

MICROENER

DTRV/TG Operation Manual



FDE N°:

12JMC0341550 - Rev B

GESTION DES MODIFICATIONS

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A	Diffusion	12/03/21	JMC	LA
B	Modification suivant DEV 1429	14/05/13	JMC	LA

CONTENTS

CONFIGURATION DESCRIPTION.....	4
Application.....	4
Protection functions	4
Measurement functions.....	6
Hardware configuration	6
The applied hardware modules	7
Meeting the device.....	8
Software configuration.....	9
Protection functions	9
Three-phase instantaneous overcurrent protection function (IOC50)	10
Residual instantaneous overcurrent protection function (IOC50N)	13
Residual overcurrent protection function (TOC51N low, high)	14
Generator differential protection function (DIF87G).....	17
Out of Step (Pole slipping) protection function (PSLIP78).....	18
Negative sequence overcurrent protection function (TOC46)	20
Line thermal protection function (TTR49L).....	23
Definite time overvoltage protection function (TOV59_high, TOV59_low)	26
Definite time undervoltage protection function (TUV27_high, TUV27_low).....	27
Residual definite time overvoltage protection function (TOV59N_high, TOV59N_low).....	29
Over-frequency protection function (TOF81_high, TOF81_low).....	30
Underfrequency protection function (TUF81_high, TUF81_low).....	32
Rate of change of frequency protection function (FRC81_high, FRC81_low).....	34
Overexcitation protection function (VPH24).....	36
Loss of excitation protection function (UEX_40Z).....	39
Synchrocheck function (SYN25)	41
Voltage transformer supervision function (VTS60).....	44
Current unbalance function (VCB60).....	45
Breaker failure protection function (BRF50)	47
Directional over-power protection function (DOP32).....	49
Directional under-power protection function (DUP32).....	50
Dead line detection function (DLD).....	51
Trip logic (TRC94).....	52
Current input function (CT4).....	53
Voltage input function (VT4).....	57

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 4 / 59

CONFIGURATION DESCRIPTION

The E9-DTRV protection device is a member of the **EuroProt+** product line, made by Protecta Co. Ltd. The **EuroProt+** 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. This manual describes the specific application of the E9-DTRV factory configuration.

Application

The members of the DTRV product line are configured to protect and control high voltage/medium voltage transformers.

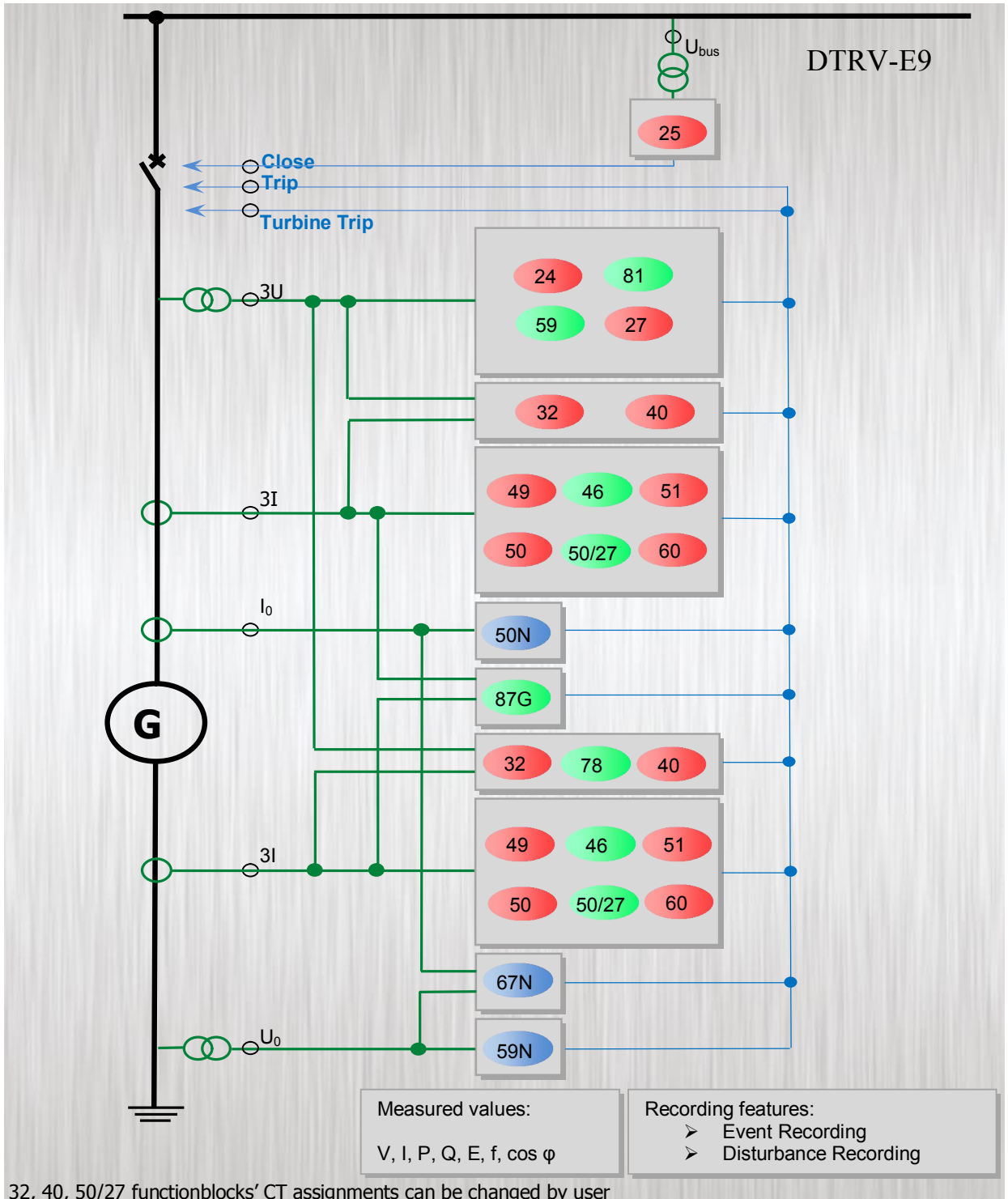
Protection functions

The E9-DTRV configuration is designed to protect generators in the 2.5 to 50 MVA power range. The device can be applied either as a main protection or as a reserve protection. The included functions can be enabled or disabled according to the requirements. The measured quantities are the signals of current transformers and voltage transformers; the device does not apply equipment on the primary voltage level. The protection functions requiring e.g. special current injection are excluded from the range of functions.

Protection functions	IEC	ANSI	DTRV-E9
Three-phase instantaneous overcurrent protection	I >>>	50	X
Three-phase time overcurrent protection	I >, I >>	51	X
Residual instantaneous overcurrent protection	Io >>>	50N	X
Residual time overcurrent protection	Io >, Io >>	51N	X
Generator differential protection		87G	X
Out-of-step		78	X
Negative sequence overcurrent protection	I ₂ >	46	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
Overfrequency protection	f >, f >>	81O	X
Underfrequency protection	f <, f <<	81U	X
Rate of change of frequency protection	df/dt	81R	X
Overexcitation	V/Hz	24	X
Loss of excitation		40	X
Synchrocheck	SYNC	25	X
Fuse failure (VTS)		60	X
Current unbalance protection		60	X
Breaker failure protection	CBFP	50BF	X
Directional overpower	P >	32	X
Directional underpower	P <	32	X

Table 1 - The protection functions of the DTRV-E9 configuration

The configured functions are drawn symbolically in the Figure below.



Measurement functions

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

Measurement functions	DTRV-E9
Current (I1, I2, I3, Io)	X
Voltage (U1, U2, U3, U12, U23, U31, Uo, Useq) and frequency	X
Power (P, Q, S, pf) and Energy (E+, E-, Eq+, Eq-)	X
Supervised trip contacts (TCS)	X

Table 2 - The measurement functions of the DTRV-E9 configuration

Hardware configuration

The hardware inputs and outputs are listed in the Table below:

Hardware configuration	ANSI	DTRV-E9
Mounting		Op.
Panel instrument case		
Current inputs (4th channel can be sensitive)		8
Voltage inputs		8
Digital inputs		12
Digital outputs		8
Fast trip outputs		4
Temperature monitoring (RTDs) *	38 / 49T	Op.

Table 3 - The hardware configuration of the DTRV-E9 configuration

The module arrangement of the DTRV-E9 configuration is shown in Figure 1.

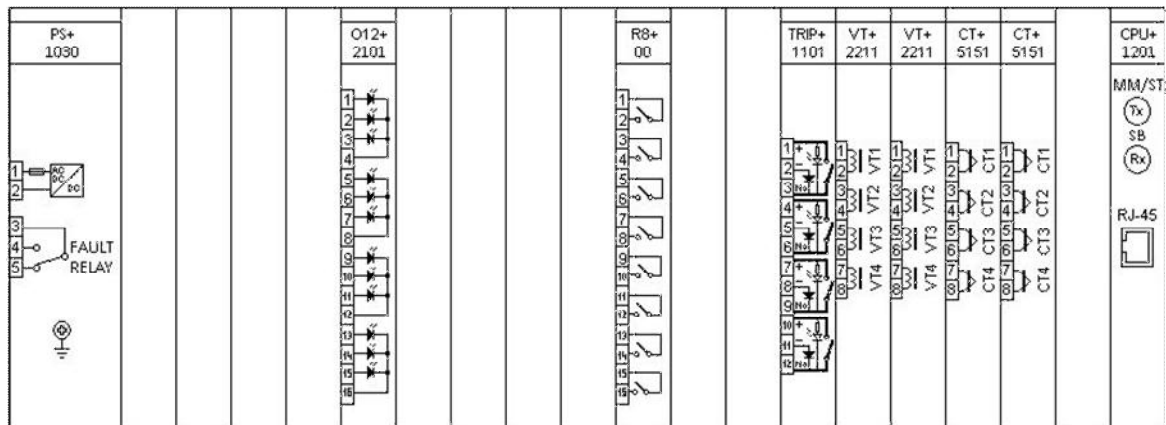


Figure 1 - Module arrangement of the DTRV-E9 configuration (rear view)

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
PS+ 1030	Power supply unit
O12+ 2101	Binary input module
R8+ 00	Signal relay output module
TRIP+ 1101	Trip relay output module
VT+ 2211	Analog voltage input module
CT + 5151	Analog current input module
CPU+ 1201	Processing and communication module

Table 4 - The applied modules of the DTRV-E9 configuration

Meeting the device

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



Figure 2 The 42 and 84 inch racks of **EuroProt+** family



Figure 3 The standard industrial box of **EuroProt+** family

Software configuration**Protection functions**

The implemented protection functions are listed in Table 5. The function blocks are described in details in separate documents. These are referred to also in this table.

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
IOC50N	Residual Instant.OC	Residual instantaneous overcurrent protection function block description
TOC51N_low TOC51N_high	Residual TOC	Residual overcurrent protection function block description
DIF87G		Generator differential protection function block description
PSLIP78	Pole slipping	Out-of-step function block description (Pole slipping)
TOC46	Neg. Seq. OC	Negative sequence overcurrent protection function block description
TTR49L	Line thermal	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	Overvoltage	Residual definite time overvoltage protection function block description
TOF81_high TOF81_low	Overfrequency	Overfrequency protection function block description
TUF81_high TUF81_low	Underfrequency	Underfrequency protection function block description
FRC81_high FRC81_low	ROC of frequency	Rate of change of frequency protection function block description
VPH24	Overexcitation	Overexcitation protection function block description
UEX_40Z	Loss of excitation	Loss of excitation function block description
SYN25	Synchrocheck	Synchro-check, synchro switch function block description
VTS60	Voltage transformer supervision	Voltage transformer supervision function block description
VCB60	Current Unbalance	Current unbalance function block description
BRF50	Breaker failure	Breaker failure protection function block description
DOP32	Directional OP	Directional overpower protection function block description
DUP32	Directional UP	Directional underpower protection function block description
DLD	Dead line detection	Dead line detection protection function block description
TRC94	Trip Logic	Trip logic function block description
CT4		Current input function block description
VT4		Voltage input function block description

Table 5 - Implemented protection 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

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		Rev. B Page 11 / 59

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

Technical data

Function	Value	Accuracy
Operating accuracy	$20 \leq G_s \leq 1000$	< 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

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 12 / 59

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)						
TOC67_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

Residual instantaneous overcurrent protection function (IOC50N)

The residual instantaneous overcurrent protection function (IOC50N) block operates immediately if the residual current ($3I_o$) 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 ($I > 0.1 I_n$)	Instantaneous	<6%
Reset ratio	0.85	
Operate time at $2 \cdot I_S$	<15 ms	
Reset time *	< 35 ms	
Transient overreach	85 %	
Using Fourier basic harmonic calculation		
Operating characteristic ($I > 0.1 I_n$)	Instantaneous	<3%
Reset ratio	0.85	
Operate time at $2 \cdot I_S$	<25 ms	
Reset time *	< 60 ms	
Transient overreach	15 %	

*Measured with signal contacts

Table 14 - 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 15 - 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 16 - The integer parameter of the residual instantaneous overcurrent protection function

Residual overcurrent protection function (TOC51N low, high)

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 (3I₀) 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:

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

where

t(G)(seconds)

k, c

a

G

G_s

TMS

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

	IEC ref		k _r	c	a
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)

k_r

α

G

G_S

TMS

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

 <p>Téléphone : 01 48 15 09 09 www.microener.com</p>	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 16 / 59

Technical data

Function	Value	Accuracy
Operating accuracy *	$20 \leq G_s \leq 1000$	< 3 %
Operate time accuracy		$\pm 5\%$ 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 17 - 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 18 - 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 19 - 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 20 - 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 21 - The timer parameters of the residual overcurrent protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 17 / 59

Generator differential protection function (DIF87G)

The generator differential protection function provides main protection for generators or large motors. The application needs current transformers in all three phases both on the network side and on the neutral side. It is a simplified version, based on the Protecta general differential protection function, using less parameter values to be set.

Technical data

Function	Value	Accuracy
Operating characteristic	2 breakpoints	
Reset ratio	0,95	
Characteristic accuracy		<2%
Operate time, unrestrained	Typically 20 ms	
Reset time, unrestrained	Typically 25 ms	
Operate time, restrained	Typically 30 ms	
Reset time, restrained	Typically 25 ms	

Table 22 - Technical data of the generator differential protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter to enable the differential protection function:			
DIF87G_Op_EPar_	Operation	Off, On	On

Table 23 - The enumerated parameter of the differential protection function

Boolean parameters of the generator differential protection function:

The generator differential protection function does not have Boolean parameters.

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Parameters of the percentage characteristic curve:						
Base sensitivity:						
DIF87G_f1_IPar_	Base Sensitivity	%	10	50	1	20
Slope of the second section of the characteristics:						
DIF87G_f2_IPar_	1st Slope	%	10	50	1	20
Bias limit of the first slope:						
DIF87G_f3_IPar_	1st Slope Bias Limit	%	200	2000	1	200
Unrestrained differential protection current level:						
DIF87G_HCurr_IPar_	UnRst Diff Current	%	800	2500	1	800

Table 24 - The integer parameters of the differential protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 18 / 59

Out of Step (Pole slipping) protection function (PSLIP78)

The pole slipping protection function can be applied mainly for synchronous generators. If a generator falls out of synchronism, then the voltage vector induced by the generator rotates slower or with a higher speed as compared to voltage vectors of the network. The result is that according to the frequency difference of the two vector systems, the cyclical voltage difference on the current carrying elements of the network are overloaded cyclically. To protect the stator coils from the harmful effects of the high currents and to protect the network elements, a disconnection is required.

The pole slipping protection function is designed for this purpose.

Main features

The main features of the pole slipping 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 the positive sequence currents being above a defined value.
- A further condition of the operation is that the negative sequence current component is less than 1/6 of the value defined for the positive sequence component.
- The operate decision is based on quadrilateral characteristics on the impedance plane using four setting parameters.
- The number of vector revolutions can be set by a parameter.
- The duration of the trip signal is set by a parameter.
- Blocking/enabling binary input signal can influence the operation.

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	0.1 – 200 Ohm	±5%
In=5A	0.1 – 40 Ohm	
Zone static accuracy	48 Hz – 52 Hz	±5%
	49.5 Hz – 50.5 Hz	±2%
Operate time	Typically 25 ms	±3 ms
Minimum operate time	<20 ms	
Reset time	16 – 25 ms	

Table 25 - The technical data of the pole slip function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for disabling the function			
PSLIP78_Oper_EPar_	Operation	Off, On	Off

Table 26 - The enumerated parameter of the pole slip function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Definition of the number of the vector revolution up to the trip command:						
PSLIP78_MaxCyc_IPar_	Max. cycle number	cycle	1	10	1	1
Definition of the minimal current for the impedance vector calculation						
PSLIP78_I1Low_IPar_	I1LowLimit	%	50	200	1	120

Table 27 - Integer parameters of the pole slip function

Float parameters

Parameter name	Title	Unit	Min	Max	Digits	Default
R setting of the impedance characteristics in forward direction						
PSLIP78_Rfw_FPar_	R forward	ohm	0.10	150.00	2	10.00
X setting of the impedance characteristics in forward direction						
PSLIP78_Xfw_FPar_	X forward	ohm	0.10	150.00	2	10.00
R setting of the impedance characteristics in backward direction						
PSLIP78_Rbw_FPar_	R backward	ohm	0.10	150.00	2	10.00
X setting of the impedance characteristics in backward direction						
PSLIP78_Xbw_FPar_	X backward	ohm	0.10	150.00	2	10.00

*Table 28 - The float parameters of the pole slip function***Timer parameters**

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for waiting the subsequent revolution						
PSLIP78_Dead_TPar_	Dead time	msec	1000	60000	1	5000
Generated trip impulse duration						
PSLIP78_TrPu_TPar_	Trip pulse	msec	50	10000	1	150

Table 29 - The timer parameters of the pole slip 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)

k, c

α

G

G_s

TMS

theoretical operate time with constant value of G,
 constants characterizing the selected curve (in seconds),
 constant characterizing the selected curve (no dimension),
 measured value of the characteristic quantity, Fourier base harmonic of the negative sequence current (INFour),
 preset starting value of the characteristic quantity,
 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 30 - The constants of the standard dependent time characteristics

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 21 / 59

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

* Measured with signal contacts

Table 31 - 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 32 - 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 33 - The integer parameter of the negative sequence 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
Time multiplier for the inverse characteristics:						
TOC46_Multip_TPar_	Time Multiplier*	msec	100	60000	1	100

*Valid for inverse type characteristics

**Valid for definite type characteristics only

Table 34 - The timer parameter of the negative sequence overcurrent protection 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:

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

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_0 is the starting temperature.

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

$$\text{Temperature}(t) = \Theta(t) + \text{Temp_ambient}$$

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:

$$H(t) = \frac{\Theta(t)}{\Theta_n} = \frac{I^2}{I_n^2} \left(1 - e^{-\frac{t}{T}} \right) + \frac{\Theta_0}{\Theta_n} e^{-\frac{t}{T}}$$

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.

$\frac{\Theta_0}{\Theta_n}$ 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 disabled 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 $I > 1.2 \cdot I_{trip}$	<3 % or <± 20 ms

Table 35 - Technical data of the line thermal protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 25 / 59

Parameters

Enumerated parameter

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

Table 36 - 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 37 - 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 38 - The boolean parameter of the line thermal protection function

Definite time overvoltage protection function (TOV59_high, TOV59_low)

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 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	60 ms	
U< → 0	50 ms	
Operate time accuracy		< ± 20 ms
Minimum operate time	50 ms	

Table 39 - 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 40 - 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 41 - 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 42 - 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 43 - The timer parameter of the definite time overvoltage protection function

Definite time undervoltage protection function (TUV27_high, TUV27_low)

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 44 - 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 45 - 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 46 - 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 47 - 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 48 - The timer parameter of the definite time undervoltage protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 29 / 59

Residual definite time overvoltage protection function (TOV59N_high, TOV59N_low)

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 ($U_N=3U_0$).

The Fourier calculation inputs are the sampled values of the residual or neutral voltage ($U_N=3U_0$) 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 49 - 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 50 - 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 51 - 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 52 - 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 53 - The time parameter of the residual definite time overvoltage protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 30 / 59

Over-frequency protection function (TOF81_high, TOF81_low)

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 54 - 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 55 - 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 56 - 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 57 - 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 58 - The timer parameter of the over-frequency protection function

Underfrequency protection function (TUF81_high, TUF81_low)

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 59 - 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 60 - 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 61 - 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 62 - The float point parameter of the under-frequency protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 33 / 59

Timer parameter

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

Table 63 - The timer parameter of the under-frequency protection function

Rate of change of frequency protection function (FRC81_high, FRC81_low)

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 64 - 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 65 - 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 66 - The boolean parameter of the rate of change of frequency protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 35 / 59

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 67 - 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 68 - The timer parameter of the rate of change of frequency protection function

Overexcitation protection function (VPH24)

The overexcitation protection function is applied to protect generators and unit transformers against high flux values causing saturation of the iron cores and consequently high magnetizing currents.

The flux is the integrated value of the voltage:

$$\Phi(t) = \Phi_0 + \int_0^t u(t)dt$$

In steady state, this integral can be high if the area under the sinusoidal voltage-time function is large. Mathematically this means that in steady state the flux, as the integral of the sinusoidal voltage function, can be expressed as

$$\Phi(t) = k \frac{U}{f} \cos \omega t$$

The peak value of the flux increases if the magnitude of the voltage increases, and/or the flux can be high if the duration of a period increases; this means that the frequency of the voltage decreases. That is, the flux is proportional to the peak value of the voltage (or to the RMS value) and inversely proportional to the frequency.

The overexcitation protection function is intended to be applied near the generator, where the voltage is expected to be pure sinusoidal, without any distortion. Therefore, a continuous integration of the voltage and a simple peak detection algorithm can be applied.

The effect of high flux values is the symmetrical saturation of the iron core of the generator or that of the unit transformer. During saturation, the magnetizing current is high and distorted; high current peaks can be detected. The odd harmonic components of the current are of high magnitude and the RMS value of the current also increases. The high peak current values generate high dynamic forces, the high RMS value causes overheating. During saturation, the flux leaves the iron core and high eddy currents are generated in the metallic part of the generator or transformer in which normally no current flows, and which is not designed to withstand overheating.

The frequency can deviate from the rated network frequency during start-up of the generator or at an unwanted disconnection of the load. In this case the generator is not connected to the network and the frequency is not kept at a "constant" value. If the generator is excited in this state and the frequency is below the rated value, then the flux may increase above the tolerated value. Similar problems may occur in distributed generating stations in case of island operation.

The overexcitation protection is designed to prevent this long-term overexcited state.

The flux is calculated continuously as the integral of the voltage. In case of the supposed sinusoidal voltage, the shape of the integrated flux will be sinusoidal too, the frequency of which is identical with that of the voltage. The magnitude of the flux can be found by searching for the maximum and the minimum values of the sinusoid.

The magnitude can be calculated if at least one positive and one negative peak value have been found, and the function starts if the calculated flux magnitude is above the setting value. Accordingly, the starting delay of the function depends on the frequency: if the frequency is low, more time is needed to reach the opposite peak value. In case of energizing, the time to find the first peak depends on the starting phase angle of the sinusoidal flux. If the voltage is increased continuously by increasing the excitation of the generator, this time delay cannot be measured.

As the heating effect of the distorted current is not directly proportional to the flux value, the applied characteristic is of inverse type (so called IEEE type): If the overexcitation increases, the operating time decreases. To meet the requirements of application, a definite-time characteristic is also offered in this protection function as an alternative.

The supervised quantity is the calculated U/f value as a percentage of the nominal values (index N):

$$G = \frac{\frac{U}{f}}{\frac{U_N}{f_N}} 100[\%] = \frac{\frac{U}{U_N}}{\frac{f}{f_N}} 100[\%]$$

The over-dimensioning of generators in this respect is usually about 5%, that of the transformer about 10%, but for unit transformers this factor can be even higher.

At start-up of the function, the protection function generates a warning signal aimed to inform the controller to decrease the excitation. If the time delay determined by the parameter values of the selected characteristics expires, the function generates a trip command to decrease or to switch off the excitation and the generator.

The time delay of the independent characteristic is

$$t(G) = t_{OP} \text{ when } G > G_S$$

where

t_{OP} (seconds) theoretical operating time if $G > G_S$, fix, according to the parameter *Min Time Delay* setting

G measured value of the characteristic quantity; this is the $\frac{U}{f}$ peak value as a percentage of the rated $\frac{U_N}{f_N}$ value.

G_S setting value of the characteristic quantity (Start U/f LowSet). This is the $\frac{U_{set}}{f_{set}}$ peak value as a percentage of the rated $\frac{U_N}{f_N}$ value.

The reset time:

$$t(G) = t_{Drop-off} \text{ when } G < 0.95 * G_S$$

where

$t_{Drop-off}$ (seconds) drop-off time if $G < 0.95 * G_S$, fix, value.

The time delay of the IEEE standard dependent time characteristic is

- "IEEE square law"

$$t = \frac{0.18 * TMS}{\left(\frac{V/f}{V_N/f_N} - \frac{V_{set}/f_{set}}{V_N/f_N}\right)^2} = \frac{0.18 * TMS}{(G - G_S)^2}$$

where

TMS = 1 ... 60
 V/f
 V_N/f_N
 V_{set}/f_{set}

time multiplier setting,
 flux value calculated at the measured voltage and frequency,
 flux at rated voltage and rated frequency,
 flux setting value.

The maximum delay time is limited by the parameter *Max Time Delay*. This time delay is valid if the flux is below the preset value *Start U/f LowSet*.

This inverse type characteristic is also combined with a minimum time delay, the value of which is set by user parameter *Min. Time Delay*. This time delay is valid if the flux is above the setting value *Start U/f HighSet*.

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 38 / 59

The reset time:

If the calculated flux is below the drop-off flux value (when $G < 0.95 * G_s$), then the calculated flux value decreases linearly to zero. The time to reach zero is defined by the parameter *Cooling Time*.

Overexcitation is a typically symmetrical phenomenon. There are other dedicated protection functions against asymmetry. Accordingly, the processing of a single voltage is sufficient. In a network with isolated start point, the phase voltage is not exactly defined due to the uncertain zero sequence voltage component. Therefore, line-to-line voltages are calculated based on the measured phase voltages, and one of them is assigned to overfluxing protection.

The effective frequency range includes all frequencies where the defined accuracy can be achieved. If the frequency is too small, then the time needed to find the peak values and to calculate the flux increases. In contrast, at high frequencies the accuracy of the detected peak value decreases. The frequency range monitored extends from 10 Hz to 70 Hz. The details are given among the technical data.

Similarly to the frequency range, the voltage range is also limited. If the voltage is too small, the voltage measurement becomes inaccurate due to the sampling. In case of high voltage at low frequencies the voltage transformers may also saturate. Accordingly, the frequency range and the voltage range are closely related. The voltage range monitored extends from 10 V to 170 V. The details are given among the technical data.

The flux range is the combination of the voltage range and the frequency range. For overfluxing protection, the effective flux range extends from 0.5 to 1.5 U_N/f_N .

Technical data

Function	Effective range	Accuracy
Voltage measurement	0,5 ... 1,2Un	< 1%
Frequency measurement	0,8 ... 1,2 fn	< 1%

Table 69 - Technical data of the overexcitation protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
VPH24_Oper_EPar_	Operation	Off, Definite Time, IEEE	Definite Time

Table 70 - The enumerated parameter of the overexcitation protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Starting value of the overexcitation protection function						
VPH24_EmaxCont_IPar_	Start U/f LowSet	%	80	140	1	110
Flux value above which the IEEE inverse type characteristic is replaced by the declared minimum time						
VPH24_Emax_IPar_	Start U/f HighSet	%	80	140	1	110
Time multiplier						
VPH24_k_IPar_	Time Multiplier		1	100	1	10

Table 71 - The integer parameters of the overexcitation protection function

Float point parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum time delay for the inverse characteristics and delay for the definite time characteristics:						
VPH24_MinDel_FPar_	Min Time Delay	sec	0.5	60.00	0.01	10.00
Maximum time delay for the inverse characteristics:						
VPH24_MaxDel_FPar_	Max Time Delay	sec	300.00	8000.00	0.01	3000.00
Reset time delay for the inverse characteristics:						
VPH24_CoolDel_FPar_	Cooling Time	sec	60.00	8000.00	0.01	1000.00

Table 72 - The float point parameters of the overexcitation protection function

Loss of excitation protection function (UEX_40Z)

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 73 - The technical data of the loss of excitation function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 40 / 59

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 74 - 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 75 - 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 76 - Integer parameter of the loss of excitation function

Float parameters

Parameter name	Title	Unit	Min	Max	Digits	Default
Rayon 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
Rayon 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 77 - 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 78 - The timer parameters of the loss of excitation function

Synchrocheck function (SYN25)

Several problems can occur in the electric power system if the circuit breaker closes and connects two systems operating asynchronously. The high current surge can cause damage in the interconnecting elements, the accelerating forces can overstress the shafts of rotating machines or, at last, the actions taken by the protective system can result in the unwanted separation of parts of the electric power system.

To prevent such problems, this function checks whether the systems to be interconnected are operating synchronously. If yes, then the close command is transmitted to the circuit breaker. In case of asynchronous operation, the close command is delayed to wait for the appropriate vector position of the voltage vectors on both sides of the circuit breaker. If the conditions for safe closing cannot be fulfilled within an expected time, then closing is declined.

The conditions for safe closing are as follows:

- The difference of the voltage magnitudes is below the declared limit,
- The difference of the frequencies is below the declared limit and
- The angle difference between the voltages on both sides of the circuit breaker is within the declared limit.

The function processes both automatic reclosing and manual close commands.

The limits for automatic reclosing and manual close commands can be set independently of each other.

The function compares the voltage of the line and the voltage of one of the bar sections (Bus1 or Bus2). The bus selection is made automatically based on a binary input signal defined by the user applying the graphic equation editor.

As to voltages: any phase-to-ground or phase-to-phase voltage can be selected.

The function processes the signals of the voltage transformer supervision function and enables the close command only in case of plausible voltages.

There are three modes of operation:

- Energizing check:
 - Dead bus, live line,
 - Live bus, dead line,
 - Any Energizing Case (including Dead bus, dead line).
- Synchro check (Live line, live bus)
- Synchro switch (Live line, live bus)

If the conditions for "Energizing check" or "Synchro check" are fulfilled, then the function generates the release command, and in case of a manual or automatic close request, the close command is generated.

If the conditions for energizing or synchronous operation are not met when the close request is received, then synchronous switching is attempted within the set time-out. In this case, the rotating vectors must fulfill the conditions for safe switching within the declared waiting time: at the moment the contacts of the circuit breaker are closed, the voltage vectors must match each other with appropriate accuracy. For this mode of operation, the expected operating time of the circuit breaker must be set as a parameter value, to generate the close command in advance taking the relative vector rotation speed into consideration.

The started checking procedure can be interrupted by a cancel command defined by the user in the graphic equation editor.

In "bypass" operation mode, the function generates the release signals and simply transmits the close command.

The function can be started by the switching request signals initiated both the automatic reclosing and the manual closing. The binary input signals are defined by the user, applying the graphic equation editor.

Blocking signal of the function are defined by the user, applying the graphic equation editor.

 <p>Téléphone : 01 48 15 09 09 www.microener.com</p>	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 42 / 59

Blocking signal of the voltage transformer supervision function for all voltage sources are defined by the user, applying the graphic equation editor.

Signal to interrupt (cancel) the automatic or the manual switching procedure are defined by the user, applying the graphic equation editor.

Technical data

Function	Effective range	Accuracy in the effective range
Rated Voltage Un	100/200V, parameter setting	
Voltage effective range	10-110 % of Un	±1% of Un
Frequency	47.5 – 52.5 Hz	±10 mHz
Phase angle		±3 °
Operate time	Setting value	±3 ms
Reset time	<50 ms	
Reset ratio	0.95 Un	

Table 79 - Technical data of the synchro check / synchro switch function

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Selection of the processed voltage			
SYN25_VoltSel_EPar_	Voltage Select	L1-N,L2-N,L3-N,L1-L2,L2-L3,L3-L1	L1-N
Operation mode for automatic switching			
SYN25_OperA_EPar_	Operation Auto	Off, On, ByPass	On
Enabling/disabling automatic synchro switching			
SYN25_SwOperA_EPar_	SynSW Auto	Off, On	On
Energizing mode for automatic switching			
SYN25_EnOperA_EPar_	Energizing Auto	Off, DeadBus LiveLine, LiveBus DeadLine, Any energ case	DeadBus LiveLine
Operation mode for manual switching			
SYN25_OperM_EPar_	Operation Man	Off, On, ByPass	On
Enabling/disabling manual synchro switching			
SYN25_SwOperM_EPar_	SynSW Man	Off, On	On
Energizing mode for manual switching			
SYN25_EnOperM_EPar_	Energizing Man	Off,DeadBus LiveLine, LiveBus DeadLine, Any energ case	DeadBus LiveLine

Table 80 - The enumerated parameters of the synchro check / synchro switch function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Voltage limit for "live line" detection						
SYN25_LiveU_IPar_	U Live	%	60	110	1	70
Voltage limit for "dead line" detection						
SYN25_DeadU_IPar_	U Dead	%	10	60	1	30
Voltage difference for automatic synchro checking mode						
SYN25_ChkUdA_IPar_	Udiff SynCheck Auto	%	5	30	1	10
Voltage difference for automatic synchro switching mode						
SYN25_SwUdA_IPar_	Udiff SynSW Auto	%	5	30	1	10
Phase difference for automatic switching						
SYN25_MaxPhDiffA_IPar_	MaxPhaseDiff Auto	deg	5	80	1	20
Voltage difference for manual synchro checking mode						
SYN25_ChkUdM_IPar_	Udiff SynCheck Man	%	5	30	1	10
Voltage difference for manual synchro switching mode						
SYN25_SwUdM_IPar_	Udiff SynSW Man	%	5	30	1	10
Phase difference for manual switching						
SYN25_MaxPhDiffM_IPar_	MaxPhaseDiff Man	deg	5	80	1	20

Table 81 - The integer parameters of the synchro check / synchro switch function

Floating point parameters

Parameter name	Title	Dim.	Min	Max	Default
Frequency difference for automatic synchro checking mode					
SYN25_ChkFrDA_FPar_	FrDiff SynCheck Auto	Hz	0.02	0.5	0.02
Frequency difference for automatic synchro switching mode					
SYN25_SwFrDA_FPar_	FrDiff SynSW Auto	Hz	0.10	1.00	0.2
Frequency difference for manual synchro checking mode					
SYN25_ChkFrDM_FPar_	FrDiff SynCheck Man	Hz	0.02	0.5	0.02
Frequency difference for manual synchro switching mode					
SYN25_SwFrDM_FPar_	FrDiff SynSW Man	Hz	0.10	1.00	0.2

Table 82 - The floating point parameters of the synchro check / synchro switch function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Breaker operating time at closing						
SYN25_CBTrav_TPar_	Breaker Time	msec	0	500	1	80
Impulse duration for close command						
SYN25_SwPu_TPar_	Close Pulse	msec	10	60000	1	1000
Maximum allowed switching time						
SYN25_MaxSw_TPar_	Max Switch Time	msec	100	60000	1	2000

Table 83 - The timer parameters of the synchro check / synchro switch function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 44 / 59

Voltage transformer supervision function (VTS60)

The voltage transformer supervision function generates a signal to indicate an error in the voltage transformer secondary circuit. This signal can serve, for example, as a warning, indicating disturbances in the measurement, or it can disable the operation of the distance protection function if appropriate measured voltage signals are not available for a distance decision.

The voltage transformer supervision function is designed to detect faulty asymmetrical states of the voltage transformer circuit caused, for example, by a broken conductor in the secondary circuit.

(Another method for detecting voltage disturbances is the supervision of the auxiliary contacts of the miniature circuit breakers in the voltage transformer secondary circuits. This function is not described here.)

The user has to generate graphic equations for the application of the signal of this voltage transformer supervision function.

This function is interconnected with the "dead line detection function". Although the dead line detection function is described fully in a separate document, the explanation necessary to understand the operation of the VT supervision function is repeated also in this document.

Technical data

Function	Value	Accuracy
Pick-up voltage Io=0A I2=0A		<1% <1%
Operation time	<20ms	
Reset ratio	0.95	

Table 84 - Technical data of the voltage transformer supervision function

Parameters

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Integer parameters of the dead line detection function						
DLD_ULev_IPar_	Min Operate Voltage	%	10	100	1	60
DLD_ILev_IPar_	Min Operate Current	%	2	100	1	10
Starting voltage and current parameter for residual and negative sequence detection:						
VTS_Uo_IPar_	Start URes	%	5	50	1	30
VTS_Io_IPar_	Start IRes	%	10	50	1	10
VTS_Uneg_IPar_	Start UNeg	%	5	50	1	10
VTS_Ineg_IPar_	Start INeg	%	10	50	1	10

Table 85 - The integer parameters of the voltage transformer supervision function

Enumerated parameter

Parameter name	Title	Selection range	Default
Parameter for type selection			
VTS_Oper_EPar_	Operation	Off, Zero sequence, Neg. sequence, Special	Zero sequence

Table 86 - The enumerated parameter of the voltage transformer supervision 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

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 46 / 59

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 (BRF50)

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 assigned to the protected object. The user has the task to define these starting signals using the graphic equation editor, or if the operation of the individual phases is needed, then the start signals for the phases individually.

Two dedicated timers start at the rising edge of the start signals at the same time, one for the backup trip command and one for the repeated trip command, separately for operation in the individual phases. During the running time of the timers 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 inputs indicating the status of the circuit breaker poles have no meaning.

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

If the parameter selection is "Current/Contact", the current parameters and the status signals 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.

If repeated trip command is to be generated for the circuit breakers that are expected to open, then the enumerated parameter Retrip must be set to "On". In this case, at the end of the retrip timer(s) a repeated trip command is also generated in the phase(s) where the retrip timer(s) run off.

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 %
Retrip time	approx. 15 ms	
BF time accuracy		± 5 ms
Current reset time	20 ms	

Table 92 - Technical data of the breaker failure protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 48 / 59

Parameters

Enumerated parameters

Parameter name	Title	Selection range	Default
Selection of the operating mode			
BRF50_Oper_EPar_	Operation	Off, Current, Contact, Current/Contact	Current
Switching on or off of the repeated trip command			
BRF50_ReTr_EPar_	Retrip	Off, On	On

Table 93 - The enumerated parameters of the breaker failure protection function

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Phase current setting						
BRF50_StCurrPh_IPar_	Start Ph Current	%	20	200	1	30
Neutral current setting						
BRF50_StCurrN_IPar_	Start Res Current	%	10	200	1	20

Table 94 - The integer parameters of the breaker failure protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Time delay for repeated trip command generation						
BRF50_TrDel_TPar_	Retrip Time Delay	msec	0	10000	1	200
Time delay for trip command generation for the backup circuit breaker(s)						
BRF50_BUDel_TPar_	Backup Time Delay	msec	60	10000	1	300
Trip command impulse duration						
BRF50_Pulse_TPar_	Pulse Duration	msec	0	60000	1	100

Table 95 - The timer parameters of the breaker failure protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 49 / 59

Directional over-power protection function (DOP32)

The directional over-power protection function can be applied to protect any elements of the electric power system mainly generators if the active and/or reactive power has to be limited.

Technical data

Function	Effective range	Accuracy
P,Q measurement	I>5% In	<3%

Table 96 - Technical data of the directional over-power protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Switching on/off of the function			
DOP32_Oper_EPar_	Operation	Off,On	On

Table 97 - The enumerated parameter of the directional over-power protection function

Boolean parameter

Parameter name	Title	Default
Selection: start signal only or both start signal and trip command		
DOP32_StOnly_BPar_	Start Signal Only	0

Table 98 - The Boolean parameter of the directional over-power protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Direction angle						
DOP32_RCA_IPar_	Direction Angle	deg	-179	180	1	0

Table 99 - Integer parameter of the directional over-power protection function

Float parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum power setting						
DOP32_StPow_FPar_	Start Power	%	1	200	0.1	10

Table 100 - Float parameter of the directional over-power protection function

Timer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Definite time delay of the trip command						
DOP32_Delay_TPar_	Time Delay	msec	0	60000	1	100

Table 101 - Timer parameter of the directional over-power protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 50 / 59

Directional under-power protection function (DUP32)

The directional under-power protection function can be applied mainly to protect any elements of the electric power system, mainly generators, if the active and/or reactive power has to be limited in respect of the allowed minimum power.

Technical data

Function	Effective range	Accuracy
P,Q measurement	I>5% In	<3%

Table 102 - Technical data of the directional under-power protection function

Parameters

Enumerated parameter

Parameter name	Title	Selection range	Default
Switching on/off of the function			
DUP32_Oper_EPar_	Operation	Off, On	On

Table 103 - The enumerated parameter of the directional under-power protection function

Boolean parameter

Parameter name	Title	Default
Selection: start signal only or both start signal and trip command		
DUP32_StOnly_BPar_	Start Signal Only	0

Table 104 - The Boolean parameter of the directional under-power protection function

Integer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Direction angle						
DUP32_RCA_IPar_	Direction Angle	deg	-179	180	1	0

Table 105 - Integer parameter of the directional under-power protection function

Float parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Minimum power setting						
DUP32_StPow_FPar_	Start Power	%	1	200	0,1	10

Table 106 - Float parameter of the directional under-power protection function

Timer parameter

Parameter name	Title	Unit	Min	Max	Step	Default
Definite time delay of the trip command						
DUP32_Delay_TPar_	Time Delay	msec	0	60000	1	100

Table 107 - Timer parameter of the directional under-power protection function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 51 / 59

Dead line detection function (DLD)

The "Dead Line Detection" (DLD) function generates a signal indicating the dead or live state of the line. Additional signals are generated to indicate if the phase voltages and phase currents are above the pre-defined limits.

The task of the "Dead Line Detection" (DLD) function is to decide the Dead line/Live line state.

Criteria of "Dead line" state: all three phase voltages are below the voltage setting value AND all three currents are below the current setting value.

Criteria of "Live line" state: all three phase voltages are above the voltage setting value.

The details are described in the document ***Dead line detection protection function block description.***

Technical data

Function	Value	Accuracy
Pick-up voltage		1%
Operation time	<20ms	
Reset ratio	0.95	

Table 108 - Technical data of the dead line detection function

Parameters

Integer parameters

Parameter name	Title	Unit	Min	Max	Step	Default
Integer parameters of the dead line detection function						
DLD_ULev_IPar_	Min. Operate Voltage	%	10	100	1	60
DLD_ILev_IPar_	Min. Operate Current	%	2	100	1	10

Table 109 - The integer parameters of the dead line detection function

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 110 - 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 111 - 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 112 - Timer parameter of the decision logic

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. (See Chapter 5 of the EuroProt+ hardware description document.) 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.

 <p>Téléphone : 01 48 15 09 09 www.microener.com</p>	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 54 / 59

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 113 - 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 114 - 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 115 - The floating point parameters of the current input function

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 55 / 59

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 116 - 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.

Figure 4 shows an example of how the calculated Fourier components are displayed in the on-line block. (See the document "EuroProt+ Remote user interface description".)

[-] CT4 module		
Current Ch - I1	<input type="text" value="0.84"/>	A
Angle Ch - I1	<input type="text" value="-9"/>	deg
Current Ch - I2	<input type="text" value="0.84"/>	A
Angle Ch - I2	<input type="text" value="-129"/>	deg
Current Ch - I3	<input type="text" value="0.85"/>	A
Angle Ch - I3	<input type="text" value="111"/>	deg
Current Ch - I4	<input type="text" value="0.00"/>	A
Angle Ch - I4	<input type="text" value="0"/>	deg

Figure 4 - Example: On-line displayed values for the current input module

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. (See Chapter 6 of the EuroProt+ hardware description document.) 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- U_n . 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- U_n 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.

 Téléphone : 01 48 15 09 09 www.microener.com	DTRV/TG OPERATION MANUAL	FDE N°: 12JMC0341550
		Rev. B Page 58 / 59

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 117 - 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 118 - 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 119 - 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 120 - 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 121 - 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.

Figure 5 shows an example of how the calculated Fourier components are displayed in the on-line block. (See the document EuroProt+ "Remote user interface description".)



[-] VT4 module		
Voltage Ch - U1	56.75	V
Angle Ch - U1	0	deg
Voltage Ch - U2	51.46	V
Angle Ch - U2	-112	deg
Voltage Ch - U3	60.54	V
Angle Ch - U3	128	deg
Voltage Ch - U4	0.00	V
Angle Ch - U4	0	deg

Figure 5 - Example: On-line displayed values for the voltage input module

The performances and the characteristics reported in this manual are not binding and can be modified at any moment without notice.



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