I/O card hardware configuration.

Table 3 The basic hardware configuration of the S24/Fr or /G configuration

The module arrangement of the S24/Fr or /G configuration is shown below.



I/O card options for S24/Fr or /G:

IO card type	Slot D	Slot E
O6R5	Standard	N/A
O12	Option	Option
O8	Option	Option
R8	Option	Option

Figure 2 Module arrangement of the S24/Fr or /G configuration (rear view)

Communication options for S24/Fr or /G:

Communication ports	No communication	Legacy protocols	IEC 61850	Redundant Ethernet
COM A	Standard	N/A	N/A	Option
COM B	Standard	Option	Option	N/A

The applied hardware modules

The applied modules are listed in Table 4.
The technical specification of the device and that of the modules are described in the document "***Hardware description***".

Module identifier	Explanation
PSTP+ xx01	Power supply unit with trip contacts
O6R5+ xx01	Binary I/O module
O12+ xx01	Binary input module
O8+ xx01	Binary input module
R8+ 00	Signal relay output module
CT+ 5151	Analog current input module
VT+ 2211	Analog voltage input module
CPU+ xxxx	Processing and communication module

Table 4 The applied modules of the S24/Fr or /G configuration

Meeting the device

The basic information for working with the ***SMARTLINE*** devices are described in the document "***Quick start guide to the devices of the PROTECTA product line***".

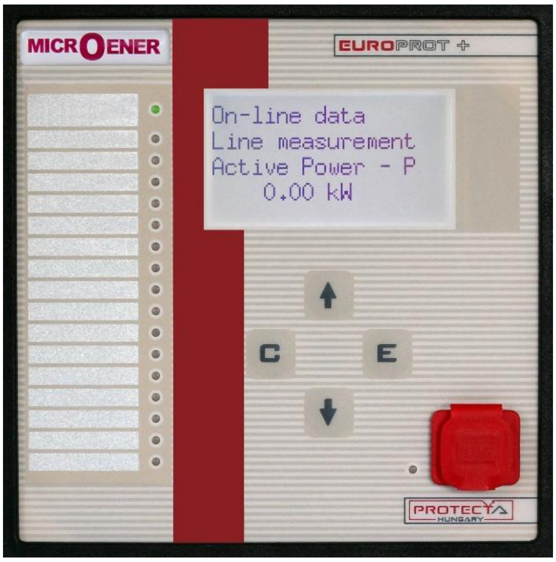


Figure 3 SMARTLINE S24 with B&W HMI front panel ***as standard***

Figure 4 SMARTLINE S24 with true colour HMI front panel ***as optional***

Protection and control functions

The implemented protection and control functions are listed in
* The true color HMI is required to use the control functions
** optional
Table 5. The function blocks are described in details in separate documents. These are referred to also in this table.

The range of the parameter settings of the following function blocks can be modified, if it doesn't correspond to the costumer's request. In this case please, contact to the developer team on the Microener Support Site: https://www.microener.com

Name	Title	Document
IOC50	3ph Instant.OC	***Three-phase instantaneous overcurrent protection function block description***
TOC51_low TOC51_high	3ph Overcurr	***Three-phase overcurrent protection function block description***
TOC67_low TOC67_high	3ph Dir.Overcurr	***Directional three-phase overcurrent protection function block description***
IOC50N	Residual Instant.OC	***Residual instantaneous overcurrent protection function block description***
TOC51N_low TOC51N_high	Residual TOC	***Residual overcurrent protection function block description***
TOC67N_low TOC67N_high	Dir.Residual TOC	***Directional residual overcurrent protection function block description***
VOC51_low VOC51_high	VoltRestr OC	**Voltage dependent overcurrent protection**
TOC46	Neg. Seq. OC	***Negative sequence overcurrent protection function block description***
TTR49L	Thermal overload	***Line thermal protection function block description***
TOV59_high TOV59_low	Overvoltage	***Definite time overvoltage protection function block description***
TUV27_high TUV27_low	Undervoltage	***Definite time undervoltage protection function block description***
TOV59N_high TOV59N_low	Res. Overvoltage	***Residual definite time overvoltage protection function block description***
VectJmp	Vector Jump	
TOF81_high TOF81_low	Overfrequency	***Overfrequency protection function block description***
TUF81_high TUF81_low	Underfrequency	***Underfrequency protection function block description***
FRC81	ROC of frequency	***Rate of change of frequency protection function block description***
** DIF87N	Restricted EF	***Restricted Earth Fault protection function block description***
REC79MV	MV autoreclosing	***Automatic reclosing function for medium voltage networks, function block description***
VCB60	Current Unbalance	***Current unbalance function block description***
TRC94	Trip Logic	***Trip logic function block description***
BRF50MV	Breaker failure	***Breaker failure protection for not solidly***

		grounded networks function block description
CT4		***Current input function block description***
VT4		***Voltage input function block description***
CB1Pol*		***Circuit breaker control function block descrpition***
DisConn*		***Disconnector control function block descrpition***
MXU		***Line measurement function block description***
UEX_40Z	Loss of excitation	***Loss of excitation function block description***

* The true color HMI is required to use the control functions
** optional

Table 5 Implemented protection and control functions

Three-phase instantaneous overcurrent protection function (IOC50)

The three-phase instantaneous overcurrent protection function (IOC50) operates immediately if the phase currents are higher than the setting value.

The setting value is a parameter, and it can be doubled by graphic programming of the dedicated input binary signal defined by the user.

The function is based on peak value selection or on the RMS values of the Fourier basic harmonic calculation, according to the parameter setting. The fundamental Fourier components are results of an external function block.

Parameter for type selection has selection range of Off, Peak value and Fundamental value. When Fourier calculation is selected then the accuracy of the operation is high, the operation time however is above one period of the network frequency. If the operation is based on peak values then fast sub-cycle operation can be expected, but the transient overreach can be high.

The function generates trip commands without additional time delay if the detected values are above the current setting value.

The function generates trip commands for the three phases individually and a general trip command as well.

The instantaneous overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function		Accuracy
Using peak value calculation		
Operating characteristic	Instantaneous	<6%
Reset ratio	0.85	
Operate time at 2*I_S	<15 ms	
Reset time *	< 40 ms	
Transient overreach	90 %	
Using Fourier basic harmonic calculation		
Operating characteristic	Instantaneous	<2%
Reset ratio	0.85	
Operate time at 2* I_S	<25 ms	
Reset time *	< 60 ms	
Transient overreach	15 %	

**Measured with signal contacts*

Table 6 Technical data of of the instantaneous overcurrent protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
IOC50_Oper_EPar_	Operation	Off, Peak value, Fundamental value	Peak value

Table 7 The enumerated parameter of the instantaneous overcurrent protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current parameter:						
IOC50_StCurr_IPar_	Start Current	%	20	3000	1	200

Table 8 The integer parameter of the instantaneous overcurrent protection function

Three-phase time overcurrent protection function (TOC51)

The overcurrent protection function realizes definite time or inverse time characteristics according to IEC or IEEE standards, based on three phase currents. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08. This function can be applied as main protection for medium-voltage applications or backup or overload protection for high-voltage network elements.

The definite (independent) time characteristic has a fixed time delay when the current is above the starting current I_s previously set as a parameter.

The standard operating characteristics of the inverse time overcurrent protection function are defined by the following formula:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_S$$

where

t(G)(seconds)	theoretical operate time with constant value of G,
k, c	constants characterizing the selected curve (in seconds),
α	constants characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the phase currents (IL1Four, IL2Four, IL3Four),
G_S	preset value of the characteristic quantity (Start current),
TMS	preset time multiplier (no dimension).

	IEC ref	Title	k_r	c	α
1	A	IEC Inv	0,14	0	0,02
2	B	IEC VeryInv	13,5	0	1
3	C	IEC ExtInv	80	0	2
4		IEC LongInv	120	0	1
5		ANSI Inv	0,0086	0,0185	0,02
6	D	ANSI ModInv	0,0515	0,1140	0,02
7	E	ANSI VeryInv	19,61	0,491	2
8	F	ANSI ExtInv	28,2	0,1217	2
9		ANSI LongInv	0,086	0,185	0,02
10		ANSI LongVeryInv	28,55	0,712	2
11		ANSI LongExtInv	64,07	0,250	2

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_S$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G_D}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_D = 20 * G_S$$

Additionally a minimum time delay can be defined by a dedicated parameter. This delay is valid if it is longer than t(G), defined by the formula above.

Resetting characteristics:

- for IEC type characteristics the resetting is after a fix time delay defined by TOC51_Reset_TPar_ (Reset delay),
- for ANSI types however according to the formula below:

$$t_r(G) = TMS\left[\frac{k_r}{1-\left(\frac{G}{G_S}\right)^{\alpha}}\right] \text{ when } G < G_S$$

where

$t_r(G)$(seconds)	theoretical reset time with constant value of G,
k_r	constants characterizing the selected curve (in seconds),
α	constants characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the phase currents,
G_S	preset value of the characteristic quantity (Start current),
TMS	preset time multiplier (no dimension).

	IEC ref	Title	k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter TOC51_Reset_TPar_ “Reset delay”	
2	B	IEC VeryInv		
3	C	IEC ExtInv		
4		IEC LongInv		
5		ANSI Inv	0,46	2
6	D	ANSI ModInv	4,85	2
7	E	ANSI VeryInv	21,6	2
8	F	ANSI ExtInv	29,1	2
9		ANSI LongInv	4,6	2
10		ANSI LongVeryInv	13,46	2
11		ANSI LongExtInv	30	2

The binary output status signals of the three-phase overcurrent protection function are starting signals of the three phases individually, a general starting signal and a general trip command.

The overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Operating accuracy	20 ≤ G_S ≤ 1000	< 2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time char. Definite time char.	 Approx 60 ms	< 2% or ±35 ms, whichever is greater
Transient overreach		< 2 %
Pickup time *	< 40 ms	
Overshot time Dependent time char. Definite time char.	 30 ms 50 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* Measured with signal relay contact

Table 9 Technical data of of the instantaneous overcurrent protection function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Parameter for type selection			
TOC51_Oper_EPar_	Operation	Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	Definit Time

Table 10 The enumerated parameters of the time overcurrent protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current parameter:						
TOC51_StCurr_IPar_	Start Current	%	20	1000	1	200

Table 11 The integer parameter of the time overcurrent protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time multiplier of the inverse characteristics (OC module)						
TOC51_Multip_FPar_	Time Multiplier	sec	0.05	999	0.01	1.0

Table 12 The float point parameter of the time overcurrent protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics:						
TOC51_MinDel_TPar_	Min Time Delay *	msec	0	60000	1	100
Definite time delay:						
TOC51_DefDel_TPar_	Definite Time Delay **	msec	0	60000	1	100
Reset time delay for the inverse characteristics:						
TOC51_Reset_TPar_	Reset Time*	msec	0	60000	1	100

*Valid for inverse type characteristics
**Valid for definite type characteristics only

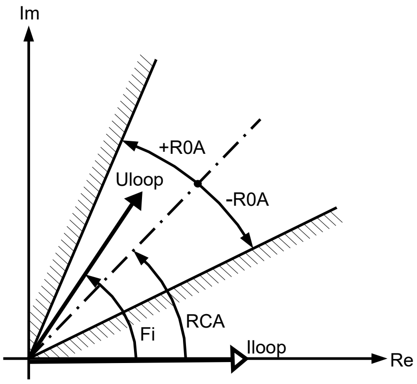
Table 13 The timer parameters of the time overcurrent protection function

Three-phase directional overcurrent protection function (TOC67)

The directional three-phase delayed overcurrent protection function can be applied on solidly grounded networks, where the overcurrent protection must be supplemented with a directional decision.

The inputs of the function are the Fourier basic harmonic components of the three phase currents and those of the three phase voltages and the three line-to-line voltages.

Based on the measured voltages and currents from among the six loops (L1L2, L2L3, L3L1, L1N, L2N, L3N), the function selects the one with the smallest calculated loop impedance. Based on the loop voltage and loop current of the selected loop, the directional decision generates a signal of TRUE value if the voltage and the current is sufficient for directional decision, and the angle difference between the vectors is within the setting range. This decision enables the output start and trip signal of a non-directional three-phase overcurrent protection function block, based on the selected current.



The function can be enabled or disabled by a parameter. The status signal of the VTS (voltage transformer supervision) function can also disable the directional operation.

The voltage must be above 5% of the rated voltage and the current must also be measurable.

If the voltages are below 5% of the rated voltage then the algorithm substitutes the small values with the voltages stored in the memory.

The directional decision module calculates the phase angle between the selected loop voltage and the loop current. The reference signal is the current according to *Figure*.

The three-phase non-directional delayed overcurrent function block (TOC51) is described in a separate document. The additional input binary signal enables the operation of the OC function if the directional decision module generates a logic TRUE value, indicating that the phase angle is in the range defined by the preset parameters or that non-directional operation is set by a parameter.

Technical data

Function	Value	Accuracy
Operating accuracy		< 2 %
Operate time accuracy	If Time multiplier is >0.1	±5% or ±15 ms, whichever is greater
Accuracy in minimum time range		±35 ms
Reset ratio	0,95	
Reset time	Approx 100 ms	
Transient overreach	2 %	
Pickup time	<100 ms	
Memory storage time span 50 Hz 60 Hz	 70 ms 60 ms	
Angular accuracy		<3°

Table 14 Technical data of the three-phase directional overcurrent protection function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Directionality of the function			
TOC67_Dir_EPar_	Direction	NonDir, Forward, Backward	Forward
Operating characteristic selection of the TOC51 module			
TOC67_Oper_EPar_	Operation	Off, DefiniteTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	DefiniteTime

Table 15 The enumerated parameters of the three-phase directional overcurrent protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Operating angle (see *Figure*)						
TOC67_ROA_IPar_	Operating Angle	deg	30	80	1	60
Characteristic angle (see *Figure*)						
TOC67_RCA_IPar_	Characteristic Angle	deg	40	90	1	60
Start current (OC module)						
TOC67_StCurr_IPar_	Start Current	%	20	1000	1	50

Table 16 The integer parameters of the three-phase directional overcurrent protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Digits	Default
Time multiplier of the inverse characteristics (OC module)						
TOC67_Multip_FPar_	Time Multiplier	sec	0.05	999	-2	1.0

Table 17 The float point parameter of the three-phase directional overcurrent protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics (OC module):						
TOC67_MinDel_TPar_	Min. Time	msec	50	60000	1	100
Definite time delay (OC module):						
TOC67_DefDel_TPar_	Definite Time	msec	0	60000	1	100
Reset time delay for the inverse characteristics (OC module):						
TOC67_Reset_TPar_	Reset Time	msec	0	60000	1	100

Table 18 The timer parameters of the three-phase directional overcurrent protection function

Residual instantaneous overcurrent protection function (IOC50N)

The residual instantaneous overcurrent protection function (IOC50N) block operates immediately if the residual current (3Io) is above the setting value. The setting value is a parameter, and it can be doubled by a dedicated binary input signal defined by the user applying the graphic programming.

The function is based on peak value selection or on the RMS values of the Fourier basic harmonic component of the residual current, according to the parameter setting. The fundamental Fourier component calculation is not part of the IOC50N function.

Parameter for type selection has selection range of Off, Peak value and Fundamental value.

The function generates a trip commands without additional time delay if the detected values are above the current setting value.

The residual instantaneous overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function		Accuracy
Using peak value calculation		
Operating characteristic (I>0.1 In)	Instantaneous	<6%
Reset ratio	0.85	
Operate time at 2*Is	<15 ms	
Reset time *	< 35 ms	
Transient overreach	85 %	
Using Fourier basic harmonic calculation		
Operating characteristic (I>0.1 In)	Instantaneous	<3%
Reset ratio	0.85	
Operate time at 2*Is	<25 ms	
Reset time *	< 60 ms	
Transient overreach	15 %	

*Measured with signal contacts

Table 19 Technical data of the residual instantaneous overcurrent protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
IOC50N_Oper_EPar_	Operation	Off, Peak value, Fundamental value	Peak value

Table 20 The enumerated parameter of the residual instantaneous overcurrent protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current parameter:						
IOC50N_StCurr_IPar_	Start Current	%	10	400	1	200

Table 21 The integer parameter of the residual instantaneous overcurrent protection function

Residual overcurrent protection function (TOC51N)

The residual delayed overcurrent protection function can realize definite time or inverse time characteristics according to IEC or IEEE standards, based on the RMS value of the fundamental Fourier component of a single measured current, which can be the measured residual current at the neutral point (3Io) or the calculated zero sequence current component. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

The definite (independent) time characteristic has a fixed time delay when the current is above the starting current I_s previously set as a parameter.

The standard operating characteristics of the inverse time overcurrent protection function are defined by the following formula:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_S$$

where

t(G)(seconds)	theoretical operate time with constant value of G,
k, c	constants characterizing the selected curve (in seconds),
α	constant characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the residual current (INFour),
G_S	preset value of the characteristic quantity (Start current),
TMS	preset time multiplier (no dimension).

	IEC ref		k_r	c	α
1	A	IEC Inv	0,14	0	0,02
2	B	IEC VeryInv	13,5	0	1
3	C	IEC ExtInv	80	0	2
4		IEC LongInv	120	0	1
5		ANSI Inv	0,0086	0,0185	0,02
6	D	ANSI ModInv	0,0515	0,1140	0,02
7	E	ANSI VeryInv	19,61	0,491	2
8	F	ANSI ExtInv	28,2	0,1217	2
9		ANSI LongInv	0,086	0,185	0,02
10		ANSI LongVeryInv	28,55	0,712	2
11		ANSI LongExtInv	64,07	0,250	2

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_S$$

Above this value the theoretical operating time is definite:

$$t(G) = TMS\left[\frac{k}{\left(\frac{G_D}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_D = 20 * G_S$$

Additionally a minimum time delay can be defined by a dedicated parameter (Min. Time Delay). This delay is valid if it is longer than t(G), defined by the formula above.

Resetting characteristics:

- for IEC type characteristics the resetting is after a fix time delay,
- for ANSI types however according to the formula below:

$$t_r(G) = TMS\left[\frac{k_r}{1-\left(\frac{G}{G_S}\right)^{\alpha}}\right] \text{ when } G < G_S$$

where

$t_r(G)$(seconds)	theoretical reset time with constant value of G,
k_r	constants characterizing the selected curve (in seconds),
α	constant characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the residual current,
G_S	preset value of the characteristic quantity (Start current),
TMS	preset time multiplier (no dimension).

	IEC ref		k_r	α
1	A	IEC Inv	Resetting after fix time delay, according to preset parameter TOC51_Reset_TPar_ "Reset delay"	
2	B	IEC VeryInv		
3	C	IEC ExtInv		
4		IEC LongInv		
5		ANSI Inv	0,46	2
6	D	ANSI ModInv	4,85	2
7	E	ANSI VeryInv	21,6	2
8	F	ANSI ExtInv	29,1	2
9		ANSI LongInv	4,6	2
10		ANSI LongVeryInv	13,46	2
11		ANSI LongExtInv	30	2

The binary output status signals of the residual overcurrent protection function are the general starting signal and the general trip command if the time delay determined by the characteristics expired.

The residual overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Operating accuracy *	20 ≤ G_S ≤ 1000	< 3 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time char. Definite time char.	Approx 60 ms	< 2% or ±35 ms, whichever is greater
Transient overreach		2 %
Pickup time	≤ 40 ms	
Overshot time Dependent time char. Definite time char.	30 ms 50 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* Measured in version In = 200 mA

Table 22 The technical data of the residual overcurrent protection function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Parameter for type selection			
TOC51N_Oper_EPar_	Operation	Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	Definite Time

Table 23 The enumerated parameters of the residual overcurrent protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current parameter:						
TOC51N_StCurr_IPar_	Start Current *	%	5	200	1	50
TOC51N_StCurr_IPar_	Start Current **	%	10	1000	1	50

* *In = 1 A or 5 A*
** *In = 200 mA or 1 A*

Table 24 The integer parameter of the residual overcurrent protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time multiplier of the inverse characteristics (OC module)						
TOC51N_Multip_FPar_	Time Multiplier	sec	0.05	999	0.01	1.0

Table 25 The float parameter of the residual overcurrent protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics:						
TOC51N_MinDel_TPar_	Min Time Delay*	msec	0	60000	1	100
Definite time delay:						
TOC51N_DefDel_TPar_	Definite Time Delay**	msec	0	60000	1	100
Reset time delay for the inverse characteristics:						
TOC51N_Reset_TPar_	Reset Time*	msec	0	60000	1	100

*Valid for inverse type characteristics
**Valid for definite type characteristics only

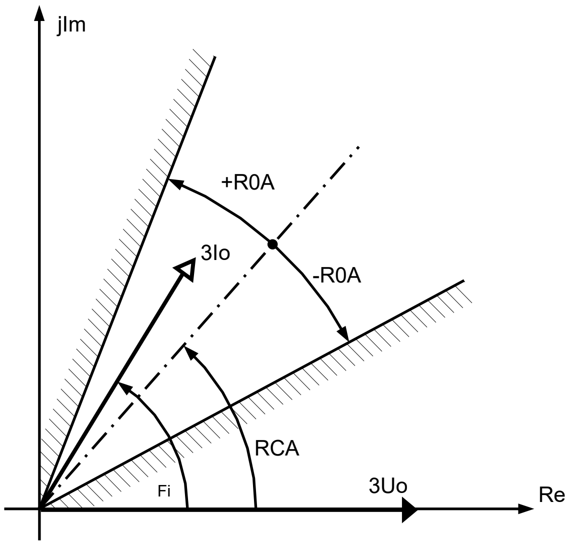
Table 26 The timer parameters of the residual overcurrent protection function

Residual directional overcurrent protection function (TOC67N)

The main application area of the directional residual delayed overcurrent protection function is an earth-fault protection.

The inputs of the function are the RMS value of the Fourier basic harmonic components of the zero sequence current (IN=3Io) and those of the zero sequence voltage (UN=3Uo).

The block of the directional decision generates a signal of TRUE value if the UN=3Uo zero sequence voltage and the IN=3Io zero sequence current are above the limits needed for correct directional decision, and the angle difference between the vectors is within the preset range. The decision enables the output start and trip signal of an overcurrent protection function block (TOC51N). This non-directional residual overcurrent protection function block is described in a separate document.



The directional decision module calculates the phase angle between the residual voltage and the residual current. The reference signal is the residual voltage according to the *Figure.*

The output of the directional decision module is OK, namely it is TRUE if the phase angle between the residual voltage and the residual current is within the limit range defined by the preset parameter OR if non-directional operation is selected by the preset parameter (Direction=NonDir).

Technical data

Function	Value	Accuracy
Operating accuracy		< ±2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Accuracy in minimum time range		±35 ms
Reset ratio	0,95	
Reset time	Approx 50 ms	±35 ms
Transient overreach	<2 %	
Pickup time	25 – 30 ms	
Angular accuracy Io ≤ 0.1 In 0.1 In < Io ≤ 0.4 In 0.4 In < Io		 < ±10° < ±5° < ±2°
Angular reset ratio Forward and backward All other selection	 10° 5°	

Table 27 The technical data of the residual directional overcurrent protection function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Directionality of the function			
TOC67N_Dir_EPar_	Direction	NonDir,Forward-Angle,Backward-Angle,Forward-I*cos(fi),Backward-I*cos(fi),Forward-I*sin(fi),Backward-I*sin(fi),Forward-I*sin(fi+45),Backward-I*sin(fi+45)	Forward-Angle
Operating characteristic selection of the TOC51N module			
TOC67N_Oper_EPar_	Operation	Off,DefiniteTime,IEC Inv,IEC VeryInv,IEC ExtInv,IEC LongInv,ANSI Inv,ANSI ModInv,ANSI VeryInv,ANSI ExtInv,ANSI LongInv,ANSI LongVeryInv,ANSI LongExtInv	DefiniteTime

Table 28 The enumerated parameters of the residual directional overcurrent protection function

Short explanation of the enumerated parameter "Direction"

Selected value	Explanation
NonDir,	Operation according to non-directional TOC51N
Forward-Angle	See *Figure*, set RCA (Characteristic Angle) and ROA (Operating Angle) as required
Backward-Angle	RCAactual=RCAset+180°, set RCA (Characteristic Angle) and ROA (Operating Angle) as required
Forward-I*cos(fi)	RCA=0°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*cos(fi)	RCA=180°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Forward-I*sin(fi)	RCA=90°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*sin(fi)	RCA=–90°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Forward-I*sin(fi+45)	RCA=45°fix, ROA=85°fix, the setting values RCA and ROA are not applied
Backward-I*sin(fi+45)	RCA=–135°fix, ROA=85°fix, the setting values RCA and ROA are not applied

Table 29 The short explanation of the enumerated parameters of the residual directional overcurrent protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
The threshold value for the 3Uo zero sequence voltage, below which no directionality is possible. % of the rated voltage of the voltage transformer input						
TOC67N_UoMin_IPar_	URes Min	%	1	10	1	2
The threshold value for the 3Io zero sequence current, below which no operation is possible. % of the rated current of the current transformer input						
TOC67N_IoMin_IPar_	IRes Min	%	1	50	1	5
Operating angle (See *Figure*)						
TOC67N_ROA_IPar_	Operating Angle	deg	30	80	1	60
Characteristic angle (See *Figure*)						
TOC67N_RCA_IPar_	Characteristic Angle	deg	-180	180	1	60
Start current (TOC51N module)						
TOC67N_StCurr_IPar_	Start Current	%	5	200	1	50

Table 30 The integer parameters of the residual directional overcurrent protection function

Float point parameter

Parameter name	Title	Unit	Min	Step	Step	Default
Time multiplier of the inverse characteristics (TOC51N module)						
TOC67N_Multip_FPar_	Time Multiplier	sec	0.05	999	0.01	1.0

Table 31 The float point parameter of the residual directional overcurrent protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics (TOC 51N module):						
TOC67N_MinDel_TPar_	Min Time Delay	msec	50	60000	1	100
Definite time delay (TOC 51N module):						
TOC67N_DefDel_TPar_	Definite Time Delay	msec	0	60000	1	100
Reset time delay for the inverse characteristics (TOC 51N module):						
TOC67N_Reset_TPar_	Reset Time	msec	0	60000	1	100

Table 32 The timer parameters of the residual directional overcurrent protection function

Voltage dependent overcurrent protection function

When overcurrent protection function is applied and the current in normal operation can be high, related to the lowest fault current then the correct setting is not possible based on current values only. In this case however, if the voltage during fault is considerably below the lowest voltage during operation then the voltage can be applied to distinguish between faulty state and normal operating state. This is the application area of the voltage dependent overcurrent protection function.

The function has two modes of operation, depending on the parameter setting:

- Voltage restrained
- Voltage controlled.

The overcurrent protection function realizes definite time characteristic based on three phase currents. The operation is restrained or controlled by three phase voltages. The function operates in three phases individually, but the generated general start signal and the general trip command is the OR relationship of the three decisions.

The function can be blocked by a user-defined signal or by the voltage transformer supervision function block, if the measured voltage is not available.

This function can be applied as main protection for medium-voltage applications or generator overcurrent protection.

Operating characteristics

Voltage dependent characteristics

The function is basically a definite time overcurrent protection function, but the current threshold is influenced by the measured voltage.

The function has two modes of operation, depending on the parameter setting:

- Voltage restrained (parameter “Restr. Mode” is set to “Restrained”)
- Voltage controlled (parameter “Restr. Mode” is set to “Controlled”).

Voltage restrained characteristics:

In this case the algorithm dynamically changes the threshold value of the current, based on the measured phase voltages:

- Above the “U_Highlimit” value then the function operates if the current is above the “StartCurrent” value.
- If the voltage is below the “U_lowlimit” value then the characteristic is lowered automatically to the “StartCurrent*Ik_limit/100.
- Between the two setting values the threshold value is increasing along a straight line.

The voltage restrained characteristic is shown in Figure 0-5.

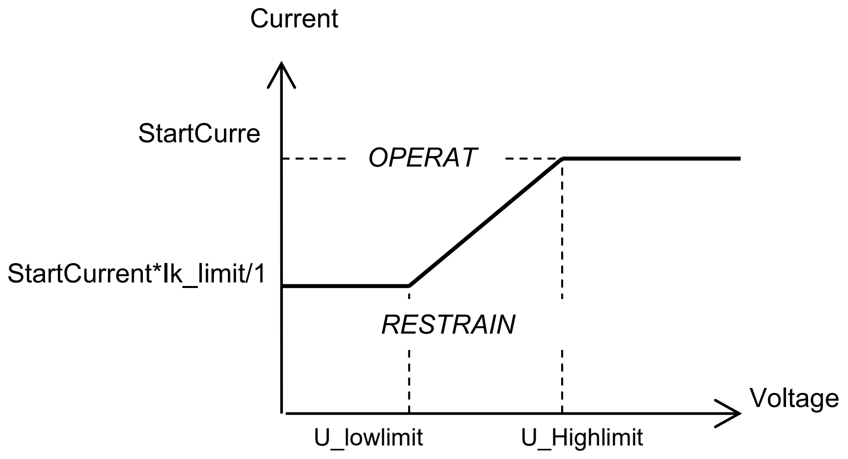


Figure 0-5 Voltage restrained characteristic

<u>Voltage controlled characteristics:</u>

In this case the overcurrent protection operates only if the voltage is below the “U_lowlimit” value and the current is above the “SatrtCurrent” value. (No operation is expected if the voltage is above the U_lowlimit” value.)

The threshold current is the constant “StartCurrent” value. The voltage controlled characteristic is shown in Figure 0-6.

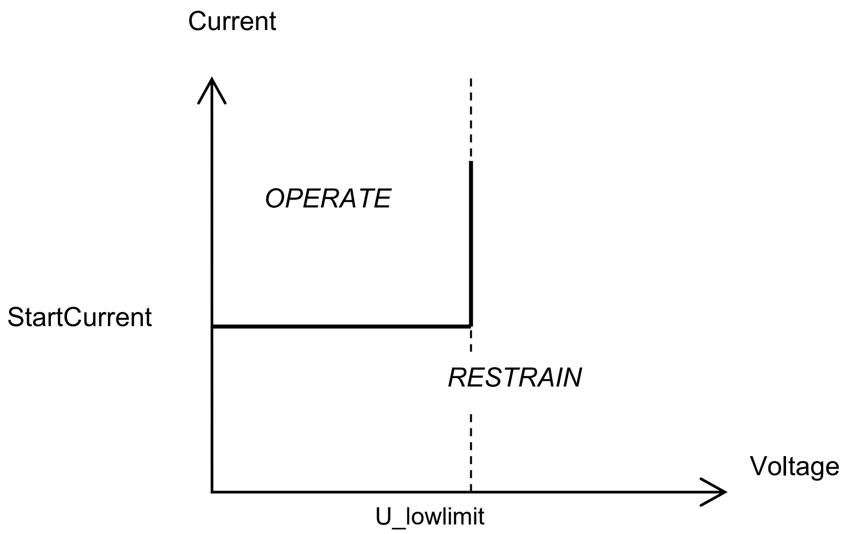


Figure 0-6 Voltage controlled characteristic

Definite time characteristic

The threshold value set dynamically according to the voltage restrained characteristic or set to constant value according to the voltage controlled characteristic.

If the Voltage-current point is in the "operate" range the a definite time delay is calculated according to the timer setting "Time Delay".

Technical data

Function	Value	Accuracy
Operating accuracy	20 ≤ G_S ≤ 1000	< 2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time char. Definite time char.	 Approx 60 ms	< 2% or ±35 ms, whichever is greater
Transient overreach		< 2 %
Pickup time *	< 40 ms	
Overshot time Dependent time char. Definite time char.	 30 ms 50 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* Measured with signal relay contact

Table 0-33 Technical data of the voltage dependent overcurrent protection function

The parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Parameter for enabling			
VOC51_Oper_EPar__	Operation	Off, On	Off
Parameter for type selection			
VOC51_RstMode_EPar_	Restr. mode	Restrained, Controlled	Restrained

Table 0-34 The enumerated parameters of the voltage dependent overcurrent protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current high limit						
VOC51_StCurr_IPar_	Start Current	%	20	3000	1	200
Voltage low limit						
VOC51_Ulow_IPar_	U_lowlimit	%	20	60	1	30
Voltage high limit						
VOC51_Uhigh_IPar_	U_highlimit	%	60	110	1	80
Starting current low limit						
VOC51_Uhigh_IPar_	Ik_limit	%	20	60	1	30

Table 0-35 The integer parameters of the voltage dependent overcurrent protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Definite time delay						
VOC51_DefDel_TPar_	Time Delay	msec	0	60000	1	100

Table 0-36 Timer parameters of the voltage dependent overcurrent protection function

Negative sequence overcurrent protection function (TOC46)

The negative sequence overcurrent protection function (TOC46) block operates if the negative sequence current is higher than the preset starting value.

In the negative sequence overcurrent protection function, definite-time or inverse-time characteristics are implemented, according to IEC or IEEE standards. The function evaluates a single measured current, which is the RMS value of the fundamental Fourier component of the negative sequence current. The characteristics are harmonized with IEC 60255-151, Edition 1.0, 2009-08.

The definite (independent) time characteristic has a fixed delaying time when the current is above the starting current G_s previously set as a parameter.

The standard dependent time characteristics of the negative sequence overcurrent protection function are as follows.

$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha} - 1} + c\right] \text{ when } G > G_S$$

where

t(G)(seconds)	theoretical operate time with constant value of G,
k, c	constants characterizing the selected curve (in seconds),
α	constant characterizing the selected curve (no dimension),
G	measured value of the characteristic quantity, Fourier base harmonic of the negative sequence current (INFour),
G_S	preset starting value of the characteristic quantity,
TMS	preset time multiplier (no dimension).

	IEC ref		k_r	c	α
1	A	IEC Inv	0,14	0	0,02
2	B	IEC VeryInv	13,5	0	1
3	C	IEC ExtInv	80	0	2
4		IEC LongInv	120	0	1
5		ANSI Inv	0,0086	0,0185	0,02
6	D	ANSI ModInv	0,0515	0,1140	0,02
7	E	ANSI VeryInv	19,61	0,491	2
8	F	ANSI ExtInv	28,2	0,1217	2
9		ANSI LongInv	0,086	0,185	0,02
10		ANSI LongVeryInv	28,55	0,712	2
11		ANSI LongExtInv	64,07	0,250	2

Table 37 The constants of the standard dependent time characteristics

A parameter (Operation) serves for choosing overcurrent function of independent time delay or dependent one with type selection above.

Time multiplier of the inverse characteristics (TMS) is also a parameter to be preset.

The end of the effective range of the dependent time characteristics (G_D) is:

$$G_D = 20 * G_S$$

Above this value the theoretical operating time is definite. The inverse type characteristics are also combined with a minimum time delay, the value of which is set by user parameter TOC46_MinDel_TPar_ (Min. Time Delay).

The negative phase sequence components calculation is based on the Fourier components of the phase currents.

The binary output status signals of the negative sequence overcurrent protection function are the general starting and the general trip command of the function.

The negative sequence overcurrent protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Operating accuracy	$10 \leq G_s$ [%] ≤ 200	< 2 %
Operate time accuracy		±5% or ±15 ms, whichever is greater
Reset ratio	0,95	
Reset time * Dependent time charact. Definite time charact.	 approx. 60 ms	<2 % or ±35 ms, whichever is greater
Transient overreach		< 2 %
Pickup time at 2* G_s	<40 ms	
Overshot time Dependent time charact. Definite time charact.	 25 ms 45 ms	
Influence of time varying value of the input current (IEC 60255-151)		< 4 %

* *Measured with signal contacts*

Table 38 Technical data of the negative sequence overcurrent protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
TOC46_Oper_EPar_	Operation	Off, DefinitTime, IEC Inv, IEC VeryInv, IEC ExtInv, IEC LongInv, ANSI Inv, ANSI ModInv, ANSI VeryInv, ANSI ExtInv, ANSI LongInv, ANSI LongVeryInv, ANSI LongExtInv	Definit Time

Table 39 The enumerated parameter of the negative sequence overcurrent protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting current parameter:						
TOC46_StCurr_IPar_	Start Current	%	5	200	1	50

Table 40 The integer parameter of the negative sequence overcurrent protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time multiplier of the inverse characteristics (OC module)						
TOC46_Multip_FPar_	Time Multiplier		0.05	999	0.01	1.0

*Valid for inverse type characteristics

Table 41 The float point parameter of the time overcurrent protection function

Timer parameters

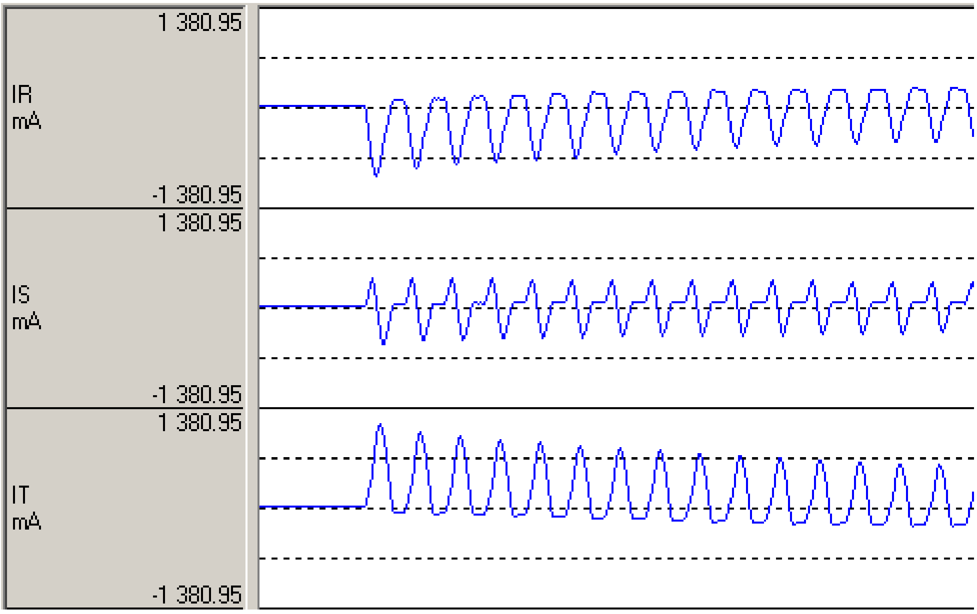
Parameter name	Title	Unit	Min	Max	Step	Default
Minimal time delay for the inverse characteristics:						
TOC46_MinDel_TPar_	Min Time Delay*	msec	0	60000	1	100
Definite time delay:						
TOC46_DefDel_TPar_	Definite Time Delay**	msec	0	60000	1	100
Reset time delay for the inverse characteristics:						
TOC46_Reset_TPar_	Reset Time*	msec	0	60000	1	100

*Valid for inverse type characteristics
**Valid for definite type characteristics only

Table 42 The timer parameter of the negative sequence overcurrent protection function

Inrush detection function (INR68)

When an inductive element with an iron core (transformer, reactor, etc.) is energized, high current peak values can be detected. This is caused by the transient asymmetric saturation of the iron core as a nonlinear element in the power network. The sizing of the iron core is usually sufficient to keep the steady state magnetic flux values below the saturation point of the iron core, so the inrush transient slowly dies out. These current peaks depend also on random factors such as the phase angle at energizing. Depending on the shape of the magnetization curve of the iron core, the detected peaks can be several times above the rated current peaks. Additionally, in medium or high voltage networks, where losses and damping are low, the indicated high current values may be sustained at length. Figure below shows a typical example for the inrush current shapes of a three-phase transformer.



A typical inrush current

As a consequence, overcurrent relays, differential relays or distance relays may start, and because of the long duration of the high current peaks, they may generate an unwanted trip command.

The inrush current detection function can distinguish between high currents caused by overload or faults and the high currents during the inrush time.

The operating principle of the inrush current detection function is based on the special shape of the inrush current.

The typical inrush current in one or two phases is asymmetrical to the time axis. For example, in IT of the Figure above the positive peaks are high while no peaks can be detected in the negative domain.

The theory of the Fourier analysis states that even harmonic components (2^{nd}, 4^{th} etc.) are dominant in waves asymmetrical to the time axis. The component with the highest value is the second one.

Typical overload and fault currents do not contain high even harmonic components.

The inrush current detection function processes the Fourier basic harmonic component and the second harmonic component of the three phase currents. If the ratio of the second harmonic and the base Fourier harmonic is above the setting value of the parameter *2nd Harm Ratio*, an inrush detection signal is generated.

The signal is output only if the base harmonic component is above the level defined by the setting of the parameter *IPh Base Sens.* This prevents unwanted operation in the event that low currents contain relatively high error signals.

The function operates independently using all three phase currents individually, and additionally, a general inrush detection signal is generated if any of the phases detects inrush current.

The function can be disabled by the binary input *Disable*. This signal is the result of logic equations graphically edited by the user.

Using the inrush detection binary signals, other protection functions can be blocked during the transient period so as to avoid the unwanted trip.

Some protection functions use these signals automatically, but a stand-alone inrush detection function block is also available for application at the user's discretion.

Technical data

Function	Range	Accuracy
Current accuracy	20 … 2000% of In	±1% of In

Table 43 Technical data of the inrush detection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Disabling or enabling the operation of the function			
INR2_Op_EPar_	Operation	Off,On	On

Table 44 The enumerated parameter of the inrush detection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Ratio of the second and basic harmonic Fourier components						
INR2_2HRat_IPar_,	2nd Harm Ratio	%	5	50	1	15
Basic sensitivity of the function						
INR2_MinCurr_IPar_	IPh Base Sens	%	20	100	1	30

Table 45 The integer parameter of the inrush detection function

Line thermal protection function (TTR49L)

Basically, line thermal protection measures the three sampled phase currents. RMS values are calculated and the temperature calculation is based on the highest RMS value of the phase currents.

The temperature calculation is based on the step-by-step solution of the thermal differential equation. This method yields "overtemperature", meaning the temperature above the ambient temperature. Accordingly, the temperature of the protected object is the sum of the calculated "overtemperature" and the ambient temperature.

If the calculated temperature (calculated "overtemperature"+ambient temperature) is above the threshold values, alarm, trip and restart blocking status signals are generated.

For correct setting, the following values must be measured and set as parameters: rated load current is the continuous current applied for the measurement, rated temperature is the steady state temperature at rated load current, base temperature is the temperature of the environment during the measurement and the time constant is the measured heating/cooling time constant of the exponential temperature function.

When energizing the protection device, the algorithm permits the definition of the starting temperature as the initial value of the calculated temperature. The parameter Startup Term. is the initial temperature above the temperature of the environment as compared to the rated temperature above the temperature of the environment

The ambient temperature can be measured using e.g. a temperature probe generating electric analog signals proportional to the temperature. In the absence of such measurement, the temperature of the environment can be set using the dedicated parameter TTR49L_Amb_IPar_ (Ambient Temperature). The selection between parameter value and direct measurement is made by setting the binary Boolean parameter.

The problem of metal elements (the protected line) exposed to the sun is that they are overheated as compared to the „ambient" temperature even without a heating current; furthermore, they are cooled mostly by the wind and the heat transfer coefficient is highly dependent on the effects of the wind. As the overhead lines are located in different geographical environments along the tens of kilometers of the route, the effects of the sun and the wind cannot be considered in detail. The best approximation is to measure the temperature of a piece of overhead line without current but exposed to the same environmental conditions as the protected line itself.

The application of thermal protection of the overhead line is a better solution than a simple overcurrent-based overload protection because thermal protection "remembers" the preceding load states of the line and the setting of the thermal protection does not need so a high security margin between the permitted current and the permitted continuous thermal current of the line. In a broad range of load states and in a broad range of ambient temperatures this permits the better exploitation of the thermal and consequently current carrying capacity of the line.

The thermal differential equation to be solved is:

$$\frac{d\Theta}{dt} = \frac{1}{T}\left(\frac{I^2(t)R}{hA} - \Theta\right)$$, and the definition of the heat time constant is: $$T = \frac{cm}{hA}$$

In this differential equation:

I(t) (RMS)	heating current, the RMS value usually changes over time;
R	resistance of the line;
c	specific heat capacity of the conductor;
m	mass of the conductor;
θ	rise of the temperature above the temperature of the environment;
h	heat transfer coefficient of the surface of the conductor;
A	area of the surface of the conductor;
t	time.

The solution of the thermal differential equation for constant current is the temperature as the function of time (the mathematical derivation of this equation is described in a separate document):

$$\Theta(t) = \frac{I^2 R}{hA}\left(1 - e^{-\frac{t}{T}}\right) + \Theta_o e^{-\frac{t}{T}}$$

where

Θ_o is the starting temperature.

Remember that the calculation of the measurable temperature is as follows:

Temperature(t) = Θ(t)+Temp_ambient

where

Temp_ambient is the ambient temperature.

In a separate document it is proven that some more easily measurable parameters can be introduced instead of the aforementioned ones. Thus, the general form of equation above is:

$$H(t) = \frac{\Theta(t)}{\Theta_n} = \frac{I^2}{I_n^2}\left(1 - e^{-\frac{t}{T}}\right) + \frac{\Theta_o}{\Theta_n} e^{-\frac{t}{T}}$$

where:

H(t) is the „thermal level" of the heated object, this is the temperature as a percentage of the Θ_n reference temperature. (This is a dimensionless quantity but it can also be expressed in a percentage form.)

Θ_n is the reference temperature above the temperature of the environment, which can be measured in steady state, in case of a continuous I_n reference current.

I_n is the reference current (can be considered as the nominal current of the heated object). If it flows continuously, then the reference temperature can be measured in steady state.

$\frac{\Theta_o}{\Theta_n}$ is a parameter of the starting temperature related to the reference temperature

The *RMS calculations modul* calculate the RMS values of the phase currents individually. The sampling frequency of the calculations is 1 kHz; therefore, theoretically, the frequency components below 500Hz are considered correctly in the RMS values. This module is not part of the thermal overload function; it belongs to the preparatory phase.

The *Max selection module* selects the maximal value of the three RMS phase currents.

The *Thermal replica module* solves the first order thermal differential equation using a simple step-by-step method and compares the calculated temperature to the values set by parameters. The temperature sensor value proportional to the ambient temperature can be an input (this signal is optional, defined at parameter setting).

The function can be disblaed by parameter, or generates a trip pulse if the calculated temperature exceeds the trip value, or generates a trip signal if the calculated temperature exceeds the trip value given by a parameter but it resets only if the temperature cools below the "Unlock temperature".

The line thermal protection function has two binary input signals. The conditions of the input signal are defined by the user, applying the graphic equation editor. One of the signals can block the line thermal protection function, the other one can reset the accumulated heat and set the temperature to the defined value for the subsequent heating test procedure.

Technical data

Function	Accuracy
Operate time at I>1.2*Itrip	<3 % or <+ 20 ms

Table 46 Technical data of the line thermal protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for mode of operation			
TTR49L_Oper_EPar_	Operation	Off, Pulsed, Locked	Pulsed

Table 47 The enumerated parameter of the line thermal protection function

The meaning of the enumerated values is as follows:

Off the function is switched off; no output status signals are generated;
Pulsed the function generates a trip pulse if the calculated temperature exceeds the trip value
Locked the function generates a trip signal if the calculated temperature exceeds the trip value. It resets only if the temperature cools below the “Unlock temperature”.

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Alarm Temperature						
TTR49L_Alm_IPar_	Alarm Temperature	deg	60	200	1	80
Trip Temperature						
TTR49L_Trip_IPar_	Trip Temperature	deg	60	200	1	100
Rated Temperature						
TTR49L_Max_IPar_	Rated Temperature	deg	60	200	1	100
Base Temperature						
TTR49L_Ref_IPar_	Base Temperature	deg	0	40	1	25
Unlock Temperature						
TTR49L_Unl_IPar_	Unlock Temperature	deg	20	200	1	60
Ambient Temperature						
TTR49L_Amb_IPar_	Ambient Temperature	deg	0	40	1	25
Startup Term.						
TTR49L_Str_IPar	Startup Term	%	0	60	1	0
Rated Load Current						
TTR49L_Inom_IPar_	Rated Load Current	%	20	150	1	100
Time constant						
TTR49L_pT_IPar_	Time Constant	min	1	999	1	10

Table 48 The integer parameters of the line thermal protection function

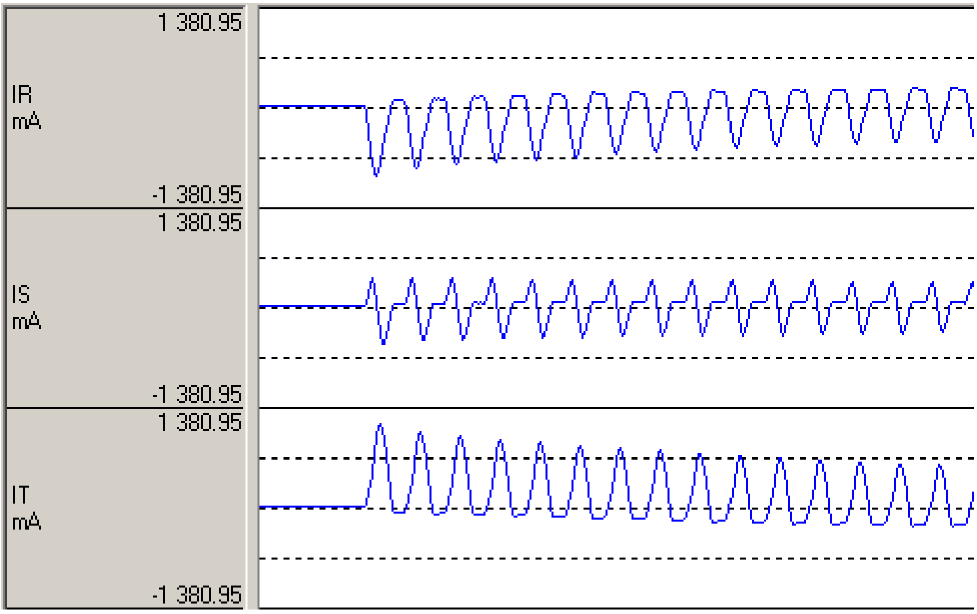
Boolean parameter

Boolean parameter	Signal title	Selection range	Default
Parameter for ambient temperature sensor application			
TTR49L_Sens_BPar_	Temperature Sensor	No, Yes	No

Table 49 The boolean parameter of the line thermal protection function

Inrush detection function (INR68)

When an inductive element with an iron core (transformer, reactor, etc.) is energized, high current peak values can be detected. This is caused by the transient asymmetric saturation of the iron core as a nonlinear element in the power network. The sizing of the iron core is usually sufficient to keep the steady state magnetic flux values below the saturation point of the iron core, so the inrush transient slowly dies out. These current peaks depend also on random factors such as the phase angle at energizing. Depending on the shape of the magnetization curve of the iron core, the detected peaks can be several times above the rated current peaks. Additionally, in medium or high voltage networks, where losses and damping are low, the indicated high current values may be sustained at length. Figure below shows a typical example for the inrush current shapes of a three-phase transformer.



A typical inrush current

As a consequence, overcurrent relays, differential relays or distance relays may start, and because of the long duration of the high current peaks, they may generate an unwanted trip command.

The inrush current detection function can distinguish between high currents caused by overload or faults and the high currents during the inrush time.

The operating principle of the inrush current detection function is based on the special shape of the inrush current.

The typical inrush current in one or two phases is asymmetrical to the time axis. For example, in IT of the Figure above the positive peaks are high while no peaks can be detected in the negative domain.

The theory of the Fourier analysis states that even harmonic components (2^{nd}, 4^{th} etc.) are dominant in waves asymmetrical to the time axis. The component with the highest value is the second one.

Typical overload and fault currents do not contain high even harmonic components.

The inrush current detection function processes the Fourier basic harmonic component and the second harmonic component of the three phase currents. If the ratio of the second harmonic and the base Fourier harmonic is above the setting value of the parameter *2nd Harm Ratio*, an inrush detection signal is generated.

The signal is output only if the base harmonic component is above the level defined by the setting of the parameter *IPh Base Sens.* This prevents unwanted operation in the event that low currents contain relatively high error signals.

The function operates independently using all three phase currents individually, and additionally, a general inrush detection signal is generated if any of the phases detects inrush current.

The function can be disabled by the binary input *Disable*. This signal is the result of logic equations graphically edited by the user.

Using the inrush detection binary signals, other protection functions can be blocked during the transient period so as to avoid the unwanted trip.

Some protection functions use these signals automatically, but a stand-alone inrush detection function block is also available for application at the user's discretion.

Technical data

Function	Range	Accuracy
Current accuracy	20 … 2000% of In	±1% of In

Table 50 Technical data of the inrush detection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Disabling or enabling the operation of the function			
INR2_Op_EPar_	Operation	Off,On	On

Table 51 The enumerated parameter of the inrush detection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Ratio of the second and basic harmonic Fourier components						
INR2_2HRat_IPar_,	2nd Harm Ratio	%	5	50	1	15
Basic sensitivity of the function						
INR2_MinCurr_IPar_	IPh Base Sens	%	20	100	1	30

Table 52 The integer parameter of the inrush detection function

Definite time overvoltage protection function (TOV59)

The definite time overvoltage protection function measures three voltages. The measured values of the characteristic quantity are the RMS values of the basic Fourier components of the phase voltages.

The Fourier calculation inputs are the sampled values of the three phase voltages (UL1, UL2, UL3), and the outputs are the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four). They are not part of the TOV59 function; they belong to the preparatory phase.

The function generates start signals for the phases individually. The general start signal is generated if the voltage in any of the three measured voltages is above the level defined by parameter setting value.

The function generates a trip command only if the definite time delay has expired and the parameter selection requires a trip command as well.

The overvoltaget protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy		< ± 0,5 %
Blocking voltage		< ± 1,5 %
Reset time U< → Un U< → 0	 60 ms 50 ms	
Operate time accuracy		< ± 20 ms
Minimum operate time	50 ms	

Table 53 Technical data of the definite time overvoltage protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Enabling or disabling the overvoltage protection function			
TOV59_Oper_EPar_	Operation	Off, On	On

Table 54 The enumerated parameter of the definite time overvoltage protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage level setting. If the measured voltage is above the setting value, the function generates a start signal.						
TOV59_StVol_IPar_	Start Voltage	%	30	130	1	63

Table 55 The integer parameter of the definite time overvoltage protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
TOV59_StOnly_BPar_	Start Signal Only	FALSE

Table 56 The boolean parameter of the definite time overvoltage protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay of the overvoltage protection function.						
TOV59_Delay_TPar_	Time Delay	ms	0	60000	1	100

Table 57 The timer parameter of the definite time overvoltage protection function

Definite time undervoltage protection function (TUV27)

The definite time undervoltage protection function measures the RMS values of the fundamental Fourier component of three phase voltages.

The Fourier calculation inputs are the sampled values of the three phase voltages (UL1, UL2, UL3), and the outputs are the basic Fourier components of the analyzed voltages (UL1Four, UL2Four, UL3Four). They are not part of the TUV27 function; they belong to the preparatory phase.

The function generates start signals for the phases individually. The general start signal is generated if the voltage is below the preset starting level parameter setting value and above the defined blocking level.

The function generates a trip command only if the definite time delay has expired and the parameter selection requires a trip command as well.

The operation mode can be chosen by the type selection parameter. The function can be disabled, and can be set to “1 out of 3”, “2 out of 3”, and “All”.

The overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy		< ± 0,5 %
Blocking voltage		< ± 1,5 %
Reset time U> → Un U> → 0	 50 ms 40 ms	
Operate time accuracy		< ± 20 ms
Minimum operate time	50 ms	

Table 58 Technical data of the definite time undervoltage protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
TUV27_Oper_EPar_	Operation	Off, 1 out of 3, 2 out of 3, All	1 out of 3

Table 59 The enumerated parameter of the definite time undervoltage protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Starting voltage level setting						
TUV27_StVol_IPar_	Start Voltage	%	30	130	1	52
Blocking voltage level setting						
TUV27_BlkVol_IPar_	Block Voltage	%	0	20	1	10

Table 60 The integer parameters of the definite time undervoltage protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
TUV27_StOnly_BPar_	Start Signal Only	FALSE

Table 61 The boolean parameter of the definite time undervoltage protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay of the undervoltage protection function.						
TUV27_Delay_TPar_	Time Delay	ms	0	60000	1	100

Table 62 The timer parameter of the definite time undervoltage protection function

Residual definite time overvoltage protection function (TOV59N)

The residual definite time overvoltage protection function operates according to definite time characteristics, using the RMS values of the fundamental Fourier component of the zero sequence voltage (UN=3Uo).

The Fourier calculation inputs are the sampled values of the residual or neutral voltage (UN=3Uo) and the outputs are the RMS value of the basic Fourier components of those.

The function generates start signal if the residual voltage is above the level defined by parameter setting value.

The function generates a trip command only if the definite time delay has expired and the parameter selection requires a trip command as well.

The residual overvoltage protection function has a binary input signal, which serves the purpose of disabling the function. The conditions of disabling are defined by the user, applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy	2 – 8 % 8 – 60 %	< ± 2 % < ± 1.5 %
Reset time U> → Un U> → 0	 60 ms 50 ms	
Operate time	50 ms	< ± 20 ms

Table 63 Technical data of the residual definite time overvoltage protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for enabling/disabling:			
TOV59N_Oper_EPar_	Operation	Off, On	On

Table 64 The enumerated parameter of the residual definite time overvoltage protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Starting voltage parameter:						
TOV59N_StVol_IPar_	Start Voltage	%	2	60	1	30

Table 65 The integer parameter of the residual definite time overvoltage protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
TOV59N_StOnly_BPar_	Start Signal Only	FALSE

Table 66 The boolean parameter of the residual definite time overvoltage protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Definite time delay:						
TOV59N_Delay_TPar_	Time Delay	ms	0	60000	1	100

Table 67 The time parameter of the residual definite time overvoltage protection function

Over-frequency protection function (TOF81)

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value. The over-frequency protection function is usually applied to decrease generation to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of high frequency can be one of the indication of island operation.

Accurate frequency measurement is also the criterion for the synchro-check and synchro-switch functions.

The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal. For the acceptance of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value.

The over-frequency protection function generates a start signal if at least five measured frequency values are above the preset level.

Time delay can also be set.

The function can be enabled/disabled by a parameter.

The over-frequency protection function has a binary input signal. The conditions of the input signal are defined by the user, applying the graphic equation editor. The signal can block the under-frequency protection function.

Technical data

Function	Range	Accuracy
Operate range	40 - 70 Hz	30 mHz
Effective range	45 - 55 Hz / 55 - 65 Hz	2 mHz
Operate time		min 140 ms
Time delay	140 – 60000 ms	± 20 ms
Reset ratio		0,99

Table 68 Technical data of the over-frequency protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating mode			
TOF81_Oper_EPar_	Operation	Off,On	On

Table 69 The enumerated parameter of the over-frequency protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
TOF81_StOnly_BPar_	Start Signal Only	FALSE

Table 70 The boolean parameter of the over-frequency protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Setting value of the comparison						
TOF81_St_FPar_	Start Frequency	Hz	40	60	0.01	51

Table 71 The float point parameter of the over-frequency protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay						
TOF81_Del_TPar_	Time Delay	msec	100	60000	1	200

Table 72 The timer parameter of the over-frequency protection function

Underfrequency protection function (TUF81)

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is small compared to the consumption by the load connected to the power system, then the system frequency is below the rated value. The under-frequency protection function is usually applied to increase generation or for load shedding to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of low frequency can be one of the indications of island operation.

Accurate frequency measurement is also the criterion for the synchro-check and synchro-switch functions.

The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal. For the acceptance of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value.

The under-frequency protection function generates a start signal if at least five measured frequency values are below the setting value.

Time delay can also be set.

The function can be enabled/disabled by a parameter.

The under-frequency protection function has a binary input signal. The conditions of the input signal are defined by the user, applying the graphic equation editor. The signal can block the under-frequency protection function.

Technical data

Function	Range	Accuracy
Operate range	40 - 70 Hz	30 mHz
Effective range	45 - 55 Hz / 55 - 65 Hz	2 mHz
Operate time		min 140 ms
Time delay	140 – 60000 ms	± 20 ms
Reset ratio		0,99

Table 73 Technical data of the under-frequency protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating mode			
TUF81_Oper_EPar_	Operation	Off, On	On

Table 74 The enumerated parameter of the under-frequency protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
TUF81_StOnly_BPar_	Start Signal Only	FALSE

Table 75 The boolean parameter of the under-frequency protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Digits	Default
Preset value of the comparison						
TUF81_St_FPar_	Start Frequency	Hz	40	60	0.01	49

Table 76 The float point parameter of the under-frequency protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay						
TUF81_Del_TPar_	Time Delay	ms	100	60000	1	200

Table 77 The timer parameter of the under-frequency protection function

Rate of change of frequency protection function (FRC81)

The deviation of the frequency from the rated system frequency indicates unbalance between the generated power and the load demand. If the available generation is large compared to the consumption by the load connected to the power system, then the system frequency is above the rated value, and if it is small, the frequency is below the rated value. If the unbalance is large, then the frequency changes rapidly. The rate of change of frequency protection function is usually applied to reset the balance between generation and consumption to control the system frequency.

Another possible application is the detection of unintended island operation of distributed generation and some consumers. In the island, there is low probability that the power generated is the same as consumption; accordingly, the detection of a high rate of change of frequency can be an indication of island operation.

Accurate frequency measurement is also the criterion for the synchro-switch function.

The source for the rate of change of frequency calculation is an accurate frequency measurement.

In some applications, the frequency is measured based on the weighted sum of the phase voltages.

The accurate frequency measurement is performed by measuring the time period between two rising edges at zero crossing of a voltage signal. For the acceptance of the measured frequency, at least four subsequent identical measurements are needed. Similarly, four invalid measurements are needed to reset the measured frequency to zero. The basic criterion is that the evaluated voltage should be above 30% of the rated voltage value.

The rate of change of frequency protection function generates a start signal if the df/dt value is above the setting value. The rate of change of frequency is calculated as the difference of the frequency at the present sampling and at three periods earlier.

Time delay can also be set.

The function can be enabled/disabled by a parameter.

The rate of change of frequency protection function has a binary input signal. The conditions of the input signal are defined by the user, applying the graphic equation editor. The signal can block the rate of change of frequency protection function.

Technical data

Function	Effective range	Accuracy
Operating range	-5 - -0.05 and +0.05 - +5 Hz/sec	
Pick-up accuracy		±20 mHz/sec
Operate time	min 140 ms	
Time delay	140 – 60000 ms	+ 20 ms

Table 78 Technical data of the rate of change of frequency protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating mode			
FRC81_Oper_EPar_	Operation	Off,On	On

Table 79 The enumerated parameter of the rate of change of frequency protection function

Boolean parameter

Parameter name	Title	Default
Enabling start signal only:		
FRC81_StOnly_BPar_	Start Signal Only	True

Table 80 The boolean parameter of the rate of change of frequency protection function

Float point parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Setting value of the comparison						
FRC81_St_FPar_	Start df/dt	Hz/sec	-5	5	0.01	0.5

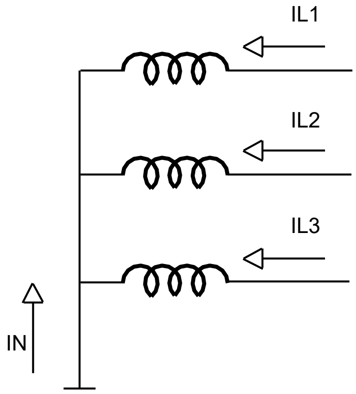
Table 81 The float point parameter of the rate of change of frequency protection function

Timer parameters

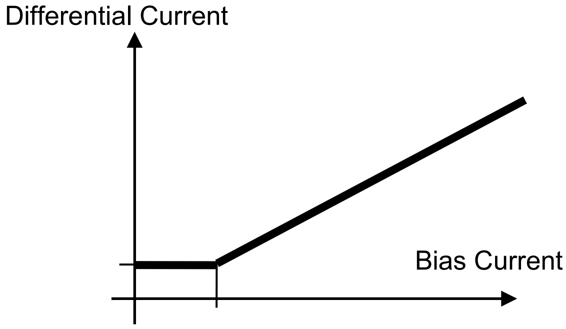
Parameter name	Title	Unit	Min	Max	Step	Default
Time delay						
FRC81_Del_TPar_	Time Delay	msec	100	60000	1	200

Table 82 The timer parameter of the rate of change of frequency protection function

Rectricted earth fault protection function (DIF87N) - optional



The restricted earth-fault protection function is basically a low-impedance differential protection function based on zero sequence current components. It can be applied to protect one side winding of transformers with grounded neutral against single-phase-to-earth fault (see Figure). The function compares the measured neutral current at the star point (IN) and the calculated zero sequence current component of the phase currents (IL1, IL2, IL3) and generates a trip command if the difference of these currents is above the characteristics.



The function performs evaluation

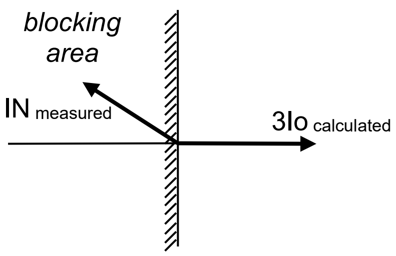
differential of the zero This curve current, currents and

the necessary calculations for the of the “percentage differential characteristics”, and decides to trip if the current is above the characteristic curve sequence differential protection function. is the function of the restraint (Bias) which is the maximum of the phase the current of the neutral point.

$$Differential\ Current = IL1Four + IL2Four + IL3Four + INFour$$
$$Bias\ Current = MAX(IL1Four, IL2Four, IL3Four, INFour)$$

Note: Four = Fourier

Additionally the function compares the direction of the neutral current and that of the calculated zero sequence current. In case of small zero sequence component of the high fault currents in the phases, this decision improves the stability of the function.



In this system, if the angle between the calculated zero sequence current 3Io and the measured neutral current IN is out of the range of ±90 degrees, then the restricted earth fault protection can be blocked (see the Figure). For the directional decision, the positive directions are drawn in Figure above. The output signal of the directional decision module can block the restricted earth-fault protection function.

A Boolean parameter of the restricted earth-fault protection function serves to enable the directional checking of the measured and calculated zero sequence currents.

The restricted earth-fault protection function generates a trip signal if the differential current as the function of the bias current is above the differential characteristic lines and the function is not blocked by the directional decision. Additionally the operation of the function is enabled by parameter setting. The conditions of enabling are defined by the user applying the graphic equation editor.

Technical data

Function	Value	Accuracy
Operating characteristic	1 breakpoint	
Reset ratio	0,95	
Characteristic accuracy		<2%
Operate time, restrained	typically 20 ms	
Reset time, restrained	typically 25 ms	

Table 83 The technical data of the restricted earth fault protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter to enable the zero sequence differential protection function:			
DIF87N_Oper_EPar_	Operation	Off, On	On

Table 84 The enumerated parameter of the restricted earth fault protection function

Boolean parameter

Parameter name	Title	Default	Explanation
DIF87N_DirCheck_BPar_	Directional check	True	Enabling the directional checking of the measured and calculated zero sequence currents

Table 85 The boolean parameter of the restricted earth fault protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters for the current magnitude compensation:						
DIF87N_TRPri_IPar_	Io Primary Match	%	20	500	1	100
DIF87N_TRNeut_IPar_	Neutral Match	%	100	1000	1	500
Base sensitivity:						
DIF87N_f1_IPar_	Base Sensitivity	%	10	50	1	30
Slope of the second section of the characteristics:						
DIF87N_f2_IPar_	Slope	%	50	100	1	70
Break point of the characteristic line:						
DIF87N_f2Brk_IPar_	Base Sens Bias Limit	%	100	200	1	125

Table 86 The integer parameters of the restricted earth fault protection function

Current unbalance function (VCB60)

The current unbalance protection function (VCB60) can be applied to detect unexpected asymmetry in current measurement.

The applied method selects maximum and minimum phase currents (RMS value of the fundamental Fourier components). If the difference between them is above the setting limit, the function generates a start signal. It is a necessary precondition of start signal generation that the maximum of the currents be above 10 % of the rated current and below 150% of the rated current.

The Fourier calculation modules calculate the RMS value of the basic Fourier current components of the phase currents individually. They are not part of the VCB60 function; they belong to the preparatory phase.

The analog signal processing module processes the RMS value of the basic Fourier current components of the phase currents to prepare the signals for the decision. It calculates the maximum and the minimum value of the RMS values and the difference between the maximum and minimum of the RMS values of the fundamental Fourier components of the phase currents as a percentage of the maximum of these values (ΔI>). If the maximum of the currents is above 10 % of the rated current and below 150% of the rated current and the ΔI> value is above the limit defined by the preset parameter (Start Current Diff) an output is generated to the decision module.

The decision logic module combines the status signals to generate the starting signal and the trip command of the function.

The trip command is generated after the defined time delay if trip command is enabled by the Boolean parameter setting.

The function can be disabled by parameter setting, and by an input signal programmed by the user with the graphic programming tool.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy at In		< 2 %
Reset ratio	0.95	
Operate time	70 ms	

Table 87 Technical data of the current unbalance function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating mode			
VCB60_Oper_EPar_	Operation	Off, On	On

Table 88 The enumerated parameter of the current unbalance function

Boolean parameter

Parameter name	Title	Explanation	Default
Selection for trip command			
VCB60_StOnly_BPar_	Start Signal Only	0 to generate trip command	0

Table 89 The boolean parameter of the current unbalance function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Phase difference current setting						
VCB60_StCurr_IPar_	Start Current Diff	%	10	90	1	50

Table 90 The integer parameter of the current unbalance function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay						
VCB60_Del_TPar_	Time Delay	msec	100	60000	100	1000

Table 91 The timer parameter of the current unbalance function

Breaker failure protection function (BRF50MV)

After a protection function generates a trip command, it is expected that the circuit breaker opens and the fault current drops below the pre-defined normal level.

If not, then an additional trip command must be generated for all backup circuit breakers to clear the fault. At the same time, if required, a repeated trip command can be generated to the circuit breakers which are a priori expected to open.

The breaker failure protection function can be applied to perform this task.

The starting signal of the breaker failure protection function is usually the trip command of any other protection function. The user has the task to define these starting signals using the graphic equation editor as the “General Start” (BRF50MV_GenSt_GrO_). Individually phase starting is not available in the version of the function block described in this document. If these are needed, the function block “Breaker failure protection for solidly grounded networks” has to be used.

Dedicated timer starts at the rising edge of the general start signal for the backup trip command. During the running time of the timer the function optionally monitors the currents, the closed state of the circuit breakers or both, according to the user’s choice. The selection is made using an enumerated parameter .

If current supervision is selected by the user then the current limit values must be set correctly. The binary input indicating the status of the circuit breaker has no meaning.

If contact supervision is selected by the user then the current limit values have no meaning. The binary input indicating the status of the circuit breaker must be programmed correctly using the graphic equation editor.

If the parameter selection is “Current/Contact”, the current parameters and the status signal must be set correctly. The breaker failure protection function resets only if all conditions for faultless state are fulfilled.

If at the end of the running time of the backup timer the currents do not drop below the pre-defined level, and/or the monitored circuit breaker is still in closed position, then a backup trip command is generated.

The pulse duration of the trip command is not shorter than the time defined by setting the parameter Pulse length.

The breaker failure protection function can be disabled by setting the enabling parameter to “Off”.

Dynamic blocking (inhibition) is possible using the binary input Block. The conditions are to be programmed by the user, using the graphic equation editor.

Technical data

Function	Effective range	Accuracy
Current accuracy		<2 %
BF time accuracy		± 5 ms
Current reset time	20 ms	

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Selection of the operating mode			
BRF50MV_Oper_EPar_	Operation	Off, Current, Contact, Current/Contact	Off

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Phase current setting						
BRF50MV_StCurrPh_IPar_	Start Ph Current	%	20	200	1	30
Neutral current setting						
BRF50MV_StCurrN_IPar_	Start Res Current	%	10	200	1	20

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for trip command generation for the backup circuit breaker(s)						
BRF50MV_BUDel_TPar_	Backup Time Delay	msec	60	1000	1	200
Trip command impulse duration						
BRF50MV_Pulse_TPar_	Pulse Duration	msec	0	60000	1	100

Trip logic (TRC94)

The simple trip logic function operates according to the functionality required by the IEC 61850 standard for the "Trip logic logical node". This simplified software module can be applied if only three-phase trip commands are required, that is, phase selectivity is not applied.

The function receives the trip requirements of the protective functions implemented in the device and combines the binary signals and parameters to the outputs of the device.

The trip requirements are programmed by the user, using the graphic equation editor. The aim of the decision logic is

- to define a minimal impulse duration even if the protection functions detect a very short-time fault.
-

Technical data

Function		Accuracy
Impulse time duration	Setting value	<3 ms

Table 92 Technical data of the simple trip logic function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Selection of the operating mode			
TRC94_Oper_EPar_	Operation	Off, On	On

Tables 93 The enumerated parameter of the decision logic

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum duration of the generated impulse						
TRC94_TrPu_TPar_	Min Pulse Duration	msec	50	60000	1	150

Table 94 Timer parameter of the decision logic

Auto-reclose protection (REC79MV)

The MV automatic reclosing function can realize up to four shots of reclosing for medium-voltage networks. The dead time can be set individually for each reclosing and separately for earth faults and for multi-phase faults. All shots are of three phase reclosing.

The starting signal of the cycles can be generated by any combination of the protection functions or external signals of the binary inputs.

The automatic reclosing function is triggered if as a consequence of a fault a protection function generates a trip command to the circuit breaker and the protection function resets because the fault current drops to zero or the circuit breaker's auxiliary contact signals open state. According to the preset parameter values, either of these two conditions starts counting the dead time, at the end of which the MV automatic reclosing function generates a close command automatically. If the fault still exits or reappears, then within the "Reclaim time" the protection functions picks up again and the subsequent cycle is started. If the fault still exists at the end of the last cycle, the MV automatic reclosing function trips and generates the signal for final trip. If no pickup is detected within this time, then the MV automatic reclosing cycle resets and a new fault will start the procedure with the first cycle again.

At the moment of generating the close command, the circuit breaker must be ready for operation, which is signaled via the binary input "CB Ready". The preset parameter value "CB Supervision time" decides how long the MV automatic reclosing function is allowed to wait at the end of the dead time for this signal. If the signal is not received during this dead time extension, then the MV automatic reclosing function terminates.

Depending on binary parameter settings, the automatic reclosing function block can accelerate trip commands of the individual reclosing cycles. This function needs user-programmed graphic equations to generate the accelerated trip command.

The duration of the close command depends on preset parameter value "Close command time", but the close command terminates if any of the protection functions issues a trip command.

The MV automatic reclosing function can control up to four reclosing cycles. Depending on the preset parameter values "EarthFaults Rec,Cycle" and "PhaseFaults Rec,Cycle", there are different modes of operation, both for earth faults and for multi-phase faults:

Disabled	No automatic reclosing is selected,
1. Enabled	Only one automatic reclosing cycle is selected,
1.2. Enabled	Two automatic reclosing cycles are activated,
1.2.3. Enabled	Three automatic reclosing cycles are activated,
1.2.3.4. Enabled	All automatic reclosing cycles are activated.

The function can be switched Off /On using the parameter "Operation".

The user can also block the MV automatic reclosing function applying the graphic equation editor. The binary status variable to be programmed is "Block".

Depending on the preset parameter value "Reclosing started by", the MV automatic reclosing function can be started either by resetting of the TRIP command or by the binary signal indicating the open state of the circuit breaker.

If the reset state of the TRIP command is selected to start the MV automatic reclosing function, then the conditions are defined by the user applying the graphic equation editor. The binary status variable to be programmed is "AutoReclosing Start".

If the open state of the circuit breaker is selected to start the MV automatic reclosing function, then additionally to programming the “AutoReclosing Start“ signal, the conditions for detecting the open state of the CB are defined by the user applying the graphic equation editor.

For all four reclosing cycles, separate dead times can be defined for line-to-line faults and for earth faults. The dead time counter of any reclosing cycle is started by the starting signal but starting can be delayed.

Reclosing is possible only if the conditions required by the “synchro-check” function are fulfilled. The conditions are defined by the user applying the graphic equation editor. The HV automatic reclosing function waits for a pre-programmed time for this signal. This time is defined by the user. If the “SYNC Release” signal is not received during the running time of this timer, then the “synchronous switch” operation is started. If no synchronous switching is possible, then the MV automatic reclosing function resets.

In case of a manual close command which is assigned to the binary input “Manual Close“ using graphic equation programming, a preset parameter value decides how long the MV automatic reclosing function should be disabled after the manual close command.

The MV automatic reclosing function can be blocked by a binary input. The conditions are defined by the user applying the graphic equation editor.

Technical data

Function	Accuracy
Operating time	±1% of setting value or ±30 ms

Table 95 Technical data of the auto-reclosing protection function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Switching ON/OFF the MV automatic reclosing function			
REC79_Op_EPar_	Operation	Off, On	On
Selection of the number of reclosing sequences in case of earth faults			
REC79_EFCycEn_EPar_	EarthFault RecCycle	Disabled, 1. Enabled, 1.2. Enabled, 1.2.3. Enabled, 1.2.3.4. Enabled	1. Enabled
Selection of the number of reclosing sequences in case of line-to-line faults			
REC79_PhFCycEn_EPar_	PhaseFault RecCycle	Disabled, 1. Enabled, 1.2. Enabled, 1.2.3. Enabled, 1.2.3.4. Enabled	1. Enabled
Selection of triggering the dead time counter (trip signal reset or circuit breaker open position)			
REC79_St_EPar_	Reclosing Started by	Trip reset, CB open	Trip reset

Table 96 The enumerated parameters of the auto-reclosing protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Dead time setting for the first reclosing cycle for line-to-line fault						
REC79_PhDT1_TPar_	1. Dead Time Ph	msec	0	100000	10	500
Dead time setting for the second reclosing cycle for line-to-line fault						
REC79_PhDT2_TPar_	2. Dead Time Ph	msec	10	100000	10	600
Dead time setting for the third reclosing cycle for line-to-line fault						
REC79_PhDT3_TPar_	3. Dead Time Ph	msec	10	100000	10	700
Dead time setting for the fourth reclosing cycle for line-to-line fault						
REC79_PhDT4_TPar_	4. Dead Time Ph	msec	10	100000	10	800
Dead time setting for the first reclosing cycle for earth fault						
REC79_EFDT1_TPar_	1. Dead Time EF	msec	0	100000	10	1000
Dead time setting for the second reclosing cycle for earth fault						
REC79_ EF DT2_TPar_	2. Dead Time EF	msec	10	100000	10	2000
Dead time setting for the third reclosing cycle for earth fault						
REC79_ EF DT3_TPar_	3. Dead Time EF	msec	10	100000	10	3000
Dead time setting for the fourth reclosing cycle for earth fault						
REC79_ EF DT4_TPar_	4. Dead Time EF	msec	10	100000	10	4000
Reclaim time setting						
REC79_Rec_TPar_	Reclaim Time	msec	100	100000	10	2000
Impulse duration setting for the CLOSE command						
REC79_Close_TPar_	Close Command Time	msec	10	10000	10	100
Setting of the dynamic blocking time						
REC79_DynBlk_TPar_	Dynamic Blocking Time	msec	10	100000	10	1500
Setting of the blocking time after manual close command						
REC79_MC_TPar_	Block after Man Close	msec	0	100000	10	1000
Setting of the action time (max. allowable duration between protection start and trip)						
REC79_Act_TPar_	Action Time	msec	0	20000	10	1000
Limitation of the starting signal (trip command is too long or the CB open signal received too late)						
REC79_MaxSt_TPar_	Start Signal Max Time	msec	0	10000	10	1000
Max. delaying the start of the dead-time counter						
REC79_DtDel_TPar_	DeadTime Max Delay	msec	0	100000	10	3000
Waiting time for circuit breaker ready to close signal						
REC79_CBTO_TPar_	CB Supervision Time	msec	10	100000	10	1000
Waiting time for synchronous state signal						
REC79_SYN1_TPar_	SynCheck Max Time	msec	500	100000	10	10000
Waiting time for synchronous switching signal						
REC79_SYN2_TPar_	SynSW Max Time	msec	500	100000	10	10000

Table 97 The timer parameters of the auto-reclosing protection function

Boolean parameters

Parameter name	Title	Default	Explanation
REC79_CBState_BPar_	CB State Monitoring	0	Enable CB state monitoring for “Not Ready” state
REC79_Acc1_BPar_	Accelerate 1.Trip	0	Accelerate trip command at starting cycle 1
REC79_Acc2_BPar_	Accelerate 2.Trip	0	Accelerate trip command at starting cycle 2
REC79_Acc3_BPar_	Accelerate 3.Trip	0	Accelerate trip command at starting cycle 3
REC79_Acc4_BPar_	Accelerate 4.Trip	0	Accelerate trip command at starting cycle 4
REC79_Acc5_BPar_	Accelerate FinTrip	0	Accelerate final trip command

Table 98 The boolean parameters of the auto-reclosing protection function

Circuit breaker control function block (CB1Pol)

The Circuit breaker control function block can be used to integrate the circuit breaker control of the PROTECTA device into the station control system and to apply active scheme screens of the local LCD of the device.

The Circuit breaker control function block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the circuit breaker. It processes the status signals received from the circuit breaker and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- The signals and commands of the synchro check / synchro switch function block can be integrated into the operation of the function block.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” (enabled trip command) and “EnaOn” (enabled close command), using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
  - Time limitation to execute a command
  - Command pulse duration
  - Filtering the intermediate state of the circuit breaker
  - Checking the synchro check and synchro switch times
  - Controlling the individual steps of the manual commands
- Sending trip and close commands to the circuit breaker (to be combined with the trip commands of the protection functions and with the close command of the automatic reclosing function; the protection functions and the automatic reclosing function directly gives commands to the CB). The combination is made graphically using the graphic equation editor
- Operation counter
- Event reporting

The Circuit breaker control function block has binary input signals. The conditions are defined by the user applying the graphic equation editor. The signals of the circuit breaker control are seen in the binary input status list.

Technical data

Function	Accuracy
Operate time accuracy	±5% or ±15 ms, whichever is greater

Table 99 Technical data of the circuit breaker control function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
The control model of the circuit breaker node according to the IEC 61850 standard			
CB1Pol_ctlMod_EPar_	ControlModel*	Direct normal, Direct enhanced, SBO enhanced	Direct normal

**ControlModel*

- Direct normal: only command transmission
- Direct enhanced: command transmission with status check and command supervision
- SBO enhanced: Select Before Operate mode with status check and command supervision

Table 100 Enumerated parameter of the circuit breaker control function

Boolean parameter

Boolean parameter	Title	Explanation
CB1Pol_DisOverR_BPar_	Forced check	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard

Table 101 Boolean parameter of the circuit breaker control function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Timeout for signaling failed operation						
CB1Pol_TimOut_TPar_	Max.Operating time	msec	10	1000	1	200
Duration of the generated On and Off impulse						
CB1Pol_Pulse_TPar_,	Pulse length	msec	50	500	1	100
Waiting time, at expiry intermediate state of the CB is reported						
CB1Pol_MidPos_TPar_	Max.Intermediate time	msec	20	30000	1	100
Length of the time period to wait for the conditions of the synchron state. After expiry of this time, the synchro switch procedure is initiated (see synchro check/ synchro switch function block description)						
CB1Pol_SynTimOut_TPar_	Max.SynChk time	msec	10	5000	1	1000
Length of the time period to wait for the synchro switch impulse (see synchro check/ synchro switch function block description). After this time the function resets, no switching is performed						
CB1Pol_SynSWTimOut_TPar_	Max.SynSW time*	msec	0	60000	1	0
Duration of the waiting time between object selection and command selection. At timeout no command is performed						
CB1Pol_SBOTimeout_TPar_	SBO Timeout	msec	1000	20000	1	5000

* If this parameter is set to 0, then the "StartSW" output is not activated

Table 102 Timer parameters of the circuit breaker control function

Available internal status variable and command channel

To generate an active scheme on the local LCD, there is an internal status variable indicating the state of the circuit breaker. Different graphic symbols can be assigned to the values.

Status variable	Title	Explanation
CB1Pol_stVal_Ist_	Status	Can be: 0: Intermediate 1: Off 2: On 3: Bad

The available control channel to be selected is:

Command channel	Title	Explanation
CB1Pol_Oper_Con_	Operation	Can be: On Off

Using this channel, the pushbuttons on the front panel of the device can be assigned to close or open the circuit breaker. These are the “Local commands”.

Disconnector control function (DisConn)

The Disconnector control function block can be used to integrate the disconnector control of the PROTECTA device into the station control system and to apply active scheme screens of the local LCD of the device.

The Disconnector control function block receives remote commands from the SCADA system and local commands from the local LCD of the device, performs the prescribed checking and transmits the commands to the disconnector. It processes the status signals received from the disconnector and offers them to the status display of the local LCD and to the SCADA system.

Main features:

- Local (LCD of the device) and Remote (SCADA) operation modes can be enabled or disabled individually.
- Interlocking functions can be programmed by the user applying the inputs “EnaOff” (enabled trip command) and “EnaOn” (enabled close command), using the graphic equation editor.
- Programmed conditions can be used to temporarily disable the operation of the function block using the graphic equation editor.
- The function block supports the control models prescribed by the IEC 61850 standard.
- All necessary timing tasks are performed within the function block:
  - Time limitation to execute a command
  - Command pulse duration
  - Filtering the intermediate state of the disconnector
  - Controlling the individual steps of the manual commands
- Sending trip and close commands to the disconnector
- Operation counter
- Event reporting

The Disconnector control function block has binary input signals. The conditions are defined by the user applying the graphic equation editor. The signals of the disconnector control are seen in the binary input status list.

Technical data

Function	Accuracy
Operate time accuracy	±5% or ±15 ms, whichever is greater

Table 103 Technical data of the disconnector control functio

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
The control model of the disconnector node according to the IEC 61850 standard			
DisConn_ctlMod_EPar_	ControlModel*	Direct normal, Direct enhanced, SBO enhanced	Direct normal
Type of switch			
DisConn_SwTyp_EPar_	Type of Switch	N/A,Load break, Disconnector, Earthing Switch, HS Earthing Switch	Disconnector

**ControlModel*

- Direct normal: only command transmission
- Direct enhanced: command transmission with status check and command supervision
- SBO enhanced: Select Before Operate mode with status check and command supervision

Table 104 Enumerated parameters of the disconnector control function

Boolean parameter

Boolean parameter	Title	Explanation
DisConn_DisOverR_BPar_	Forced check	If true, then the check function cannot be neglected by the check attribute defined by the IEC 61850 standard

Table 105 Boolean parameter of the disconnector control function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Timeout for signaling failed operation						
DisConn_TimOut_TPar_	Max.Operating time	msec	10	20000	1	1000
Duration of the generated On and Off impulse						
DisConn_Pulse_TPar_	Pulse length	msec	50	30000	1	100
Waiting time, at expiry intermediate state of the disconnector is reported						
DisConn_MidPos_TPar_	Max.Intermediate time	msec	20	30000	1	100
Duration of the waiting time between object selection and command selection. At timeout no command is performed						
DisConn_SBOTimeout_ TPar_	SBO Timeout	msec	1000	20000	1	5000

Table 106 Timer parameters of the disconnector control function

Available internal status variable and command channel
To generate an active scheme on the local LCD, there is an internal status variable indicating the state of the disconnector. Different graphic symbols can be assigned to the values.

Status variable	Title	Explanation
DisConn I_stVal_Ist_	Status	Can be: 0: Intermediate 1: Off 2: On 3:Bad

The available control channel to be selected is:

Command channel	Title	Explanation
DisConn _Oper_Con_	Operation	Can be: On Off

Using this channel, the pushbuttons on the front panel of the device can be assigned to close or open the disconnector. These are the “Local commands”.

Vector jump protection function

Application

The modern electric power systems include an increasing number of small generators (distributed generation system). There can be several events in the network resulting that the small generators get disconnected from the system, and the small generator supplies some consumer only, remaining in the electric "island" (unintended islanding).

If a small generator remains in an island with some consumers, it is highly possible that the balance of the generated and consumed active and reactive power is not fulfilled. This results changing of the frequency and/or voltage, accordingly the voltage vector position of the island is changing, related to that of the disconnected grid. An automatic reclosing of the circuit breaker at an unfavorable vector position can result high currents and serious damages. To prevent these damages a protection is needed to detect the islanding and to disconnect the generator from the island.

One of the protection methods to detect unintended islanding is this vector jump protection function.

Mode of operation

When an unintended islanding occurs then the induced voltage inside the generator (EMF) may not change abruptly. As a consequence, on other locations within the island (at the connection point of the generator, at the bus-bar or at the consumer) a sudden change of the voltage vector can be detected. It means that the vector „jumps", the time period of the sinusoid at the moment of the change can be shorter or longer than the previous or subsequent ones.

The main task of the vector jump protection function is to detect the unintended islanding, when the generator with some consumer area is disconnected from the electric power grid.

The application of the vector jump function needs careful setting. One of the problems is caused by the scenario, when the balance of the electric power before and after the islanding is not changing significantly (the generated and consumed power within the island is balanced). Accordingly the limit for jump detection must be set to a low angle value, but there is no guarantee that the islanding is detected by this method. At the same time, however, a switching of a relatively large consumer can cause also a vector jump. To prevent the unwanted trip, in this scenario the setting limit for the vector jump angle should be selected large.

For vector jump detection the function must be enabled, and the measured positive sequence voltage component must be above a minimum value.

If a fault occurs on the network, the voltage vector jumps. In this case a decision is needed if the role of the vector jump function is the fault protection, or the fault is to be cleared at other locations of the network. For excluding the operation in case of asymmetrical faults, the negatives sequence and zero sequence voltage components must be supervised. If they are above the setting, asymmetrical fault is detected and the operation of the vector jump protection function is blocked.

For vector jump detection the function must be enabled, and the measured voltage must be above a minimum value. For disabling the operation in case of low voltage an additional undervoltage binary input is provided.

If the network frequency is deviating from the nominal frequency then the voltage vector rotates slowly in the complex coordinate system. As the vector jump detection function is based on comparison of the vectors of the actual and some previous states, the vector rotation caused by the frequency deviation must be compensated. For this purpose also the network frequency is measured continuously.

Technical data

Function	Value	Accuracy
Pick-up starting accuracy		< ± 0,5°
Blocking voltage	U>0.2Un	< 5%
Operate time Jump>2*setting	<50 ms	
Minimum operate time	40 ms	
Pulse duration	150 … 500 ms	<10 ms

Table 107 Technical data of the vector jump protection function

The parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Enabling or disabling the vector jump protection function			
VectJmp_Oper_EPar_	Operation	Off,On	Off

Table 108 The enumerated parameters of the vector jump protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Starting phase difference level setting. If the vector jump is above the setting value, the function generates a start signal.						
VectJmp_PhDiff_IPar_	PhaseDiff Limit	deg	5	25	1	10
Enabling positive voltage level setting. If the measured positive sequence voltage component is above the setting value, the function enables the trip signal.						
VectJmp_UposLim_IPar_	Min PosSeq Voltage	%	10	100	1	30
Blocking negative sequence voltage level setting. If the measured negative sequence voltage component is above the setting value, the function blocks the trip signal.						
VectJmp_UnegLim_IPar_	Max NegSeq Voltage	%	5	50	1	10
Blocking zero sequence voltage level setting. If the measured voltage is above the setting value, the function blocks the trip signal.						
VectJmp_UoLim_IPar_	Max ZeroSeq Voltage	%	1	30	1	5

Table 109 Integer parameters of the vector jump protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Trip command pulse duration						
VectJmp_Pulse_TPar_	Pulse Duration	msec	150	500	1	150

Table 110 Timer parameter of the vector jump protection function

Loss of excitation protection function (UEX_40Z) – S24/G only

The loss of excitation protection function can be applied mainly for synchronous generators. On loss of excitation, the flux decreases relatively slowly and at the end the machine draws high reactive current from the power system. To protect the stator coils from the harmful effects of the high currents and to protect the rotor from damages caused by the induced slip-frequency current, a disconnection is required.

The loss of excitation (loss-of-field) protection function is designed for this purpose.

When the excitation is removed then a relatively high inductive current flows into the generator. With the positive direction from the generator to the network, the calculated impedance based on this current and on the phase voltage is a negative reactive value. As the internal e.m.f. collapses, the locus of the impedance on the impedance plane travels to this negative reactive value. With an appropriate characteristic curve on the impedance plane, the loss of excitation state can be detected. The applied characteristic line is a closed offset circle, the radius and the centre of which is defined by parameter setting.

If the calculated impedance is within the offset circle then the function generates a trip command.

The loss of excitation protection function provides two stages, where the parameters of the circles and additionally the delay times can be set independently.

The main features of the loss of excitation protection function are as follows:

- A full-scheme system provides continuous measurement of impedances separately in three independent phase-to-phase measuring loops.
- Impedance calculation is conditional on the values of phase currents being sufficient.
- The operate decision is based on offset circle characteristics.
    - Two independent stages.
- Binary input signals and conditions can influence the operation:
    - Blocking/enabling.
    - VT failure signal.

Technical data

Function	Range	Accuracy
Rated current In	1/5A, parameter setting	
Rated Voltage Un	100/200V, parameter setting	
Current effective range	20 – 2000% of In	±1% of In
Voltage effective range	2-110 % of Un	±1% of Un
Impedance effective range In=1A In=5A	0.1 – 200 Ohm 0.1 – 40 Ohm	±5%
Zone static accuracy	48 Hz – 52 Hz 49.5 Hz – 50.5 Hz	±5% ±2%
Operate time	Typically 25 ms	±3 ms
Minimum operate time	<20 ms	
Reset time	16 – 25 ms	
Reset ratio	1.1	

Table 111 - The technical data of the loss of excitation function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Parameter for disabling stage 1			
UEX_40Z_Op1_EPar_	Stage 1 Operation	Off, On	Off
Parameter for disabling stage 1			
UEX_40Z _Op2_EPar_	Stage 2 Operation	Off, On	Off

Table 112 - The enumerated parameters of the loss of excitation function

Boolean parameters

Parameter name	Title	Default	Explanation
Boolean parameter to disable the trip command for stage 1			
UEX_40Z _StOnly1_BPar_	Impedance Start Only	0	Set 0 value to generate also an operate signal
Boolean parameter to disable the trip command for stage 2			
UEX_40Z _StOnly2_BPar_	Impedance Start Only	0	Set 0 value to generate also an operate signal

Table 113 - The Boolean parameters of the loss of excitation function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Definition of minimal current enabling impedance calculation:						
UEX_40Z_Imin_IPar_	IPh Base Sens	%	10	30	1	20

Table 114 - Integer parameter of the loss of excitation function

Float parameters

Parameter name	Title	Unit	Min	Max	Digits	Default
Raduis of the circle of stage 1						
UEX_40Z _Z_1_FPar_	Stage1 Z	ohm	0.1	250	2	10.0
X offset of the circle of stage 1						
UEX_40Z _Z1_1_FPar_	Stage1 X offset	ohm	0.1	250	2	10.0
R offset of the circle of stage 1						
UEX_40Z _Z1_2_FPar_	Stage1 R offset	ohm	0.0	100	2	0.0
Raduis of the circle of stage 2						
UEX_40Z _Z_2_FPar_	Stage2 Z	ohm	0.1	250	2	10.0
X offset of the circle of stage 2						
UEX_40Z _Z2_1_FPar_	Stage2 X offset	ohm	0.1	250	2	10.0
R offset of the circle of stage 2						
UEX_40Z _Z2_2_FPar_	Stage2 R offset	ohm	0.0	100	2	0.0

Table 115 - The float parameters of the loss of excitation function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for stage 1						
UEX_40Z _Del1_TPar_	Stage1 Delay	msec	0	60000	1	500
Time delay for stage 2						
UEX_40Z _Del2_TPar_	Stage2 Delay	msec	0	60000	1	500

Table 116 - The timer parameters of the loss of excitation function

Measuring functions

The measured values can be checked on the touch-screen of the device in the “On-line functions” page, or using an Internet browser of a connected computer. The displayed values are secondary voltages and currents, except the block “Line measurement”. This specific block displays the measured values in primary units, using VT and CT primary value settings.

Analog value	**Explanation**
VT4 module	
Voltage Ch – U1	RMS value of the Fourier fundamental harmonic voltage component in phase L1
Angle Ch – U1	Phase angle of the Fourier fundamental harmonic voltage component in phase L1*
Voltage Ch – U2	RMS value of the Fourier fundamental harmonic voltage component in phase L2
Angle Ch – U2	Phase angle of the Fourier fundamental harmonic voltage component in phase L2*
Voltage Ch – U3	RMS value of the Fourier fundamental harmonic voltage component in phase L3
Angle Ch – U3	Phase angle of the Fourier fundamental harmonic voltage component in phase L3*
Voltage Ch – U4	RMS value of the Fourier fundamental harmonic voltage component in Channel U4
Angle Ch – U4	Phase angle of the Fourier fundamental harmonic voltage component in Channel U4*
CT4 module	
Current Ch - I1	RMS value of the Fourier fundamental harmonic current component in phase L1
Angle Ch - I1	Phase angle of the Fourier fundamental harmonic current component in phase L1*
Current Ch - I2	RMS value of the Fourier fundamental harmonic current component in phase L2
Angle Ch - I2	Phase angle of the Fourier fundamental harmonic current component in phase L2*
Current Ch - I3	RMS value of the Fourier fundamental harmonic current component in phase L3
Angle Ch - I3	Phase angle of the Fourier fundamental harmonic current component in phase L3*
Current Ch - I4	RMS value of the Fourier fundamental harmonic current component in Channel I4
Angle Ch - I4	Phase angle of the Fourier fundamental harmonic current component in Channel I4*
Line measurement (MXU_L) (here the displayed information means primary value)	
Active Power – P	Three-phase active power
Reactive Power – Q	Three-phase reactive power
Apparent Power – S	Three-phase power based on true RMS voltage and current measurement
Current L1	True RMS value of the current in phase L1
Current L2	True RMS value of the current in phase L2
Current L3	True RMS value of the current in phase L3
Voltage L1	True RMS value of the voltage in phase L1
Voltage L2	True RMS value of the voltage in phase L2
Voltage L3	True RMS value of the voltage in phase L3

Voltage L12	True RMS value of the voltage between phases L1 L2
Voltage L23	True RMS value of the voltage between phases L2 L3
Voltage L31	True RMS value of the voltage between phases L3 L1
Frequency	Frequency

* *The reference angle is the phase angle of "Voltage Ch - U1"*

Table 117 Measured analog values

Voltage input function (VT4)

If the factory configuration includes a voltage transformer hardware module, the voltage input function block is automatically configured among the software function blocks. Separate voltage input function blocks are assigned to each voltage transformer hardware module.

A voltage transformer hardware module is equipped with four special intermediate voltage transformers. As usual, the first three voltage inputs receive the three phase voltages (UL1, UL2, UL3), the fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchron switching. All inputs have a common parameter for type selection: 100V or 200V.

Additionally, there is a correction factor available if the rated secondary voltage of the main voltage transformer (e.g. 110V) does not match the rated input of the device.

The role of the voltage input function block is to

- set the required parameters associated to the voltage inputs,
- deliver the sampled voltage values for disturbance recording,
- perform the basic calculations
  - Fourier basic harmonic magnitude and angle,
  - True RMS value;
- provide the pre-calculated voltage values to the subsequent software modules,
- deliver the basic calculated values for on-line displaying.

Operation of the voltage input algorithm

The voltage input function block receives the sampled voltage values from the internal operating system. The scaling (even hardware scaling) depends on parameter setting. See the parameter VT4_Type_EPar_ (Range). The options to choose from are 100V or 200V. This parameter influences the internal number format and, naturally, accuracy. (A small voltage is processed with finer resolution if 100V is selected.)

The connection of the first three VT secondary winding must be set to reflect actual physical connection. The associated parameter is VT4_Ch13Nom_EPar_ (Connection U1-3). The selection can be: Ph-N, Ph-Ph or Ph-N-Isolated.

The Ph-N option is applied in solidly grounded networks, where the measured phase voltage is never above 1.5-Un. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-NEUTRAL voltage.

The Ph-N option is applied in compensated or isolated networks, where the measured phase voltage can be above 1.5-Un even in normal operation. In this case the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage.

If phase-to-phase voltage is connected to the VT input of the device, then the Ph-Ph option is to be selected. Here, the primary rated voltage of the VT must be the value of the rated PHASE-TO-PHASE voltage. This option must not be selected if the distance protection function is supplied from the VT input.

The fourth input is reserved for zero sequence voltage or for a voltage from the other side of the circuit breaker for synchron switching. Accordingly, the connected voltage must be identified with parameter setting VT4_Ch4Nom_EPar_ (Connection U4). Here, phase-to-neutral or phase-to-phase voltage can be selected: Ph-N,Ph-Ph

If needed, the phase voltages can be inverted by setting the parameter VT4_Ch13Dir_EPar_ (Direction U1-3). This selection applies to each of the channels UL1, UL2 and UL3. The fourth voltage channel can be inverted by setting the parameter VT4_Ch4Dir_EPar_ (Direction U4). This inversion may be needed in protection functions such as distance protection, differential protection or for any functions with directional decision, or for checking the voltage vector positions.

Additionally, there is a correction factor available if the rated secondary voltage of the main voltage transformer (e.g. 110V) does not match the rated input of the device. The related parameter is VT4_CorrFact_IPar_ (VT correction). As an example: if the rated secondary voltage of the main voltage transformer is 110V, then select Type 100 for the parameter "Range" and the required value to set here is 110%.

These sampled values are available for further processing and for disturbance recording.

The performed basic calculation results the Fourier basic harmonic magnitude and angle and the true RMS value of the voltages. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

The function block also provides parameters for setting the primary rated voltages of the main voltage transformer. This function block does not need that parameter setting. These values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc. Concerning the rated voltage, see the instructions related to the parameter for the connection of the first three VT secondary winding.

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary voltage of the input channels. 100 V or 200V is selected by parameter setting, no hardware modification is needed.			
VT4_Type_EPar_	Range	Type 100,Type 200	Type 100
Connection of the first three voltage inputs (main VT secondary)			
VT4_Ch13Nom_EPar_	Connection U1-3	Ph-N, Ph-Ph, Ph-N-Isolated	Ph-N
Selection of the fourth channel input: phase-to-neutral or phase-to-phase voltage			
VT4_Ch4Nom_EPar_	Connection U4	Ph-N,Ph-Ph	Ph-Ph
Definition of the positive direction of the first three input channels, given as normal or inverted			
VT4_Ch13Dir_EPar_	Direction U1-3	Normal,Inverted	Normal
Definition of the positive direction of the fourth voltage, given as normal or inverted			
VT4_Ch4Dir_EPar_	Direction U4	Normal,Inverted	Normal

Table 118 The enumerated parameters of the voltage input function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage correction						
VT4_CorrFact_IPar_	VT correction	%	100	115	1	100

Table 119 The integer parameter of the voltage input function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary voltage of channel1					
VT4_PriU1_FPar	Rated Primary U1	kV	1	1000	100
Rated primary voltage of channel2					
VT4_PriU2_FPar	Rated Primary U2	kV	1	1000	100
Rated primary voltage of channel3					
VT4_PriU3_FPar	Rated Primary U3	kV	1	1000	100
Rated primary voltage of channel4					
VT4_PriU4_FPar	Rated Primary U4	kV	1	1000	100

Table 120 The floating point parameters of the voltage input function

NOTE: The rated primary voltage of the channels is not needed for the voltage input function block itself. These values are passed on to the subsequent function blocks.

Function	Range	Accuracy
Voltage accuracy	30% … 130%	< 0.5 %

Table 121 Technical data of the voltage input

Measured values

Measured value	Dim.	Explanation
Voltage Ch - U1	V(secondary)	Fourier basic component of the voltage in channel UL1
Angle Ch - U1	degree	Vector position of the voltage in channel UL1
Voltage Ch – U2	V(secondary)	Fourier basic component of the voltage in channel UL2
Angle Ch – U2	degree	Vector position of the voltage in channel UL2
Voltage Ch – U3	V(secondary)	Fourier basic component of the voltage in channel UL3
Angle Ch – U3	degree	Vector position of the voltage in channel UL3
Voltage Ch – U4	V(secondary)	Fourier basic component of the voltage in channel U4
Angle Ch – U4	degree	Vector position of the voltage in channel U4

Table 122 The measured analogue values of the voltage input function

NOTE1: The scaling of the Fourier basic component is such if pure sinusoid 57V RMS of the rated frequency is injected, the displayed value is 57V. (The displayed value does not depend on the parameter setting values “Rated Secondary”.)

NOTE2: The reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module.

The figure below shows an example of how the calculated Fourier components are displayed in the on-line block.

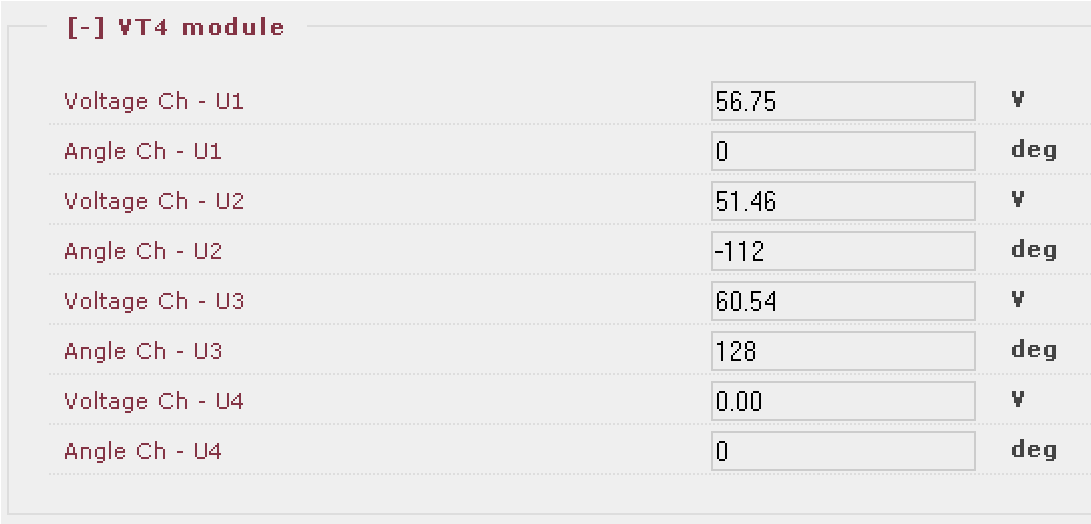


Figure 7 Example: On-line displayed values for the voltage input module

Current input function (CT4)

If the factory configuration includes a current transformer hardware module, the current input function block is automatically configured among the software function blocks. Separate current input function blocks are assigned to each current transformer hardware module.

A current transformer hardware module is equipped with four special intermediate current transformers. As usual, the first three current inputs receive the three phase currents (IL1, IL2, IL3), the fourth input is reserved for zero sequence current, for the zero sequence current of the parallel line or for any additional current. Accordingly, the first three inputs have common parameters while the fourth current input needs individual setting.

The role of the current input function block is to

- set the required parameters associated to the current inputs,
- deliver the sampled current values for disturbance recording,
- perform the basic calculations
  - Fourier basic harmonic magnitude and angle,
  - True RMS value;
- provide the pre-calculated current values to the subsequent software modules,
- deliver the basic calculated values for on-line displaying.

Operation of the current input algorithm

The current input function block receives the sampled current values from the internal operating system. The scaling (even hardware scaling) depends on parameter setting. See parameters CT4_Ch13Nom_EPar_ (Rated Secondary I1-3) and CT4_Ch4Nom_EPar_ (Rated Secondary I4). The options to choose from are 1A or 5A (in special applications, 0.2A or 1A). This parameter influences the internal number format and, naturally, accuracy. (A small current is processed with finer resolution if 1A is selected.)

If needed, the phase currents can be inverted by setting the parameter CT4_Ch13Dir_EPar_ (Starpoint I1-3). This selection applies to each of the channels IL1, IL2 and IL3. The fourth current channel can be inverted by setting the parameter CT4_Ch4Dir_EPar (Direction I4). This inversion may be needed in protection functions such as distance protection, differential protection or for any functions with directional decision.

These sampled values are available for further processing and for disturbance recording.

The performed basic calculation results the Fourier basic harmonic magnitude and angle and the true RMS value. These results are processed by subsequent protection function blocks and they are available for on-line displaying as well.

The function block also provides parameters for setting the primary rated currents of the main current transformer. This function block does not need that parameter setting. These values are passed on to function blocks such as displaying primary measured values, primary power calculation, etc.

Technical data

Function	Range	Accuracy
Current accuracy	20 – 2000% of In	±1% of In

Table 123 Technical data of the current input

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Rated secondary current of the first three input channels. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch13Nom_EPar_	Rated Secondary I1-3	1A,5A	1A
Rated secondary current of the fourth input channel. 1A or 5A is selected by parameter setting, no hardware modification is needed.			
CT4_Ch4Nom_EPar_	Rated Secondary I4	1A,5A (0.2A or 1A)	1A
Definition of the positive direction of the first three currents, given by location of the secondary star connection point			
CT4_Ch13Dir_EPar_	Starpoint I1-3	Line,Bus	Line
Definition of the positive direction of the fourth current, given as normal or inverted			
CT4_Ch4Dir_EPar_	Direction I4	Normal,Inverted	Normal

Table 124 The enumerated parameters of the current input function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Rated primary current of channel1					
CT4_PriI1_FPar_	Rated Primary I1	A	100	4000	1000
Rated primary current of channel2					
CT4_PriI2_FPar	Rated Primary I2	A	100	4000	1000
Rated primary current of channel3					
CT4_PriI3_FPar_	Rated Primary I3	A	100	4000	1000
Rated primary current of channel4					
CT4_PriI4_FPar_	Rated Primary I4	A	100	4000	1000

Table 125 The floating point parameters of the current input function

NOTE: The rated primary current of the channels is not needed for the current input function block itself. These values are passed on to the subsequent function blocks.

The **measured values** of the current input function block.

Measured value	Dim.	Explanation
Current Ch - I1	A(secondary)	Fourier basic component of the current in channel IL1
Angle Ch - I1	degree	Vector position of the current in channel IL1
Current Ch – I2	A(secondary)	Fourier basic component of the current in channel IL2
Angle Ch – I2	degree	Vector position of the current in channel IL2
Current Ch – I3	A(secondary)	Fourier basic component of the current in channel IL3
Angle Ch – I3	degree	Vector position of the current in channel IL3
Current Ch – I4	A(secondary)	Fourier basic component of the current in channel I4
Angle Ch – I4	degree	Vector position of the current in channel I4

Table 126 The measured analogue values of the current input function

NOTE1: The scaling of the Fourier basic component is such that if pure sinusoid 1A RMS of the rated frequency is injected, the displayed value is 1A. (The displayed value does not depend on the parameter setting values “Rated Secondary”.)

NOTE2: The reference of the vector position depends on the device configuration. If a voltage input module is included, then the reference vector (vector with angle 0 degree) is the vector calculated for the first voltage input channel of the first applied voltage input module. If no voltage input module is configured, then the reference vector (vector with angle 0 degree) is the vector calculated for the first current input channel of the first applied current input module.

Erreur ! Source du renvoi introuvable. shows an example of how the calculated Fourier components are displayed in the on-line block.

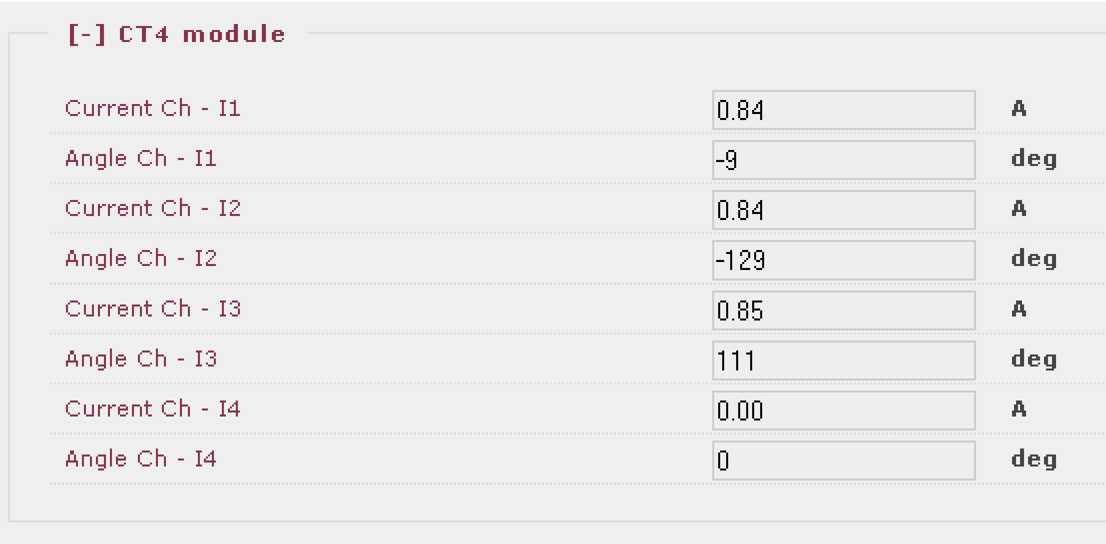


Figure 8 Example: On-line displayed values for the current input module

Line measurement function (MXU)

The measurement

The input values of the SMARTLINE devices are the secondary signals of the voltage transformers and those of the current transformers.

These signals are pre-processed by the “Voltage transformer input” function block and by the “Current transformer input” function block. These function blocks are described in separate documents. The pre-processed values include the Fourier basic harmonic phasors of the voltages and currents and the true RMS values. Additionally, it is in these function blocks that parameters are set concerning the voltage ratio of the primary voltage transformers and current ratio of the current transformers.

Based on the pre-processed values and the measured transformer parameters, the “Line measurement” function block calculates - depending on the hardware and software configuration - the primary RMS values of the voltages and currents and some additional values such as active and reactive power, symmetrical components of voltages and currents. These values are available as primary quantities and they can be displayed on the on-line screen of the device or on the remote user interface of the computers connected to the communication network and they are available for the SCADA system using the configured communication system.

Reporting the measured values and the changes

It is usual for the SCADA systems that they sample the measured and calculated values in regular time periods and additionally they receive the changed values as reports at the moment when any significant change is detected in the primary system. The “Line measurement” function block is able to perform such reporting for the SCADA system.

Operation of the line measurement function block

The **inputs** of the line measurement function are

- the Fourier components and true RMS values of the measured voltages and currents,
- frequency measurement,
- parameters.

The **outputs** of the line measurement function are

- displayed measured values,
- reports to the SCADA system.

NOTE: the scaling values are entered as parameter setting for the “Voltage transformer input” function block and for the “Current transformer input” function block.

The measured values

The **measured values** of the line measurement function depend on the hardware configuration. As an example, Table 127 shows the list of the measured values available in a configuration for solidly grounded networks.

Measured value	Explanation
MXU_P_OLM_	Active Power – P (Fourier base harmonic value)
MXU_Q_OLM_	Reactive Power – Q (Fourier base harmonic value)
MXU_S_OLM_	Apparent Power – S (Fourier base harmonic value)
MXU_I1_OLM_	Current L1
MXU_I2_OLM_	Current L2
MXU_I3_OLM_	Current L3
MXU_U1_OLM_	Voltage L1
MXU_U2_OLM_	Voltage L2
MXU_U3_OLM_	Voltage L3
MXU_U12_OLM_	Voltage L12
MXU_U23_OLM_	Voltage L23
MXU_U31_OLM_	Voltage L31
MXU_f_OLM_	Frequency

Table 127 Example: Measured values in a configuration for solidly grounded networks

Another example is Figure 9, where the measured values available are shown as on-line information in a configuration for compensated networks.

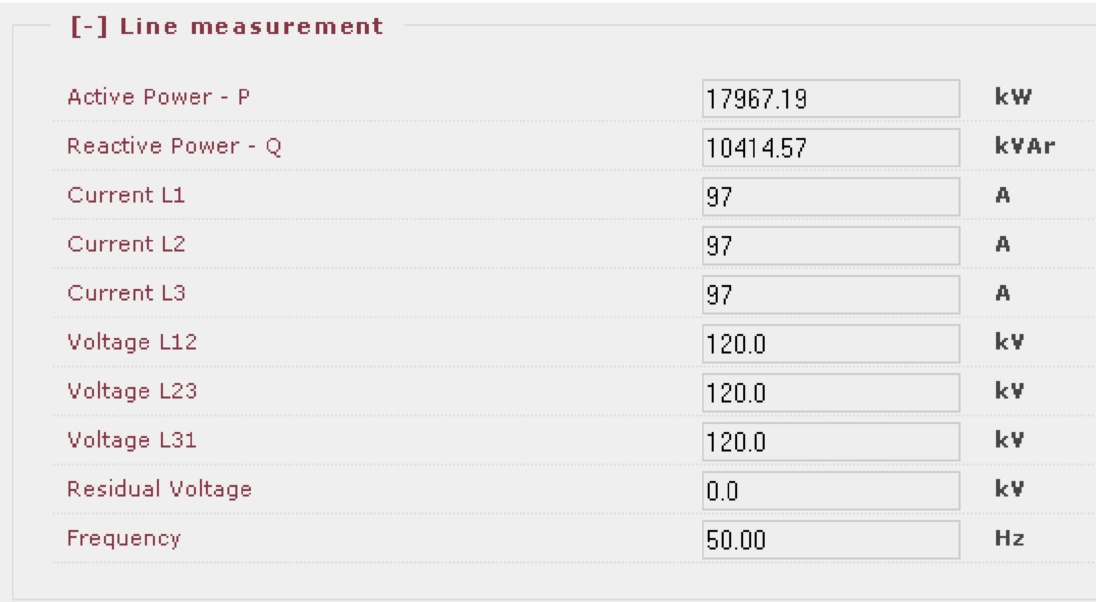


Figure 9 Example: Measured values in a configuration for compensated networks

The available quantities are described in the configuration description documents.

Reporting the measured values and the changes

For reporting, additional information is needed, which is defined in parameter setting.
As an example, in a configuration for solidly grounded networks the following parameters are available:

Enumerated parameters

Parameter name	Title	Selection range	Default
Selection of the reporting mode for active power measurement			
MXU_PRepMode_EPar_	Operation ActivePower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for reactive power measurement			
MXU_QRepMode_EPar_	Operation ActivePower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for apparent power measurement			
MXU_SRepMode_EPar_	Operation ApparPower	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for current measurement			
MXU_IRepMode_EPar_	Operation Current	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for voltage measurement			
MXU_URepMode_EPar_	Operation Voltage	Off, Amplitude, Integrated	Amplitude
Selection of the reporting mode for frequency measurement			
MXU_fRepMode_EPar_	Operation Frequency	Off, Amplitude, Integrated	Amplitude

Table 128 The enumerated parameters of the line measurement function

The selection of the reporting mode items is explained in Figure 10 and in Figure 11.

"Amplitude" mode of reporting

If the "Amplitude" mode is selected for reporting, a report is generated if the measured value leaves the deadband around the previously reported value. As an example, Figure 10 shows that the current becomes higher than the value reported in "report1" PLUS the Deadband value, this results "report2", etc.

For this mode of operation, the Deadband parameters are explained in Table 129.

The "Range" parameters in Table 129 are needed to evaluate a measurement as "out-of-range".

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Step	Default
Deadband value for the active power						
MXU_PDeadB_FPar_	Deadband value - P	MW	0.1	100000	0.01	10
Range value for the active power						
MXU_PRange_FPar_	Range value - P	MW	1	100000	0.01	500
Deadband value for the reactive power						
MXU_QDeadB_FPar_	Deadband value - Q	MVAr	0.1	100000	0.01	10
Range value for the reactive power						
MXU_QRange_FPar_	Range value - Q	MVAr	1	100000	0.01	500
Deadband value for the apparent power						
MXU_SDeadB_FPar_	Deadband value - S	MVA	0.1	100000	0.01	10
Range value for the apparent power						
MXU_SRange_FPar_	Range value - S	MVA	1	100000	0.01	500
Deadband value for the current						
MXU_IDeadB_FPar_	Deadband value - I	A	1	2000	1	10
Range value for the current						
MXU_IRange_FPar_	Range value - I	A	1	5000	1	500
Deadband value for the phase-to-neutral voltage						
MXU_UPhDeadB_FPar_	Deadband value – U ph-N	kV	0.1	100	0.01	1
Range value for the phase-to-neutral voltage						
MXU_UPhRange_FPar_	Range value – U ph-N	kV	1	1000	0.1	231
Deadband value for the phase-to-phase voltage						
MXU_UPPDeadB_FPar_	Deadband value – U ph-ph	kV	0.1	100	0.01	1
Range value for the phase-to-phase voltage						
MXU_UPPRange_FPar_	Range value – U ph-ph	kV	1	1000	0.1	400
Deadband value for the current						
MXU_fDeadB_FPar_	Deadband value - f	Hz	0.01	1	0.01	0.02
Range value for the current						
MXU_fRange_FPar_	Range value - f	Hz	0.05	10	0.01	5

Table 129 The floating-point parameters of the line measurement function

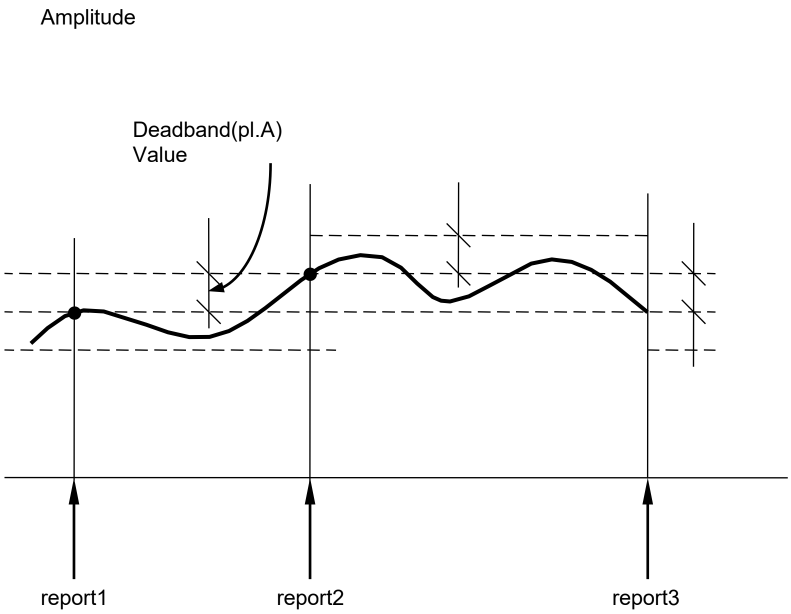


Figure 10 Reporting if "Amplitude" mode is selected

"Integral" mode of reporting

If the "Integrated" mode is selected for reporting, a report is generated if the time integral of the measured value since the last report gets becomes larger, in the positive or negative direction, then the (deadband*1sec) area. As an example, Figure 11 shows that the integral of the current in time becomes higher than the Deadband value multiplied by 1sec, this results "report2", etc.

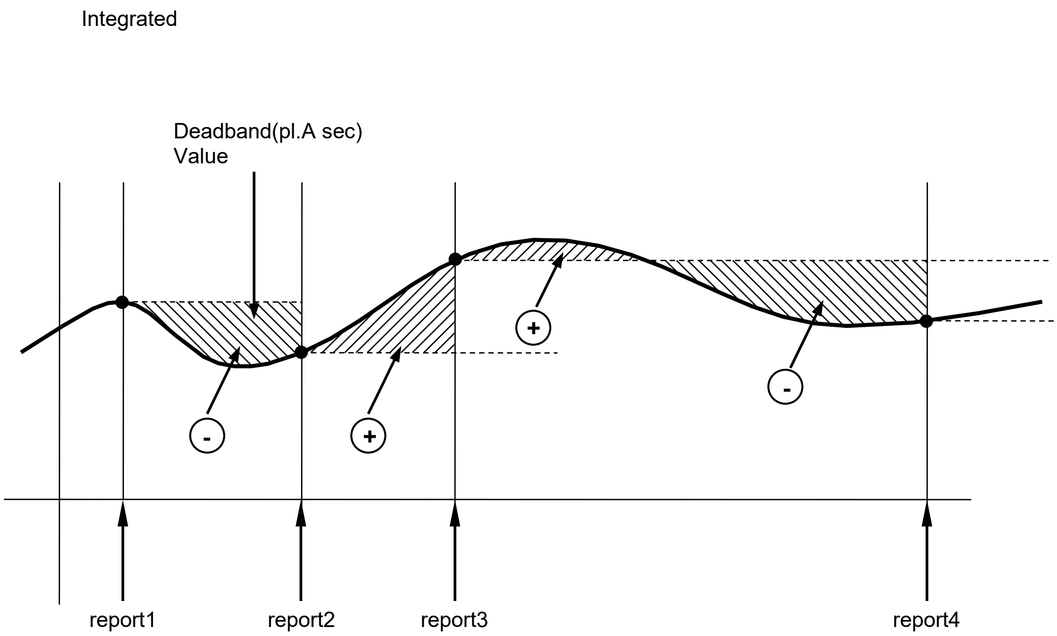


Figure 11 Reporting if "Integrated" mode is selected

Periodic reporting

Periodic reporting is generated independently of the changes of the measured values when the defined time period elapses. The required parameter setting is shown in Table 130.

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Reporting time period for the active power						
MXU_PIntPer_IPar_	Report period P	sec	0	3600	1	0
Reporting time period for the reactive power						
MXU_QIntPer_IPar_	Report period Q	sec	0	3600	1	0
Reporting time period for the apparent power						
MXU_SIntPer_IPar_	Report period S	sec	0	3600	1	0
Reporting time period for the voltage						
MXU_UIntPer_IPar_	Report period U	sec	0	3600	1	0
Reporting time period for the current						
MXU_IIntPer_IPar_	Report period I	sec	0	3600	1	0
Reporting time period for the frequency						
MXU_fIntPer_IPar_	Report period f	sec	0	3600	1	0

Table 130 The integer parameters of the line measurement function

If the reporting time period is set to 0, then no periodic reporting is performed for this quantity.

All reports can be disabled for a quantity if the reporting mode is set to “Off”. See Table 128.

Technical data

Function	Range	Accuracy
Current accuracy		
with CT/5151 or CT/5102 modules	0,2 In – 0,5 In	±2%, ±1 digit
	0,5 In – 20 In	±1%, ±1 digit
with CT/1500 module	0,03 In – 2 In	±0,5%, ±1 digit
Voltage accuracy	5 – 150% of Un	±0.5% of Un, ±1 digit
Power accuracy	I>5% In	±3%, ±1 digit
Frequency accuracy	U>3.5%Un 45Hz – 55Hz	2mHz

Table 131 Technical data of line measurement

Disturbance recorder

The S24/Fr or /G configuration contains a disturbance recorder function. The details are described in the document shown in Table 132.

Name	Title	Document
DRE	Disturbance Rec	***Disturbance recorder function block description***

Table 132 Implemented disturbance recorder function

The recorded analog channels:

Recorded analog signal	Explanation
UL1	Measured voltage of line 1
UL2	Measured voltage of line 2
UL3	Measured voltage of line 3
U4	Measured voltage of the fourth voltage input channel (Uo)
IL1	Measured current for all overcurrent protection functions in line 1
IL2	Measured current for all overcurrent protection functions in line 2
IL3	Measured current for all overcurrent protection functions in line 3
I4	Measured current of the fourth current input channel (Io)

Table 133 Disturbance recorder, recorded analog channels

The recorded binary channels:

Recorded binary signal	Explanation
Trip	Trip command of the trip logic function
Inst OC Trip	Trip command of the 3ph instantaneous OC prot. function
Res Inst OC Trip	Trip command of the residual instantaneous OC prot. function
Time OC Start Low	Low setting stage start signal of the 3ph time OC prot. function
Time OC Start High	High setting stage start signal of the 3ph time OC prot. function
Res Time OC Start Low	Low setting stage start signal of the residual time OC prot. function
Res Time OC Start High	High setting stage start signal of the residual time OC prot. function
Therm OL Alarm	Alarm signal of the thermal overload prot.
Dir OC Start Low	Low setting stage start signal of the 3ph directional OC prot. funct.
Dir OC Start High	High setting stage start signal of the 3ph directional OC prot. funct.
Res Dir OC Start Low	Low setting stage start signal of the residual directional OC prot.
Res Dir OC Start High	High setting stage start signal of the residual directional OC prot.
Overfrequ Start Low	Low setting stage start signal of the overfrequency prot. function
Overfrequ Start High	High setting stage start signal of the overfrequency prot. function
Underfrequ Start Low	Low setting stage start signal of the underfrequency prot. function
Underfrequ Start High	High setting stage start signal of the underfrequency prot. function
ROC of Frequ Start	Start signal of the rate of change of frequency prot. function
Overvoltage Start Low	Low setting stage start signal of the definite time overvoltage prot.
Overvoltage Start High	High setting stage start signal of the definite time overvoltage prot.
Res Overvolt Start Low	Low setting stage start signal of the residual overvoltage prot.
Res Overvolt Start High	High setting stage start signal of the residual overvoltage prot.

Undervoltage Start Low	Low setting stage start signal of the definite time undervoltage prot.
Undervoltage Start High	High setting stage start signal of the def. time undervoltage prot.
Unbalance Start	Unbalance signal of the current unbalance prot. function
Release Aut	Release auto signal of the synchrocheck function
REC Blocked	Blocked state of auto reclosing function
REC Close	Close command of auto reclosing function

Table 134 Disturbance recorder, recorded binary channels

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for activation			
DRE_Oper_EPar_	Operation	Off, On	Off

Table 135 The enumerated parameter of the disturbance recorder function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Pre-fault time:						
DRE_PreFault_TPar_	PreFault	msec	100	1000	1	200
Post-fault time:						
DRE_PostFault_TPar_	PostFault	msec	100	1000	1	200
Overall-fault time limit:						
DRE_MaxFault_TPar_	MaxFault	msec	500	10000	1	1000

Table 136 The timer parameters of the disturbance recorder function

TRIP contact assignment

The procedures of command processing are shown in the following symbolical figure.

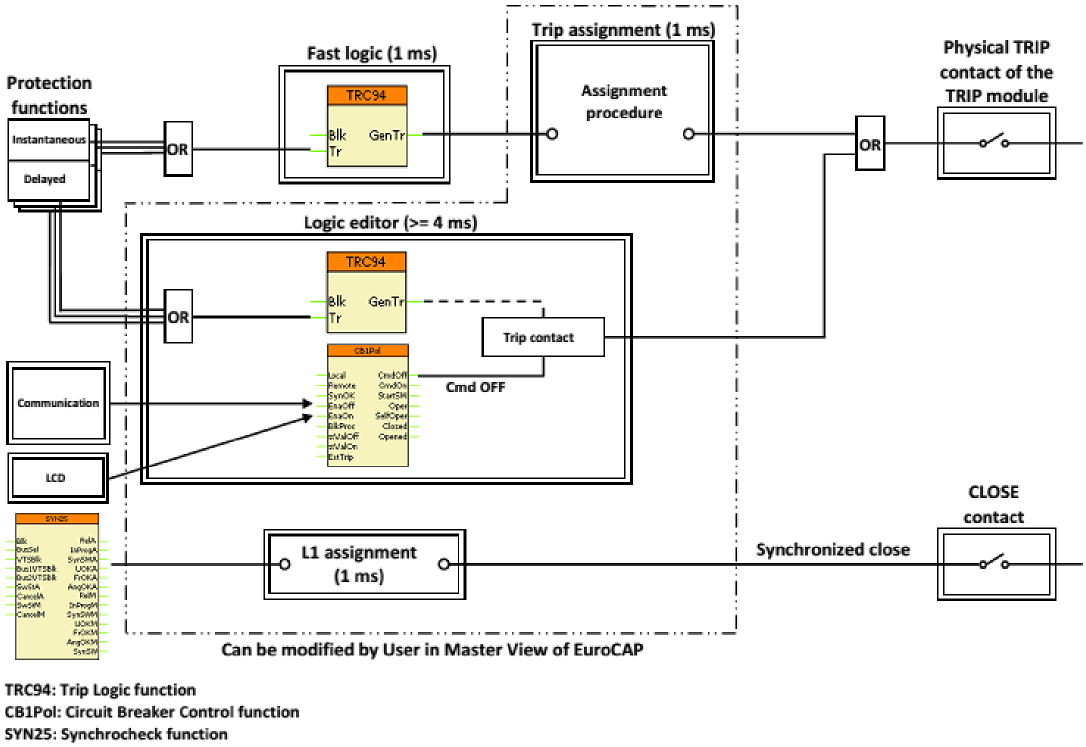


Figure 12 Principle of TRIP command processing

The left side of the Figure shows the available sources of the trip commands:

- The function blocks, configured in the device,
- The communication channels to the SCADA system,
- Commands generated using the front panel LCD of the device,
- Any other binary signals, e.g. signals from the binary inputs of the device.

The right side of the Figure shows one of the TRIP relays symbolically. The Figure provides a survey of the configured trip command processing methods. In the middle of the Figure, the locations indicated by “User” shows the possibilities for the user to modify the procedures. All other parts are factory programmed. The detailed description of the TRIP command processing can be found on the website in the following document: “**Application of high – speed TRIP contacts”**.

The outputs of the “Simplified trip logic function” are connected directly to the contacts of the trip module (PSTP+/2101 module in position “A”).

Binary status signal	**Title**	Connected to the contact PSTP+/2101 module in position “A”
TRC94_GenTr_Grl_	General Trip	Trip

Table 137 The connected signals of the phase-selective trip logic function

To the inputs of the "phase-selective trip logic function" some signals are assigned during factory configuration, some signals however depend on the programming by the user**. The conditions are defined by the user applying the graphic equation editor.** The factory defined inputs and the user defined inputs are in "**OR**" relationship.

Input	Binary status signal	Explanation
3Ph Trip	IOC50_GenTr_GrI_ OR IOC50N_GenTr_GrI_	Trip command of the instantaneous overcurrent protection function OR Trip command of the residual instantaneous overcurrent protection function
Block	n.a.	Blocking the outputs of the phase-selective trip logic function

Table 138 The factory defined binary input signals of the trip logic function

The user defined signals are listed in Table 139.

Input	Binary status signal	Explanation
3ph Trip	TRC94__GrO_	Request for three-phase trip command
Block	TRC94_Blk_GrO_	Blocking the outputs of the phase-selective trip logic function

Table 139 The user defined binary input signals of the trip logic function

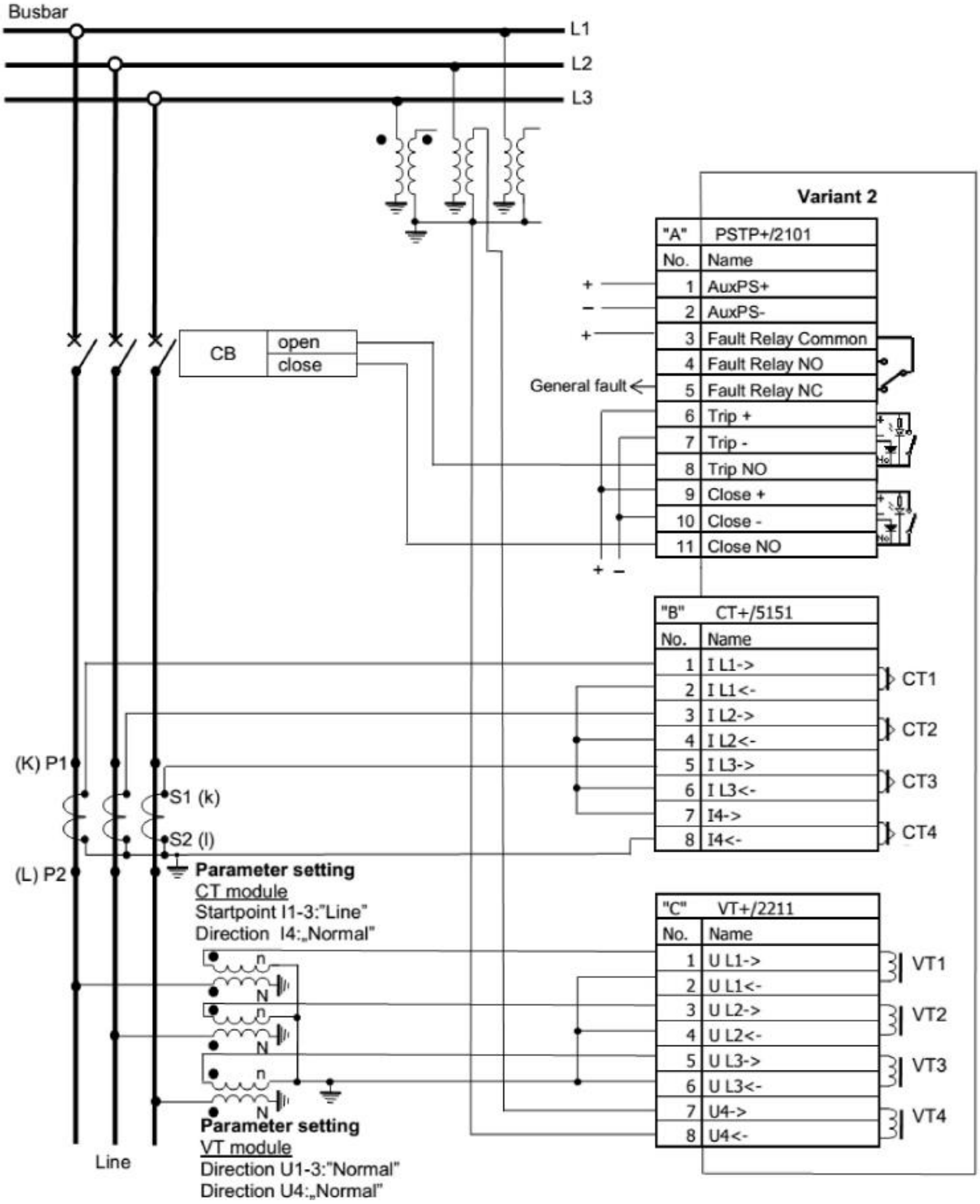
LED assignment

On the front panel of the device there are "User LED"-s with the "Changeable LED description label" (See the document "***Quick start guide to the devices of the PROTECTA product line***"). Some LED-s are factory assigned, some are free to be defined by the user.

LED	Explanation
General Trip	Trip command generated by the trip logic function
OC Trip	Trip command generated by the phase OC protection functions
Res OC Trip	Trip command generated by the residual OC protection functions
LED3104	Free LED, it can be configured by the costumer
LED3105	Free LED, it can be configured by the costumer
LED3106	Free LED, it can be configured by the costumer
LED3107	Free LED, it can be configured by the costumer
AR Blocked	Blocked state of the automatic reclosing function
OC Dir Trip	Trip command generated by the Dir OC protection functions
OCN Dir Trip	Trip command generated by the Dir Residual OC protection functions
LED3111	Free LED, it can be configured by the costumer
LED3112	Free LED, it can be configured by the costumer
LED3113	Free LED, it can be configured by the costumer
LED3114	Free LED, it can be configured by the costumer
LED3115	Free LED, it can be configured by the costumer
LED3116	Free LED, it can be configured by the costumer
AutoReclose	Close command of auto-reclosing function

Table 140 LED assignment

EXTERNAL CONNECTIONS DU S24/FR OU S24/G



HARDWARE SPECIFICATION

System design

The Smartline S24 protection device line is a scalable hardware platform to adapt to different applications. Data exchange is performed via a 16-bit high-speed digital non-multiplexed parallel bus with the help of a backplane module. Each module is identified by its location and there is no difference between module slots in terms of functionality. The only restriction is the position of the CPU module because it is limited to the “CPU” position. The built-in self-supervisory function minimizes the risk of device malfunctions.

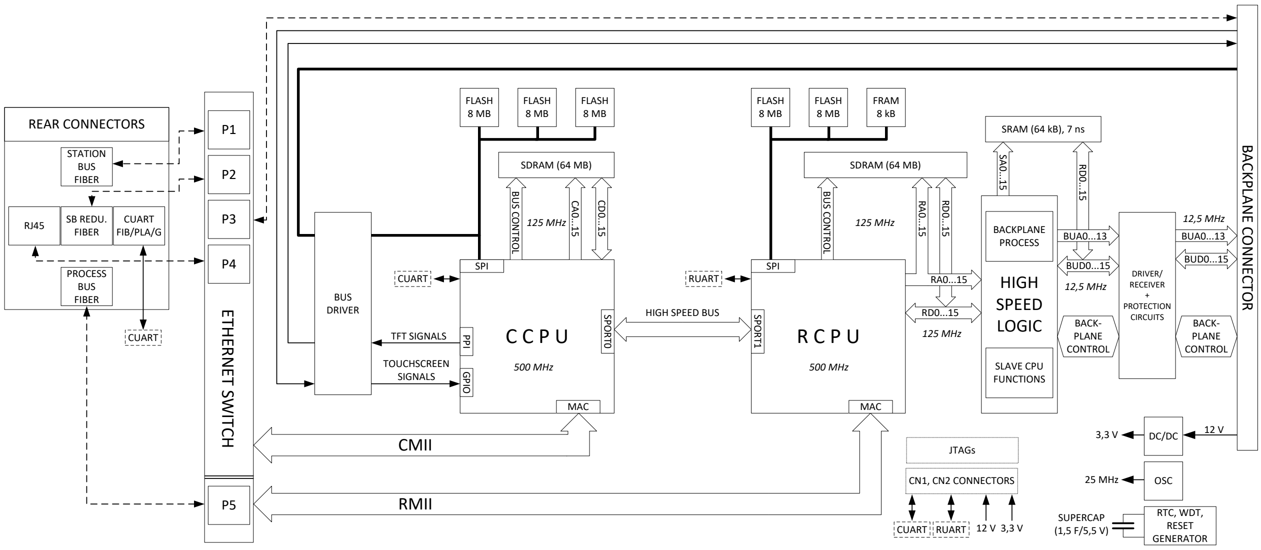


Figure 0-1 CPU block diagram

CPU module

CPU+ module

The CPU module contains all the protection, control and communication functions of the SMARTLINE S24 device. Dual 500 MHz high-performance Analog Devices Blackfin processors separate relay functions (RDSP) from communication and HMI functions (CDSP). Reliable communication between processors is performed via high-speed synchronous serial internal bus (SPORT).
Each processor has its own operative memory such as SDRAM and flash memories for configuration, parameter and firmware storage. CDSP’s operating system (uClinux) utilizes a robust JFFS flash file system, which enables fail-safe operation and the storage of disturbance record files, configuration and parameters.

Module handling

The RDSP core runs at 500 MHz and its external bus speed is 125 MHz. The backplane data speed is limited to approx. 20 MHz, which is more than enough for module data throughput. An additional logic element (CPLD and SRAM) is used as a bridge between the RDSP and the backplane. The CPLD collects analogue samples from CT/VT modules and also controls signaling outputs and inputs.

Fast startup

After power-up the RDSP processor starts up with the previously saved configuration and parameters. Generally, the power-up procedure for the RDSP and relay functions takes only a few seconds. That is to say, it is ready to trip within this time. CDSP's start-up procedure is longer because its operating system needs time to build its file system, initializing user applications such as HMI functions and the IEC61850 software stack.

HMI and communication tasks

- Embedded WEB-server:
    - Remote or local firmware upgrade possibility
    - Modification of user parameters
    - Events list and disturbance records
    - Password management
    - Online data measurement
    - Commands
    - Administrative tasks

- Front panel
    - TFT display handling: the interactive menu set is available through the TFT and the touchscreen interface
    - Black and white 128x64 pixels display with 4 tactile switches
- User keys:
    - tactile switches in B&W display configuration

The built-in 5-port Ethernet switch allows SMARTLINES24 to connect to IP/Ethernet-based networks. The following Ethernet ports are available:

- Station bus (100Base-FX Ethernet) SBW
- Redundant station bus (100Base-FX Ethernet) SBR
- Proprietary Process bus (100Base-FX Ethernet)
- RJ-45 Ethernet user interface
- Optional 10/100Base-T port via RJ-45 connector

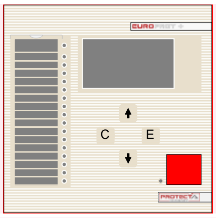
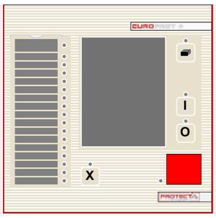
Other communication:

- RS422/RS485 interfaces (galvanic interface to support legacy or other serial protocols, ASIF)
- Plastic or glass fiber interfaces to support legacy protocols, ASIF

Human-Machine Interface (HMI) module

The SMARTLINE S24 device HMI consists of the following two main parts:

- HMI module, which is the front panel of the device,
- HMI functionality is the embedded web server and the intuitive menu system that is accessible through the HMI module. The web server is accessible via station bus or via RJ-45 Ethernet connector.

Module type	Display	User keys	Service port	Rack size	Illustration
HMI+2504	128 x 64 pixels, black and white	4 x tactile	RJ45 10/100Mbit/s	24 HP	
Optional HMI+2404	3,5" TFT	4 x tactile	RJ45 10/100Mbit/s	24 HP	

Main features of the HMI module

Function	Description
16 pieces user LEDs	Three-color, 3 mm circular LEDs
COM LED	Yellow, 3 mm circular LED indicating RJ-45 (on the front panel) communication link and activity
Device LED	1 piece three-color, 3 mm circular LED Green: normal device operation Yellow: device is in warning state Red: device is in error state
Tactile keys	Four tactile mechanical keys (On, Off, Page, LED acknowledgement)
Buzzer	Audible touch key pressure feedback
LED description	User changeable
3.5” or 128x64 pixels display	• 128 * 64 pixel B&W display • 320 × 240 pixel TFT display with resistive touchscreen interface (optional)
Ethernet service port	**IP56** rated Ethernet 10/100-Base-T interface with RJ-45 type connector

Detailed modules description

Regarding the other hardware modules detailed descriptions please find it in Smartline S24 Hardware description see the hardware description of PROTECTA range on our web site : www.microener.com

GENERAL DATA

- Storage temperature: -40 °C … +70 °C
- Operation temperature: -20 °C … +55 °C
- Humidity: 10 % - 93 %

- EMC/ESD standard conformance:
  - Electrostatic discharge (ESD) EN 61000-4-2, IEC 60255-22-2, Class 3
  - Electrical fast transients (EFT/B) EN 61000-4-4, IEC 60255-22-4, Class A
  - Surges EN 61000-4-5, IEC 60255-22-5
    - Test voltages: line to earth 4 kV, line to line 1 kV
    - Conducted radio-frequency common mode EN 61000-4-6, IEC 60255-22-6, Level 3
  - 1 MHz damped oscillatory waves IEC 60255-22-1
    - Test voltage: 2.5 kV (for common and differential mode alike)
  - Voltage interruptions IEC 60255-11
    - Duration: 5 s, Criterion for acceptance: C
  - Voltage dips and short interruptions EN 61000-4-11
    - Voltage during dips: 0%, 40%, 70%
  - Power frequency magnetic field EN 61000-4-8, Level 4
  - Power frequency IEC 60255-22-7, Class A
  - Impulse voltage withstand test EN 60255-5, Class III
  - Dielectric test EN 60255-5, Class III
  - Insulation resistance test EN 60255-5
  - Insulation resistance > 15 GΩ

- Radiofrequency interference test (RFI):
  - Radiated disturbance EN 55011, IEC 60255-25
  - Conducted disturbance at mains ports EN 55011, IEC 60255-255
  - Immunity tests according to the test specifications IEC 60255-26 (2004), EN 50263 (1999), EN 61000-6-2 (2001) and IEC TS 61000-6-5 (2001)
  - Radiated radio-frequency electromagnetic field EN 61000-4-3, IEC 60255-22-3

- Vibration, shock, bump and seismic tests on measuring relays and protection equipment:
  - Vibration tests (sinusoidal), Class I, IEC 60255-21-1
  - Shock and bump tests, Class I, IEC 60255-21-2
  - Seismic tests, Class I, IEC 60255-21-3

Mechanical data

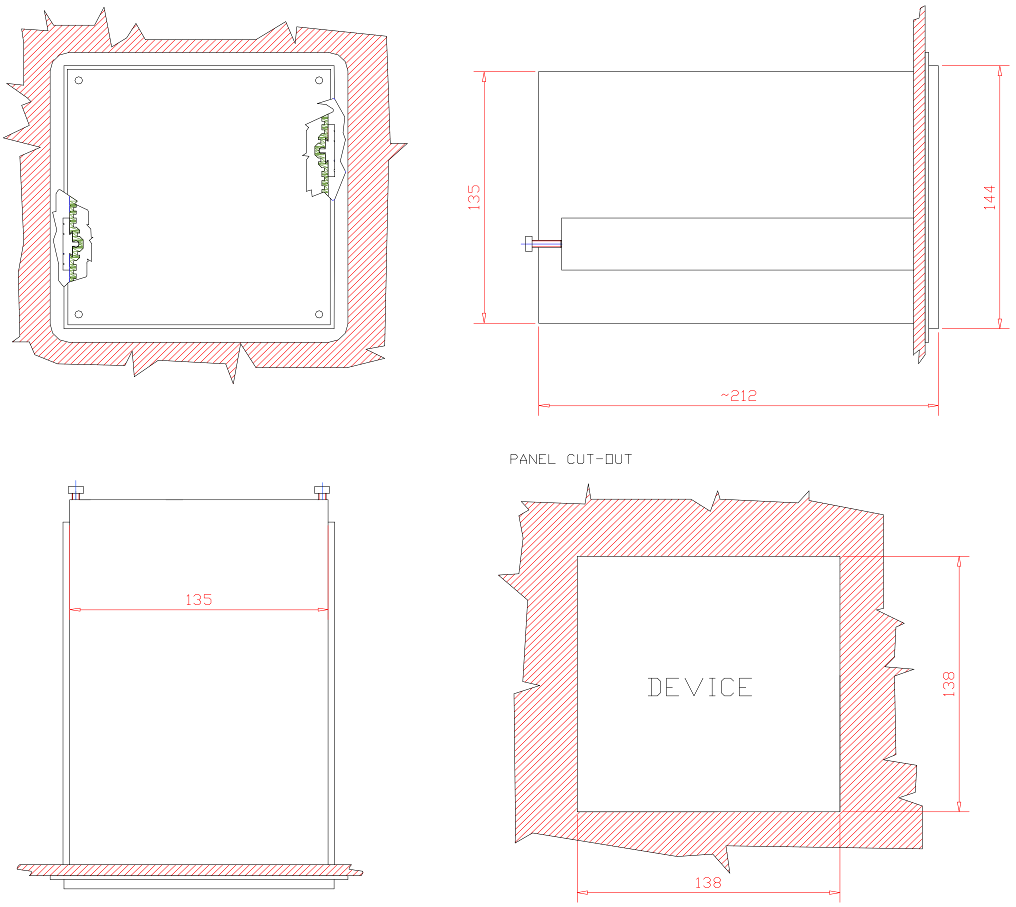
- Construction: anodized aluminum surface in tube
- EMC case protects against electromagnetic environmental influences and protects the environment from radiation from the interior
- IP20 protection from rear side (optional IP3x available)
- Size:
  - 24 HP, panel instrument case
  - Weight: max. 3 kg

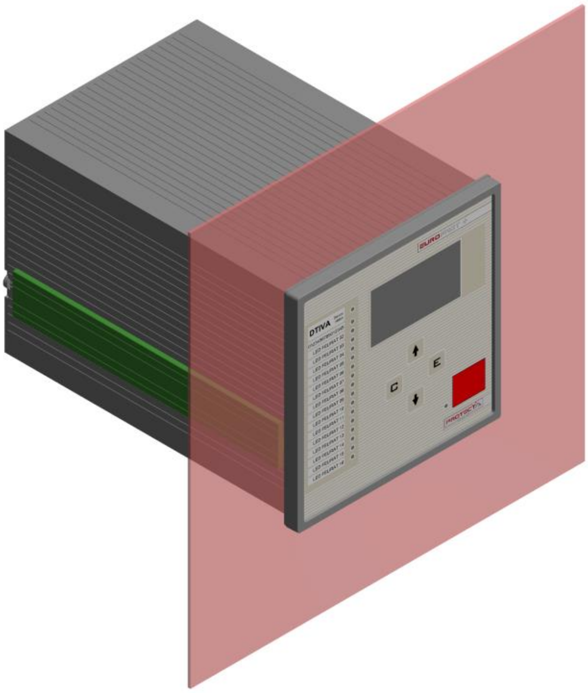
Mounting methods of SMARTLINES24

Mounting methods:

- Flush mounting panel instrument case with IP54 (front side), see 0-1. Figure
- Semi-flush mounting panel instrument case with IP54 (front side), see 0-1. Figure
- Din rail mounting with IP40 (front side), see 0-1.Figure

Flush mounting of 24 HP panel instrument case

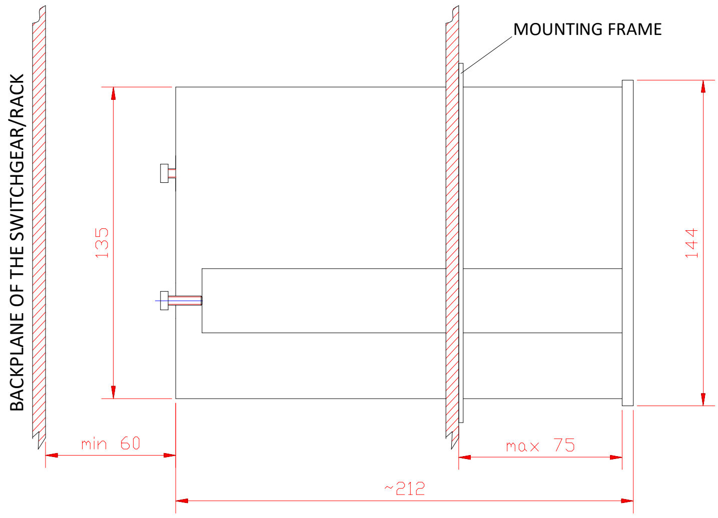


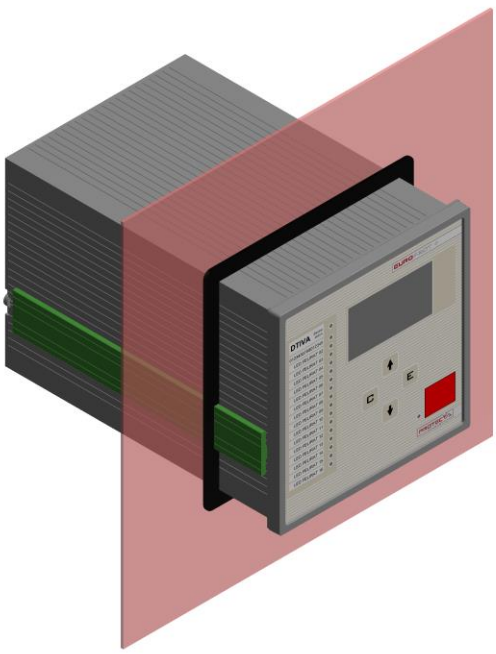


0-1. Figure S24 flush mounting method

Semi-flush mounting of 24 HP panel instrument case

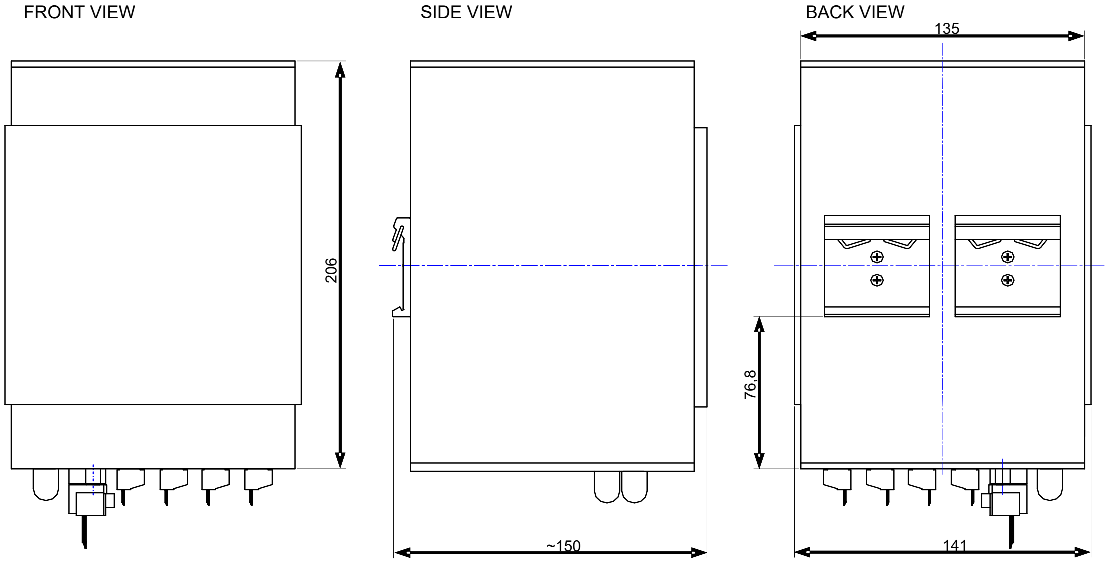
The dimensions of the panel cut-out for this type of mounting method are the same as in case of flush mounting (138 mm × 138 mm). For semi flush mounting you only have to cut in two the fixing elements (with green colour in the 3D illustration below) and make the assembly as you can see in the pictures below.





0-2. Figure S24 semi-flush mounting method (max. depth=75mm)

Din rail mounting of 24 HP panel instrument case



0-3. Figure S24 Din rail mounting

If the SMARTLINE S24 needs to be connected to legacy communication networks, the available options are

- Serial protocols (IEC 60870-5-101/103, Modbus RTU, DNP3, ABB-SPA)
- Network protocols (IEC 60870-5-104, DNP3, Modbus-TCP)
- Legacy network based protocols via 100Base-FX and 10/100Base-TX (RJ45)

Serial interfaces:

- optical (glass/fiber)
- RS485/RS422

All devices of the SMARTLINE IED product range act on an Ethernet network as servers, exchanging with connected clients all information needed for continuous supervision of the entire power network

- Local or remote access to the device by widely used browsers (e.g. Internet Explorer, Mozilla Firefox, Opera, Google Chrome, PDAs, smart phones)
- Front panel image and system characteristics
- Parameter setting
- On-line information
- Event log
- Disturbance record download and fast view
- Command screen
- Scanning the connected devices
- Download of device documentation
- Advanced functions such as diagnostic information, password manager, update manager, device test

Application of the IEC61850 based communication assures interoperability of the SMARTLINE S24 with devices made by other manufacturers

- Native and configurable IEC61850 support for both vertical and horizontal communication
- Full range of devices both for high voltage and medium voltage protection tasks with IEC61850 compatibility

The time synchronization methods offered support easy matching in existing SCADA systems

- Primary and secondary NTP server
- Legacy protocol master
- Minute pulse