VAMP 59

Line differential protection relay

Publication version: V59/en M/A009

User Manual

Trace back information:
Workspace Main version a132
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1 General

1.1 Legal notice

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Disclaimer

No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this document. This document is not intended as an instruction manual for untrained persons. This document gives instructions on device installation, commissioning and operation. However, the manual cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact Schneider Electric and request the necessary information.

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1.2 Safety information and password protection

Important Information

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this bulletin or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of either symbol to a “Danger” or “Warning” safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

DANGER

DANGER indicates an imminently hazardous situation which, if not avoided, **will result in** death or serious injury.

WARNING

WARNING indicates a potentially hazardous situation which, if not avoided, **can result in** death or serious injury.

CAUTION

CAUTION indicates a potentially hazardous situation which, if not avoided, **can result in** minor or moderate injury.

NOTICE

NOTICE is used to address practices not related to physical injury.

User qualification

Electrical equipment should be installed, operated, serviced, and maintained only by trained and qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material. A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved.

Password protection

Use IED's password protection feature in order to protect untrained person interacting this device.

⚠ WARNING

WORKING ON ENERGIZED EQUIPMENT

Do not choose lower Personal Protection Equipment while working on energized equipment.

Failure to follow these instructions can result in death or serious injury.

1.3 Relay features

The comprehensive protection functions of the relay make it ideal for utility, industrial, marine and off-shore power distribution applications. The relay features the following protection functions.

Table 1.1: List of protection functions

IEEE/ANSI code	IEC symbol	Function name
46	$I_2 / I_1 >$	Current unbalance protection
49	T>	Thermal overload protection
50/51	I>, I>>, I>>>	Overcurrent protection
50ARC/ 50NARC	ArcI>, $ArcI_0>$	Optional arc fault protection (with an external module)
50BF	CBFP	Circuit-breaker failure protection
50N/51N	$I_0>$, $I_0>>$, $I_0>>>$, $I_0>>>>$	Earth fault protection
59N	$U_0>$, $U_0>>$	Zero sequence voltage protection
67N	$I_{0\varphi}>$, $I_{0\varphi}>>$	Directional earth-fault, low-set stage, sensitive, definite or inverse time (can be used as non directional)
68F2	$I_{f2}>$	Magnetishing inrush
68F5	$I_{f5}>$	Transfomer overexitation
79	AR	Auto-reclosing
85		ANSI 85 communication
87L	LdI>, LdI>>	Line differential protection
99	Prg1 – 8	Programmable stages

Further the relay includes a disturbance recorder. Arc protection is optionally available.

The relay communicates with other systems using common protocols, such as the Modbus RTU, ModbusTCP, Profibus DP, IEC 60870-5-103, IEC 60870-5-101, IEC 61850, SPA bus, Ethernet / IP and DNP 3.0.

1.3.1 User interface

The relay can be controlled in three ways:

- Locally with the push-buttons on the relay front panel
- Locally using a PC connected to the USB port on the front
- Via remote control over the optional remote control port on the relay rear panel.

1.4 Related documents

Document	Identification*)
VAMP Relay Mounting and Commissioning Instructions	VRELAY_MC_xxxx
VAMPSET Setting and Configuration Tool User Manual	VVAMPSET_EN_M_xxxx

**) xxxx = revision number*

Download the latest software and manual at www.schneider-electric.com/vamp-protection or m.vamp.fi.

1.5 Periodical testing

The protection IED, cabling and arc sensors must periodically be tested according to the end-user's safety instructions, national safety instructions or law. Manufacturer recommends functional testing being carried minimum every five (5) years.

It is proposed that the periodic testing is conducted with a secondary injection principle for those protection stages which are used in the IED and its related units.

1.6 EU directive compliance

EMC compliance

CE 2014/30/EU

Compliance with the European Commission's EMC Directive. Product Specific Standards were used to establish conformity:

- EN 60255-26: 2013

Product safety

CE 2014/35/EU

Compliance with the European Commission's Low Voltage Directive. Compliance is demonstrated by reference to generic safety standards:

- EN60255-27:2014

1.7 Abbreviations

ANSI	American National Standards Institute. A standardization organisation.
CB	Circuit breaker
CBFP	Circuit breaker failure protection
cosφ	Active power divided by apparent power = P/S. (See power factor PF). Negative sign indicates reverse power.
CT	Current transformer
CT_{PRI}	Nominal primary value of current transformer
CT_{SEC}	Nominal secondary value of current transformer
Dead band	See hysteresis.
DI	Digital input
DO	Digital output, output relay
Document file	Stores information about the IED settings, events and fault logs.
DSR	Data set ready. An RS232 signal. Input in front panel port of VAMP relays to disable rear panel local port.
DST	Daylight saving time. Adjusting the official local time forward by one hour for summer time.
DTR	Data terminal ready. An RS232 signal. Output and always true (+8 Vdc) in front panel port of VAMP relays.
FFT	Fast Fourier transform. Algorithm to convert time domain signals to frequency domain or to phasors.
FPGA	Field-programmable gate array
HMI	Human-machine interface
Hysteresis	I.e. dead band. Used to avoid oscillation when comparing two near by values.
I_N	Nominal current. Rating of CT primary or secondary.
I_{SET}	Another name for pick up setting value I>
I_{0N}	Nominal current of I_0 input in general

IEC	International Electrotechnical Commission. An international standardization organisation.
IEC-101	Abbreviation for communication protocol defined in standard IEC 60870-5-101
IEC-103	Abbreviation for communication protocol defined in standard IEC 60870-5-103
IED	Intelligent electronic device
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local area network. Ethernet based network for computers and IEDs.
Latching	Output relays and indication LEDs can be latched, which means that they are not released when the control signal is releasing. Releasing of latched devices is done with a separate action.
LCD	Liquid crystal display
LED	Light-emitting diode
Local HMI	IED front panel with display and push-buttons
NTP	Network Time Protocol for LAN and WWW
P	Active power. Unit = [W]
PF	Power factor. The absolute value is equal to cosφ, but the sign is '+' for inductive i.e. lagging current and '-' for capacitive i.e. leading current.
P_M	Nominal power of the prime mover. (Used by reverse/under power protection.)
PT	See VT
pu	Per unit. Depending of the context the per unit refers to any nominal value. For example for overcurrent setting 1 pu = 1 x I_N.
Q	Reactive power. Unit = [var] acc. IEC
RMS	Root mean square
S	Apparent power. Unit = [VA]
SF	IED status inoperative
SNTP	Simple Network Time Protocol for LAN and WWW
TCS	Trip circuit supervision
THD	Total harmonic distortion
U_{0SEC}	Voltage at input U_c at zero ohm ground fault. (Used in voltage measurement mode “2LL+U_0”)
U_A	Voltage input for U_{12} or U_{L1} depending of the voltage measurement mode
U_B	Voltage input for U_{23} or U_{L2} depending of the voltage measurement mode
U_C	Voltage input for U_{31} or U_0 depending of the voltage measurement mode
U_N	Nominal voltage. Rating of VT primary or secondary
UTC	Coordinated Universal Time (used to be called GMT = Greenwich Mean Time)
VAMPSET	Configuration tool for VAMP protection devices
Webset	http configuration interface
VT	Voltage transformer i.e. potential transformer PT
VT_{PRI}	Nominal primary value of voltage transformer
VT_{SEC}	Nominal secondary value of voltage transformer

2 Local panel user interface

2.1 Relay front panel

The figure below shows, as an example, the front panel of the device and the location of the user interface elements used for local control.

1. Navigation push-buttons
2. LED indicators
3. LCD
4. Local port

Navigation push-button function

CANCEL push-button for returning to the previous menu. To return to the first menu item in the main menu, press the button for at least three seconds.

INFO push-button for viewing additional information, for entering the password view and for adjusting the LCD contrast.

F1 programmable function push-button. As default F1 toggles Virtual Input 1 (VI1) On/Off

F2 programmable function push-button. As default F2 toggles Virtual Input 2 (VI2) On/Off

OK ENTER push-button for activating or confirming a function.

arrow UP navigation push-button for moving up in the menu or increasing a numerical value.

arrow DOWN navigation push-button for moving down in the menu or decreasing a numerical value.

arrow LEFT navigation push-button for moving backwards in a parallel menu or selecting a digit in a numerical value.

arrow RIGHT navigation push-button for moving forwards in a parallel menu or selecting a digit in a numerical value.

LED indicators

The LEDs on the local HMI can be configured in VAMPSET. To customise the LED texts on the local HMI, the texts can be written on a template and then printed on a transparency. The transparencies can be placed to the pockets beside the LEDs.

LED indicator	Meaning	Measure/ Remarks
Power LED lit	The auxiliary power has been switched on	Normal operation state
Status LED lit	Internal fault, operates in parallel with the self supervision output relay	The relay attempts to reboot [REBOOT]. If the error LED remains lit, call for maintenance.
A- H LED lit	Application-related status indicators.	Configurable
F1 / F2 LED lit	Corresponding function key pressed / activated	Depending of function programmed to F1 / F2

Adjusting LCD contrast

1. On the local HMI, push i and OK.
2. Enter the four-digit password and push OK.
3. Push i and adjust the contrast.
   - To increase the contrast, push △.
   - To decrease the contrast, push ▽.
4. To return to the main menu, push .

Resetting latched indicators and output relays

All the indicators and output relays can be given a latching function in the configuration.

There are several ways to reset latched indicators and relays:

- From the alarm list, move back to the initial display by pushing for approx. 3s. Then reset the latched indicators and output relays by pushing OK.
- Acknowledge each event in the alarm list one by one by pushing OK equivalent times. Then, in the initial display, reset the latched indicators and output relays by pushing OK.

The latched indicators and relays can also be reset via a remote communication bus or via a digital input configured for that purpose.

2.1.1 Display

The relay is provided with a backlighted 128x64 LCD dot matrix display. The display enables showing 21 characters is one row and eight rows at the same time. The display has two different purposes: one is to show the single line diagram of the relay with the object status, measurement values, identification etc (Figure 2.1). The other purpose is to show the configuration and parameterization values of the relay (Figure 2.2).

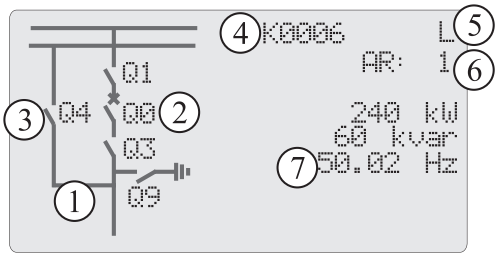


Figure 2.1: Sections of the LCD dot matrix display

1. Freely configurable single-line diagram
2. Controllable objects (max six objects)
3. Object status (max eight objects, including the six controllable objects)
4. Bay identification
5. Local/Remote selection
6. Auto-reclose on/off selection (if applicable)
7. Freely selectable measurement values (max. six values)

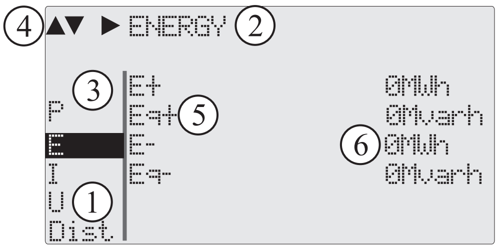


Figure 2.2: Sections of the LCD dot matrix display

1. Main menu column
2. The heading of the active menu
3. The cursor of the main menu
4. Possible navigating directions (push buttons)
5. Measured/setting parameter
6. Measured/set value

Backlight control

Display backlight can be switched on with a digital input, virtual input or virtual output. LOCALPANEL CONF/**Display backlight ctrl** setting is used for selecting trigger input for backlight control. When the selected input activates (rising edge), display backlight is set on for 60 minutes.

2.1.2 Adjusting display contrast

The readability of the LCD varies with the brightness and the temperature of the environment. The contrast of the display can be adjusted via the PC user interface, see Chapter 3 VAMPSET PC software.

2.2 Local panel operations

The front panel can be used to control objects, change the local/ remote status, read the measured values, set parameters, and to configure relay functions. Some parameters, however, can only be set by means of a PC connected to the local communication port. Some parameters are factory-set.

Moving in the menus

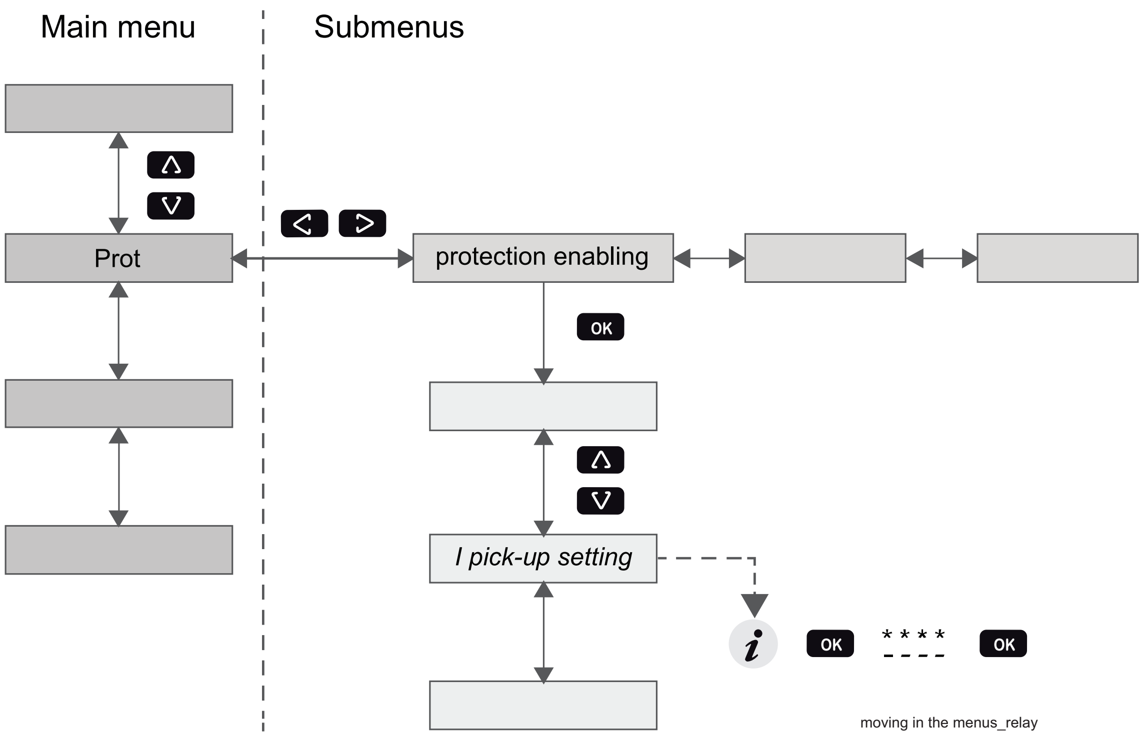


Figure 2.3: Moving in the menus using local HMI

- To move in the main menu, push Λ or V.
- To move in submenus, push > or <.
- To enter a submenu, push OK and use V or Λ for moving down or up in the menu.
- To edit a parameter value, push i and OK.
- To go back to the previous menu, push the home button.
- To go back to the first menu item in the main menu, push the home button for at least three seconds.

NOTE: To enter the parameter edit mode, give the password. When the value is in edit mode, its background is dark.

Main menu

The menu is dependent on the user's configuration and the options according the order code. For example only the enabled protection stages will appear in the menu.

A list of the local main menu

Main menu	Number of menus	Description	ANSI code	Note
	1	Interactive mimic display		1
	5	Double size measurements defined by the user		1
	1	Title screen with device name, time and firmware version.		
Meas	14	Measurements		
Imax	5	Time stamped min & max of currents		
Month	17	Maximum values of the last 31 days and the last twelve months		
Evnt	2	Events		
DR	3	Disturbance recorder		2
Runh	2	Running hour counter. Active time of a selected digital input and time stamps of the latest start and stop.		
TIMR	6	Day and week timers		
DI	5	Digital inputs including virtual inputs		
DO	4	Digital outputs (relays) and output matrix		
AO	2	Visible only when AO card installed		
Prot	9	Protection counters, combined overcurrent status, protection status, protection enabling, cold load and inrush detectionIf2> and block matrix		
MSTAT	1	Motor status		
LdI>	4	1st line differential stage	87L	4
LdI>>	4	2nd line differential stage	87L	4
I>	5	1st overcurrent stage	50/51	4
I>>	3	2nd overcurrent stage	50/51	4
I>>>	3	3rd overcurrent stage	50/51	4
I2>	3	Current unbalance stage	46	4
T>	3	Thermal overload stage	49	4
If2>	3	Second harmonic O/C stage	51F2	4
If5>	3	Fifth harmonic O/C stage	51F5	4
Io>	5	1st earth fault stage	50N/51N	4
Io>>	3	2nd earth fault stage	50N/51N	4
Io>>>	3	3rd earth fault stage	50N/51N	4
Io>>>>	3	4th earth fault stage	50N/51N	4
Ioφ >	6	1st directional earth fault stage	67N	4
Ioφ >>	7	2nd directional earth fault stage	67N	4
Uo>	3	1st residual overvoltage stage	59N	4
Uo>>	3	2nd residual overvoltage stage	59N	4

Main menu	Number of menus	Description	ANSI code	Note
Prg1	3	1st programmable stage		4
Prg2	3	2nd programmable stage		4
Prg3	3	3rd programmable stage		4
Prg4	3	4th programmable stage		4
Prg5	3	5th programmable stage		4
Prg6	3	6th programmable stage		4
Prg7	3	7th programmable stage		4
Prg8	3	8th programmable stage		4
CBFP	3	Circuit breaker failure protection	50BF	4
CBWE	5	Circuit breaker wearing supervision		4
CTSV	1	CT supervisor		4
ArcI>	11	Optional arc protection stage for phase-to-phase faults and delayed light signal.	50ARC	4
ArcIo>	10	Optional arc protection stage for earth faults. Current input = I_0	50NARC	4
AR	4	Auto-reclose	79	
OBJ	11	Object definitions		5
Lgic	2	Status and counters of user’s logic		1
CONF	9	Device setup, scaling etc.		6
Bus	11	Serial port and protocol configuration		7
OPT	1	Option cards		
Diag	9	Device selfdiagnosis		

Notes

1. Configuration is done with VAMPSET
2. Recording files are read with VAMPSET
3. The menu is visible only if protocol "ExternalIO" is selected for one of the serial ports. Serial ports are configured in menu "Bus".
4. The menu is visible only if the stage is enabled.
5. Objects are circuit breakers, disconnectors etc.
6. There are two extra menus, which are visible only if the access level "operator" or "configurator" has been opened with the corresponding password.
7. Detailed protocol configuration is done with VAMPSET.

2.2.1 Menu structure of protection functions

The general structure of all protection function menus is similar although the details do differ from stage to stage. As an example the details of the second overcurrent stage I>> menus are shown below.

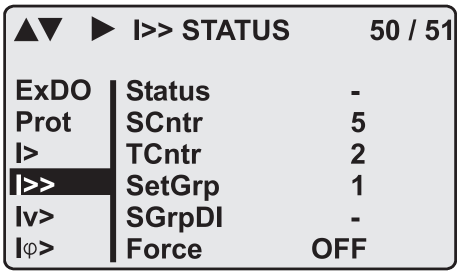


Figure 2.4: First menu of I>> 50/51 stage

This is the status, start and trip counter and setting group menu.

- Status –
  The stage is not detecting any fault at the moment. The stage can also be forced to pick-up or trip is the operating level is “Configurator” and the force flag below is on. Operating levels are explained in Chapter 2.2.4 Operating levels.
- SCntr 5
  The stage has picked-up a fault five times since the last reset or restart. This value can be cleared if the operating level is at least “Operator”.
- TCntr 2
  The stage has tripped two times since the last reset or restart. This value can be cleared if the operating level is at least “Operator”.
- SetGrp 1
  The active setting group is one. This value can be edited if the operating level is at least “Operator”. Setting groups are explained in Chapter 2.2.2 Setting groups
- SGrpDI –
  The setting group is not controlled by any digital input. This value can be edited if the operating level is at least “Configurator”.
- Force Off
  The status forcing and output relay forcing is disabled. This force flag status can be set to “On” or back to “Off” if the operating level is at least “Configurator”. If no front panel button is pressed within five minutes and there is no VAMPSET communication, the force flag will be set to “Off” position. The forcing is explained in Chapter 2.3.4 Forced control (Force).

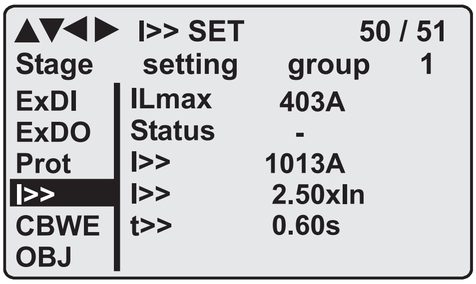


Figure 2.5: Second menu(next on the right) of I>> 50/51 stage

This is the main setting menu.

- Stage setting group 1
  These are the group 1 setting values. The other setting group can be seen by pressing push buttons OK and then > or <. Setting groups are explained in Chapter 2.2.2 Setting groups.
- ILmax 403A
  The maximum of three measured phase currents is at the moment 403 A. This is the value the stage is supervising.
- Status –
  Status of the stage. This is just a copy of the status value in the first menu.
- I>> 1013 A
  The pick-up limit is 1013 A in primary value.
- I>> 2.50 x I_N
  The pick-up limit is 2.50 times the rated current of the generator. This value can be edited if the operating level is at least “Operator”. Operating levels are explained in Chapter 2.2.4 Operating levels.
- t>> 0.60s
  The total operation delay is set to 600 ms. This value can be edited if the operating level is at least “Operator”.

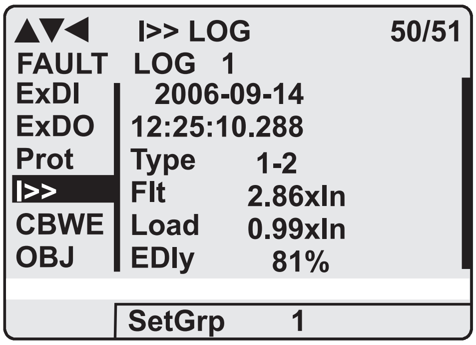


Figure 2.6: Third and last menu (next on the right) of I>> 50/51 stage

This is the menu for registered values by the I>> stage. Fault logs are explained in Chapter 2.2.3 Fault logs.

- FAULT LOG 1
  This is the latest of the eight available logs. You may move between the logs by pressing push buttons OK and then ▷ or ◁.
- 2006-09-14
  Date of the log.
- 12:25:10.288
  Time of the log.
- Type 1-2
  The overcurrent fault has been detected in phases L1 and L2 (A & B, red & yellow, R/S, u&v).
- Flt 2.86 x I_N
  The fault current has been 2.86 per unit.
- Load 0.99 x I_N
  The average load current before the fault has been 0.99 pu.
- EDly 81%
  The elapsed operation delay has been 81% of the setting 0.60 s = 0.49 s. Any registered elapsed delay less than 100 % means that the stage has not tripped, because the fault duration has been shorter that the delay setting.
- SetGrp 1
  The setting group has been 1. This line can be reached by pressing OK and several times ▽.

2.2.2 Setting groups

Most of the protection functions of the relay have four setting groups. These groups are useful for example when the network topology is changed frequently. The active group can be changed by a digital input, through remote communication or locally by using the local panel.

The active setting group of each protection function can be selected separately. Figure 2.7 shows an example where the changing of the I> setting group is handled with digital input one (SGrpDI). If the digital input is TRUE, the active setting group is group two and correspondingly, the active group is group one, if the digital input is FALSE. If no digital input is selected (SGrpDI = -), the active group can be selected by changing the value of the parameter SetGrp.

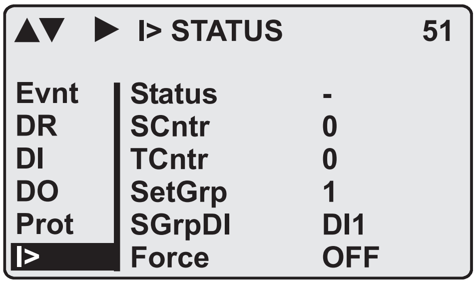


Figure 2.7: Example of protection submenu with setting group parameters

The changing of the setting parameters can be done easily. When the desired submenu has been found (with the arrow keys), press OK to select the submenu. Now the selected setting group is indicated in the down-left corner of the display (See Figure 2.8). Set1 is setting group one and Set2 is setting group two. When the needed changes, to the selected setting group, have been done, press ▷ or ◁ to select another group (◁ is used when the active setting group is 2 and ▷ is used when the active setting group is 1).

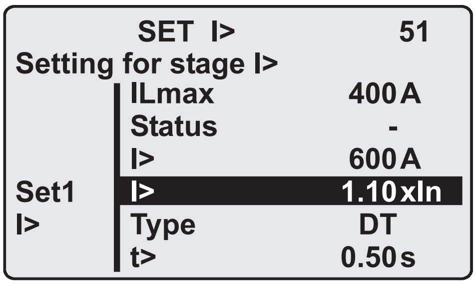


Figure 2.8: Example of I> setting submenu

2.2.3 Fault logs

All the protection functions include fault logs. The fault log of a function can register up to eight different faults with time stamp information, fault values etc. The fault logs are stored in non-volatile memory. Each function has its own logs. The fault logs are not cleared when power is switched off. The user is able to clear all logs using VAMPSET. Each function has its own logs (Figure 2.9).

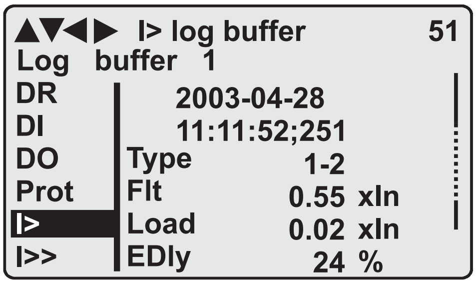


Figure 2.9: Example of fault log

To see the values of, for example, log two, press then OK to select the current log (log one). The current log number is then indicated in the down-left corner of the display (SeeFigure 2.10, Log2 = log two). The log two is selected by pressing > once.

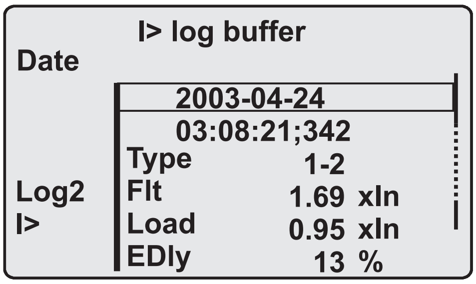


Figure 2.10: Example of selected fault log

2.2.4 Operating levels

The relay has three operating levels: **User level**, **Operator level** and **Configurator level**. The purpose of the access levels is to prevent accidental change of relay configurations, parameters or settings.

USER level

Use:	Possible to read e.g. parameter values, measurements and events
Opening:	Level permanently open
Closing:	Closing not possible

OPERATOR level

Use:	Possible to control objects and to change e.g. the settings of the protection stages
Opening:	Default password is 1
Setting state:	Push OK
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

CONFIGURATOR level

Use:	The configurator level is needed during the commissioning of the relay. E.g. the scaling of the voltage and current transformers can be set.
Opening:	Default password is 2
Setting state:	Push OK
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

Opening access

1. Push and OK on the front panel

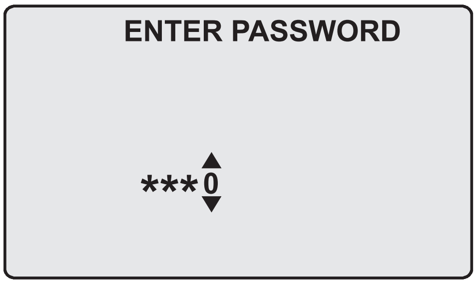


Figure 2.11: Opening the access level

2. Enter the password needed for the desired level: the password can contain four digits. The digits are supplied one by one by first moving to the position of the digit using ▷ and then setting the desired digit value using △.
3. Push OK.

Password handling

The passwords can only be changed using VAMPSET software connected to the USB -port in front of the relay.

It is possible to restore the password(s) in case the password is lost or forgotten. In order to restore the password(s), a relay program is needed. The virtual serial port settings are 38400 bps, 8 data bits, no parity and one stop bit. The bit rate is configurable via the front panel.

Command	Description
get pwd_break	Get the break code (Example: 6569403)
get serno	Get the serial number of the relay (Example: 12345)

Send both the numbers to your nearest Schneider Electric Customer Care Centre and ask for a password break. A device specific break code is sent back to you. That code will be valid for the next two weeks.

Command	Description
set pwd_break=4435876	Restore the factory default passwords (“4435876” is just an example. The actual code should be asked from your nearest Schneider Electric Customer Care Centre.)

Now the passwords are restored to the default values (See Chapter 2.2.4 Operating levels).

2.3 Operating measures

2.3.1 Control functions

The default display of the local panel is a single-line diagram including relay identification, Local/Remote indication, Auto-reclose on/off selection and selected analogue measurement values.

Please note that the operator password must be active in order to be able to control the objects. Please refer to Chapter 2.2.4 Operating levels.

Toggling Local/Remote control

1. Push OK. The previously activated object starts to blink.
2. Select the Local/Remote object ("L" or "R" squared) by using arrow keys.
3. Push OK. The L/R dialog opens. Select "REMOTE" to enable remote control and disable local control. Select "LOCAL" to enable local control and disable remote control.
4. Confirm the setting by pushing OK. The Local/Remote state will change.

Object control

- Using OK and △ / ▽

1. Push OK. The previously activated object starts to blink.
2. Select the object to control by using arrow keys. Please note that only controllable objects can be selected.
3. Push OK. A control dialog opens.
4. Select the "Open" or "Close" command by using the △ or ▽.
5. Confirm the operation by pushing OK. The state of the object changes.

- Using F1 & F2 in object control mode

1. Push F1 or F2. Object assigned to the key starts to blink and a control dialog opens.
2. Confirm the operation by pushing OK.

Toggling virtual inputs

1. Push OK. The previously activated object starts to blink.
2. Select the virtual input object (empty or black square)

3. The dialog opens
4. Select “VIon” to activate the virtual input or select “VIoff” to deactivate the virtual input

2.3.2 Measured data

The measured values can be read from the Meas menu and its submenus. Furthermore, any measurement value in the following table can be displayed on the main view next to the single line diagram. Up to six measurements can be shown.

Value	Menu/Submenu	Description
IL1	MEAS/PHASE CURRENTS	Phase current IL1 [A]
IL2	MEAS/PHASE CURRENTS	Phase current IL2 [A]
IL3	MEAS/PHASE CURRENTS	Phase current IL3 [A]
IL1da	MEAS/PHASE CURRENTS	15 min average for IL1 [A]
IL2da	MEAS/PHASE CURRENTS	15 min average for IL2 [A]
IL3da	MEAS/PHASE CURRENTS	15 min average for IL3 [A]
Io	MEAS /SYMMETRIC CURRENTS	Primary value of zerosequence/ residual current Io [A]
IoC	MEAS /SYMMETRIC CURRENTS	Calculated Io [A]
I1	MEAS /SYMMETRIC CURRENTS	Positive sequence current [A]
I2	MEAS /SYMMETRIC CURRENTS	Negative sequence current [A]
I2/I1	MEAS /SYMMETRIC CURRENTS	Negative sequence current related to positive sequence current (for unbalance protection) [%]
Uo	MEAS/MISCELLANEOUS	Residual voltage Uo [%]
f	MEAS/MISCELLANEOUS	Frequency [Hz]
AngDiag	MEAS/ANGEE DIAGRAM	Phasors
THDIL	MEAS /HARM. DISTORTION	Total harmonic distortion of the mean value of phase currents [%]
THDIL1	MEAS /HARM. DISTORTION	Total harmonic distortion of phase current IL1 [%]
THDIL2	MEAS /HARM. DISTORTION	Total harmonic distortion of phase current IL2 [%]
THDIL3	MEAS /HARM. DISTORTION	Total harmonic distortion of phase current IL3 [%]
IL1har	MEAS/HARMONICS of IL1	Harmonics of phase current IL1 [%]
IL2har	MEAS/HARMONICS of IL2	Harmonics of phase current IL2 [%]
IL3har	MEAS/HARMONICS of IL3	Harmonics of phase current IL3 [%]
IL1 wave	MEAS/IL1 WAVEFORM	Waveform of IL1
IL2 wave	MEAS/IL2 WAVEFORM	Waveform of IL2
IL3 wave	MEAS/IL3 WAVEFORM	Waveform of IL3
IL1 avg	MEAS/IL1 AVERAGE	10 min average of IL1
IL2 avg	MEAS/IL2 AVERAGE	10 min average of IL2
IL3 avg	MEAS/IL3 AVERAGE	10 min average of IL3

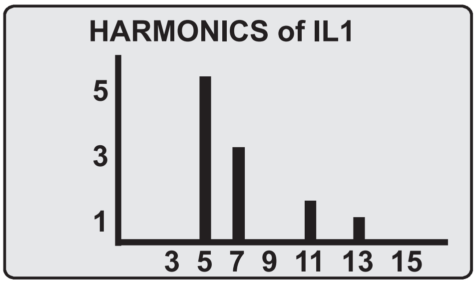


Figure 2.12: Example of harmonics bar display

2.3.3 Reading event register

The event register can be read from the Evnt submenu:

1. Push once.
2. The EVENT LIST appears. The display contains a list of all the events that have been configured to be included in the event register.

Figure 2.13: Example of an event register

3. Scroll through the event list with the and .
4. Exit the event list by pushing .

It is possible to set the order in which the events are sorted. If the “Order” -parameter is set to “New-Old”, then the first event in the EVENT LIST is the most recent event.

2.3.4 Forced control (Force)

In some menus it is possible to switch a function on and off by using a force function. This feature can be used, for instance, for testing a certain function. The force function can be activated as follows:

1. Open access level Configurator.
2. Move to the setting state of the desired function, for example DO (see Chapter 2.4 Configuration and parameter setting).
3. Select the Force function (the background color of the force text is black).

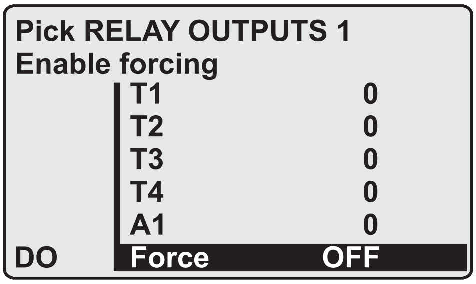


Figure 2.14: Selecting Force function

4. Push OK.
5. Push the △ or ▽ to change the "OFF" text to "ON", that is, to activate the Force function.
6. Push OK to return to the selection list. Choose the signal to be controlled by force with the △ and ▽, for instance the T1 signal.
7. Push OK to confirm the selection. Signal T1 can now be controlled by force.
8. Push the △ or ▽ to change the selection from "0" (not alert) to "1" (alert) or vice versa.
9. Push OK to execute the forced control operation of the selected function, e.g., making the output relay of T1 to pick up.
10. Repeat the steps 7 and 8 to alternate between the on and off state of the function.
11. Repeat the steps 1 – 4 to exit the Force function.
12. Push to return to the main menu.

NOTE: All the interlockings and blockings are bypassed when the force control is used.

2.4 Configuration and parameter setting

The minimum procedure to configure a device is

1. Open the access level "Configurator". The default password for configurator access level is 2.
2. Set the rated values in menu [CONF] including at least current transformers, voltage transformers and motor ratings if applicable. Also the date and time settings are in this same main menu.
3. Enable the needed protection functions and disable the rest of the protection functions in main menu [Prot].
4. Set the setting parameter of the enable protection stages according the application.
5. Connect the output relays to the start and trip signals of the enabled protection stages using the output matrix. This can be done in main menu [DO], although the VAMPSET program is recommended for output matrix editing.
6. Configure the needed digital inputs in main menu [DI].
7. Configure blocking and interlockings for protection stages using the block matrix. This can be done in main menu [Prot], although VAMPSET is recommended for block matrix editing.

Some of the parameters can only be changed via the USB-port using the VAMPSET software. Such parameters, (for example passwords, blockings and mimic configuration) are normally set only during commissioning.

Some of the parameters require the restarting of the relay. This restarting is done automatically when necessary. If a parameter change requiresrestarting, the display will show as Figure 2.15

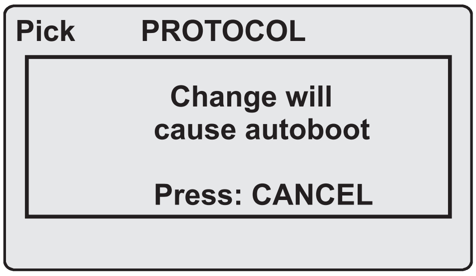


Figure 2.15: Example of auto-reset display

Press to return to the setting view. If a parameter must be changed, press OK again. The parameter can now be set. When the parameter change is confirmed with OK, a [RESTART]- text appears to the top-right corner of the display. This means that auto-resetting is pending. If no key is pressed, the auto-reset will be executed within few seconds.

2.4.1 Parameter setting

1. Move to the setting state of the desired menu (for example CONF/CURRENT SCALING) by pushing OK. The Pick text appears in the upper-left part of the display.
2. Enter the password associated with the configuration level by pushing *i* and then using the arrow keys and OK (default value is 0002). For more information about the access levels, please refer to Chapter 2.2.3 Fault logs.
3. Scroll through the parameters using the △ and ▽. A parameter can be set if the background color of the line is black. If the parameter cannot be set the parameter is framed.
4. Select the desired parameter (for example Inom) with OK.
5. Use the △ and ▽ keys to change a parameter value. If the value contains more than one digit, use the ▷ and ◁ keys to shift from digit to digit, and the △ and ▽ keys to change the digits.
6. Push OK to accept a new value. If you want to leave the parameter value unchanged, exit the edit state by pushing home.

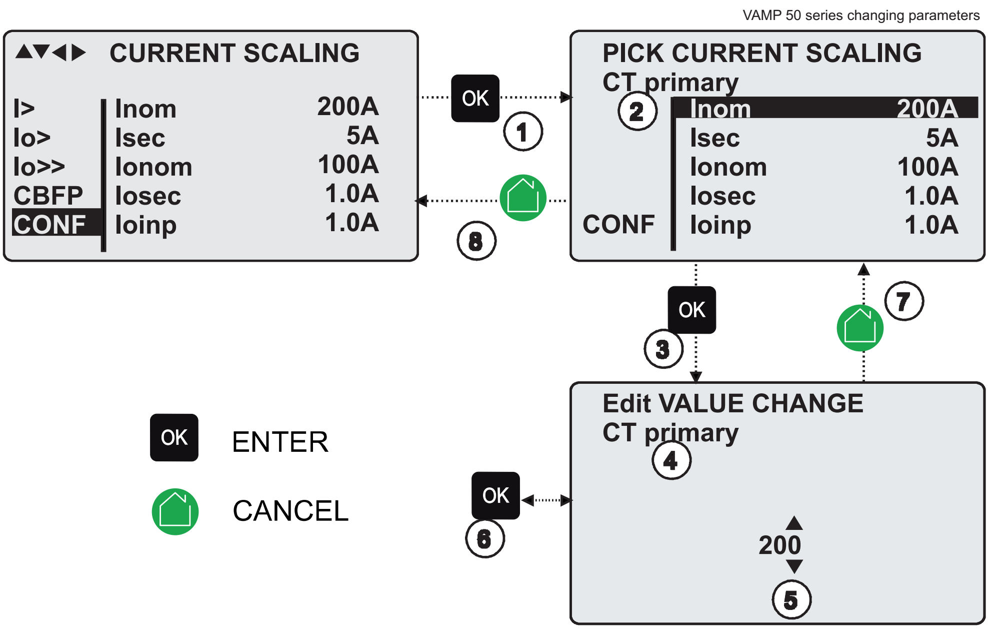


Figure 2.16: Changing parameters

2.4.2 Setting range limits

If the given parameter setting values are out-of-range values, a fault message will be shown when the setting is confirmed with OK. Adjust the setting to be within the allowed range.

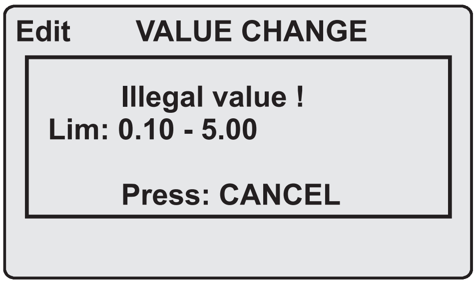


Figure 2.17: Example of a fault message

The allowed setting range is shown in the display in the setting mode. To view the range, push . Push to return to the setting mode.

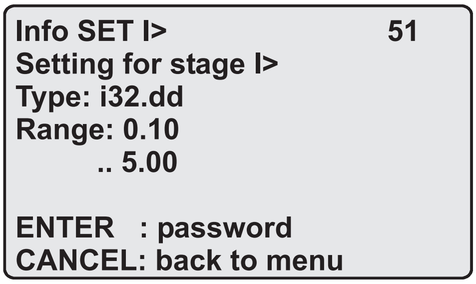


Figure 2.18: Allowed setting ranges show in the display

2.4.3 Disturbance recorder menu DR

Via the submenus of the disturbance recorder menu the following functions and features can be read and set:

Disturbance settings

1. Manual trigger (ManTrg)
2. Status (Status)
3. Clear oldest record (Clear)
4. Clear all records (ClrAll)
5. Recording completion (Stored)
6. Count of ready records (ReadyRec)

Recorder settings

1. Manual trigger (ManTrig)
2. Sample rate (SR)
3. Recording time (Time)
4. Pre trig time (PreTrig)
5. Mximum time (MaxLen)
6. Count of ready records (ReadyRec)

Rec. channels

- Add a link to the recorder (AddCh)
- Clear all links (ClrCh)

Available links

- DO, DI
- IL
- I2/In, I2/I1, I2, I1, IoCalc
- f
- Io
- IoRMS
- IL3, IL2, IL1
- IL1Rem, IL2Rem, IL3Rem
- THDIL1, THDIL2, THDIL3
- IL1RMS, IL2RMS, IL3RMS
- ILmin
- ILmax
- T
- Uo

2.4.4 Configuring digital inputs DI

The following functions can be read and set via the submenus of the digital inputs menu:

1. The status of digital inputs (DIGITAL INPUTS 1, 2)
2. Operation counters (DI COUNTERS)
3. Operation delay (DELAYs for DigIn)
4. The polarity of the input signal (INPUT POLARITY). Either normally open (NO) or normally closed (NC) circuit.
5. Event enabling EVENT MASK1

2.4.5 Configuring digital outputs DO

The following functions can be read and set via the submenus of the digital outputs menu:

- The status of the output relays (RELAY OUTPUTS1 and 2)
- The forcing of the output relays (RELAY OUTPUTS1 and 2) (only if Force = ON):
  - Forced control (0 or 1) of the Trip relays
  - Forced control (0 or 1) of the Alarm relays
  - Forced control (0 or 1) of the SF relay
- The configuration of the output signals to the output relays. The configuration of the operation indicators (LED) Alarm and Trip and application specific alarm leds A, B, C, D, E, F, G and H (that is, the output relay matrix).

NOTE: The amount of Trip and Alarm relays depends on the relay type and optional hardware.

2.4.6 Configuring analogue outputs AO (Option)

Via the submenus of the analogue output menu the following functions can be read and set:

Analog output

- Value of AO1 (AO1)
- Forced control of analogue output (Force)

Analog output 1 – 4

- Value linked to the analogue output (Lnk1)
- (See list available links)
- Scaled minimum of linked value (Min)
- Scaled maximum of linked value (Max)
- Scaled minimum of analogue output (AOmin)
- Scaled maximum of analogue output (AOmax)
- Value of analogue output (AO1)

Available links:

- IL1, IL2, IL2
- F
- IL
- Io, IoCalc
- Uo

2.4.7 Protection menu Prot

The following functions can be read and set via the submenus of the Prot menu:

1. Reset all the counters (PROTECTION SET/ClAll)
2. Read the status of all the protection functions (PROTECT STATUS 1 – x)
3. Enable and disable protection functions (ENABLED STAGES 1 – x)
4. Define the interlockings using block matrix (only with VAMPSET)

Each stage of the protection functions can be disabled or enabled individually in the Prot menu. When a stage is enabled, it will be in operation immediately without a need to reset the relay.

The relay includes several protection functions. However, the processor capacity limits the number of protection functions that can be active at the same time.

2.4.8 Configuration menu CONF

The following functions and features can be read and set via the submenus of the configuration menu:

Device setup

- Bit rate for the command line interface in communication ports and the USB-port in the front panel. The front panel is always using this setting. If SPABUS is selected for the rear panel port, the bit rate is according SPABUS settings.
- Access level [Acc]
- PC access level [PCAcc]

Language

- List of available languages in the relay

Current scaling

- Rated phase CT primary current (Inom)
- Rated phase CT secondary current (Isec)
- Rated input of the relay [Iinput] is 5 A
- Rated value of I_0 CT primary current (Ionom)
- Rated value of I_0 CT secondary current (Iosec)
- Rated I_0 input of the relay [Ioinp] is 1 A / 5 A or 0.2 A / 1 A. This is specified in the order code of the device.

The rated input values are usually equal to the rated secondary value of the CT.

The rated CT secondary may be greater than the rated input but the continuous current must be less than four times the rated input. In compensated, high impedance earthed and isolated networks using cable transformer to measure residual current I_0, it is quite usual to use a relay with 1 A or 0.2 A input although the CT is 5 A or 1A. This increases the measurement accuracy.

The rated CT secondary may also be less than the rated input but the measurement accuracy near zero current will decrease.

Voltage scaling

- Rated U_0 VT secondary voltage (Uosec)

Device info

- Relay type (Type VAMP 59)
- Serial number (SerN)
- Software version (PrgVer)
- Bootcode version (BootVer)

Date/time setup

- Day, month and year (Date)
- Time of day (Time)
- Date format (Style). The choices are "yyyy-mm-dd", "dd.nn.yyyy" and "mm/dd/yyyy".

Clock synchronisation

- Digital input for minute sync pulse (SyncDI). If any digital input is not used for synchronization, select "-".
- Daylight saving time for NTP synchronization (DST).
- Detected source of synchronization (SyScr).
- Synchronization message counter (MsgCnt).
- Latest synchronization deviation (Dev).

The following parameters are visible only when the access level is higher than "User".

- Offset, i.e. constant error, of the synchronization source (SyOS).
- Auto adjust interval (AAIntv).
- Average drift direction (AvDrft): "Lead" or "lag".
- Average synchronization deviation (FilDev).

SW options

- Application mode, fixed Feeder (ApplMod)
- External led module installed (Ledmodule)
- Mimic display selection (MIMIC)

2.4.9 Protocol menu Bus

There are three optional communication ports in the rear panel. The availability depends on the communication options (see Chapter 14 Order information).

In addition there is a USB-connector in the front panel overruling the local port in the rear panel.

Remote port

- Communication protocol for remote port [Protocol].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors]
- Communication time-out error counter [Tout].
- Information of bit rate/data bits/parity/stop bits. This value is not directly editable. Editing is done in the appropriate protocol setting menus.

The counters are useful when testing the communication.

PC (Local/SPA-bus)

This is a second menu for local port. The VAMPSET communication status is showed.

- Bytes/size of the transmitter buffer [Tx].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors]
- Communication time-out error counter [Tout].
- Same information as in the previous menu.

Extension port

- Communication protocol for extension port [Protocol].
- Message counter [Msg#]. This can be used to verify that the device is receiving messages.
- Communication error counter [Errors]
- Communication time-out error counter [Tout].
- Information of bit rate/data bits/parity/stop bits. This value is not directly editable. Editing is done in the appropriate protocol setting menus.

Ethernet port

These parameters are used by the ethernet interface module. For changing the nnn.nnn.nnn.nnn style parameter values, VAMPSET is recommended.

- Ethernet port protocol [Protoc].
- IP Port for protocol [Port]
- IP address [IpAddr].
- Net mask [NetMsk].
- Gateway [Gatew].
- Name server [NameSw].
- Network time protocol (NTP) server [NTPSvr].
- TCP Keep alive interval [KeepAlive]
- MAC address [MAC]
- IP Port for VAMPSET [VS Port]
- Message counter [Msg#]
- Error counter [Errors]
- Timeout counter [Tout]

Modbus

- Modbus address for this slave device [Addr]. This address has to be unique within the system.
- Modbus bit rate [bit/s]. Default is "9600".
- Parity [Parity]. Default is ”Even”.

For details, see Chapter 9.2.2 Modbus TCP and Modbus RTU.

External I/O protocol

External I/O is actually a set of protocols which are designed to be used with the extension I/O modules connected to the extension port. Only one instance of this protocol is possible.

Selectable protocols:

- Modbus: This is a modbus master protocol.
  Bit rate [bit/s]. Default is ”9600”.
  Parity [Parity]. Default is ”Even”.
- RTDInput: This protocol is designed to be used together with VIO 12A RTD input module.
  Bit rate [bit/s]. Default is ”9600”.
  Parity [Parity]. Default is ”Even”.

For details, see Chapter 9.2.4 External I/O (Modbus RTU master).

DNP3

Only one instance of this protocol is possible.

- Bit rate [bit/s]. Default is "9600".
- [Parity].
- Address for this device [SlvAddr]. This address has to be unique within the system.
- Master's address [MstrAddr].

For details, see Chapter 9.2.3 DNP 3.0.

2.4.10 Single line diagram editing

The single-line diagram is drawn with the VAMPSET software. For more information, please refer to the VAMPSET manual (VVAMPSET/EN M/xxxx).

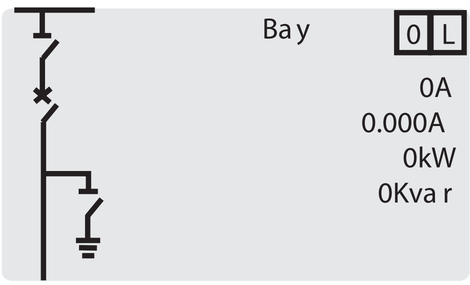


Figure 2.19: Single line diagram

2.4.11 Blocking and Interlocking configuration

The configuration of the blockings and interlockings is done with the VAMPSET software. Any start or trip signal can be used for blocking the operation of any protection stage. Furthermore, the interlocking between objects can be configured in the same blocking matrix of the VAMPSET software. For more information, please refer to the VAMPSET manual (VVAMPSET/EN M/xxxx).

3 VAMPSET PC software

The PC user interface can be used for:

- On-site parameterization of the relay
- Loading relay software from a computer
- Reading measured values, registered values and events to a computer
- Continuous monitoring of all values and events

A USB port is available for connecting a local PC with VAMPSET to the relay. A standard USB-B cable can be used.

The VAMPSET program can also use the TCP/IP LAN connection. Optional hardware is required for Ethernet connection.

There is a free of charge PC program called VAMPSET available for configuration and setting of VAMP relays. Please download the latest VAMPSET.exe from our web page. For more information about the VAMPSET software, please refer to the user's manual with the code VVAMPSET/EN M/xxxx. Also the VAMPSET user's manual is available at our web site.

When the relay is connected to a PC with a USB, a virtual comport will be created. The comport number may vary depending on your computer hardware. In order to check the correct port number, please go to Windows Device Manager: Control Panel->System->Hardware->Device Manager and under Ports (COM&LPT) for "USB Serial Port". The correct comport must be selected from the VAMPSET menu: Settings->Communication Settings. Speed setting can be set up to 187500 bps. Default setting in the relay is 38400 bps which can be manually changed from the front panel of the device.

By default every new relay will create a new comport. To avoid this behavior, the user needs to add a REG_BINARY value called IgnoreHWSerNum04036001 to the Windows registry and set it to 01. The location for this value is HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\UsbFlags\.

3.1 Folder view

In VAMPSET version 2.2.136, a feature called "Folder view" was introduced.

The idea of folder view is to make it easier for the user to work with relay functions inside VAMPSET. When folder view is enabled, VAMPSET gathers similar functions together and places them appropriately under seven different folders (GENERAL,

MEASUREMENTS, INPUTS/OUTPUTS, MATRIX, LOGS and COMMUNICATION). The contents (functions) of the folders depend on the relay type and currently selected application mode.

Folder view can be enabled in VAMPSET via Program Settings dialog (Settings -> Program Settings), see Figure 3.1.

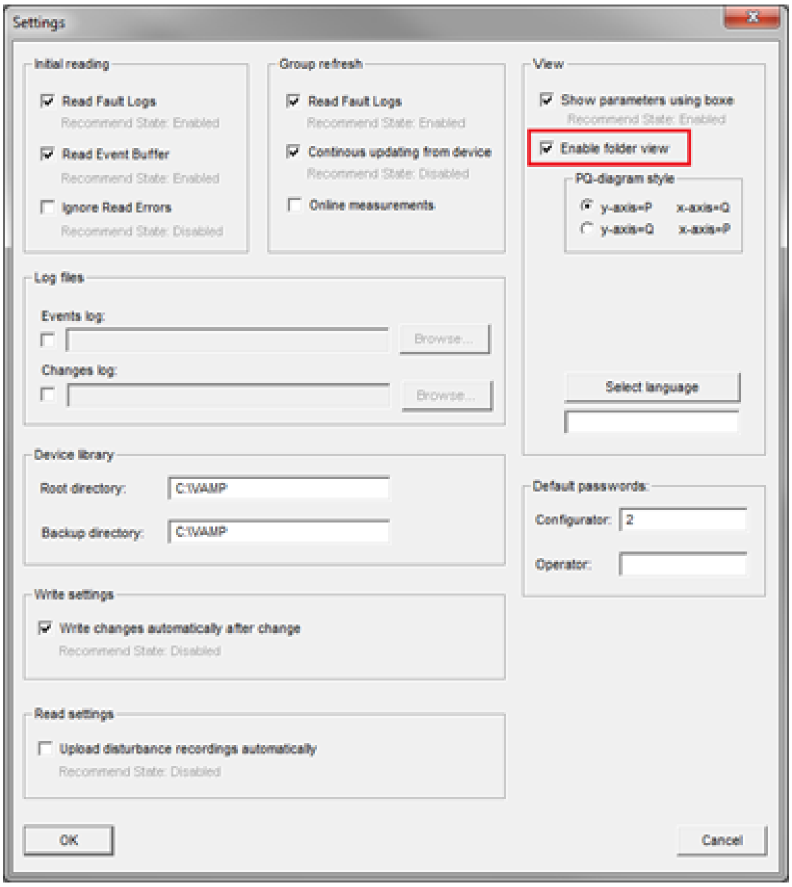


Figure 3.1: Enable folder view setting in Program Settings dialog

NOTE: It is possible to enable/ disable the folder view only when VAMPSET is disconnected from the relay and there is no configuration file opened.

When folder view is enabled, folder buttons become visible in VAMPSET, see Figure 3.2. Currently selected folder appears in bold.

Figure 3.2: Folder view buttons

4 Introduction

The numerical device includes all the essential overcurrent and earthfault protection functions needed. Further, the device includes several programmable functions, such as thermal, trip circuit supervision and circuit breaker protection and communication protocols for various protection and communication situations.

4.1 Main features

- Fully digital signal handling with microprocessor technology, and high measuring accuracy on all the setting ranges due to an accurate A/D conversion technique.
- Complete set of function for the proper protection of lines
- The device can be matched to the requirements of the application by disabling the functions that are not needed.
- Flexible control and blocking possibilities due to digital signal control inputs (DI) and outputs (DO).
- Easy adaptability of the device to various substations and alarm systems due to flexible signal-grouping matrix in the device.
- Possibility to control objects (e.g. circuit-breakers, disconnectors) from relay HMI or SCADA/automation system
- Freely configurable large display with six measurement values.
- Freely configurable interlocking schemes with basic logic functions.
- Recording of events and fault values into an event register from which the data can be read via relay HMI or by means of a PC based VAMPSET user interface.
- All events, indications, parameters and waveforms are in non-volatile memory.
- Easy configuration, parameterisation and reading of information via local HMI, or with a VAMPSET user interface.
- Easy connection to various automation systems due to several available communication protocols. Native IEC61850 implementation is available as option.
- Flexible communication option concept available to support different media requirements (serial interfaces, optical fibres, Ethernet etc),
- Built-in, self-regulating ac/dc converter for auxiliary power supply from any source within the range from 40 to 265 Vdc or Vac. The alternative power supply is for 18 to 36 Vdc.

- Built-in disturbance recorder for evaluating all the analogue and digital signals.

4.2 Principles of numerical protection techniques

The device is fully designed using numerical technology. This means that all the signal filtering, protection and control functions are implemented through digital processing.

The numerical technique used in the device is primarily based on an adapted Fast Fourier Transformation (FFT). In FFT the number of calculations (multiplications and additions), which are required to filter out the measuring quantities, remains reasonable.

By using synchronized sampling of the measured analog signals and a sample rate according to the 2^n series, the FFT technique leads to a solution, which can be realized with a 16 bit micro controller, without using a separate DSP (Digital Signal Processor).

The synchronized sampling means an even number of 2^n samples per period (e.g. 32 samples per a period). This means that the frequency must be measured and the number of the samples per period must be controlled accordingly so that the number of the samples per period remains constant if the frequency changes.

Therefore, some current has to be injected to the current input I_{L1} to adapt the network frequency for the device. However, if this is not possible then the frequency must be parameterised to the device.

Apart from the FFT calculations, some protection functions also require the symmetrical components to be calculated for obtaining the positive, negative and zero phase sequence components of the measured quantity.

Figure 4.1 shows a principle block diagram of a numerical device. The main components are the energizing inputs, digital input elements, output relays, A/D converters and the micro controller including memory circuits. Further, a device contains a power supply unit and a human-machine interface (HMI).

Figure 4.2 shows the heart of the numerical technology. That is the main block diagram for calculated functions.

Figure 4.3 shows a principle diagram of a single-phase overvoltage function.

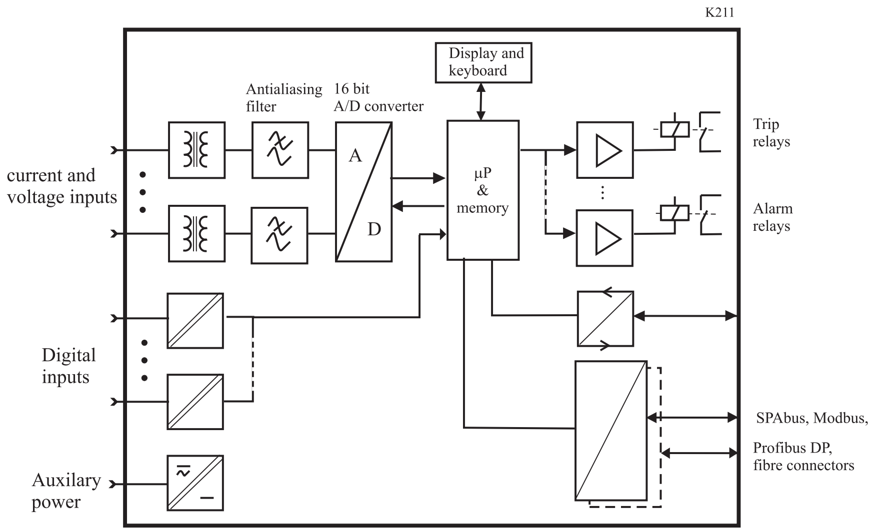


Figure 4.1: Principle block diagram of the VAMP hardware

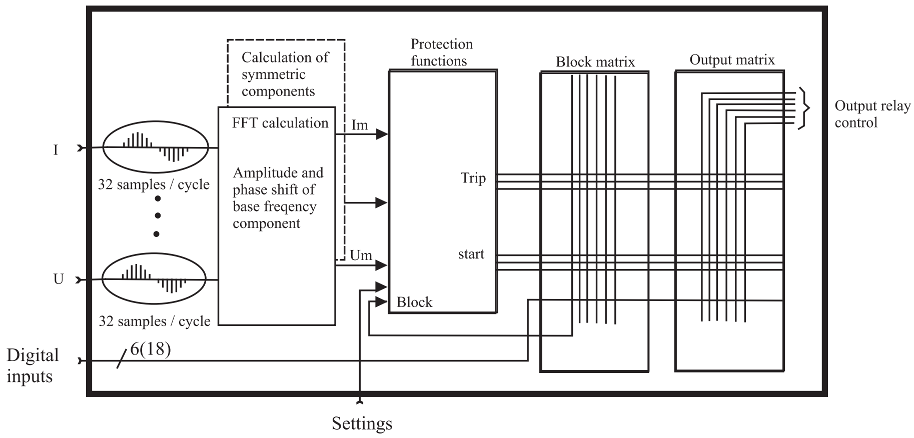


Figure 4.2: Block diagram of signal processing and protection software

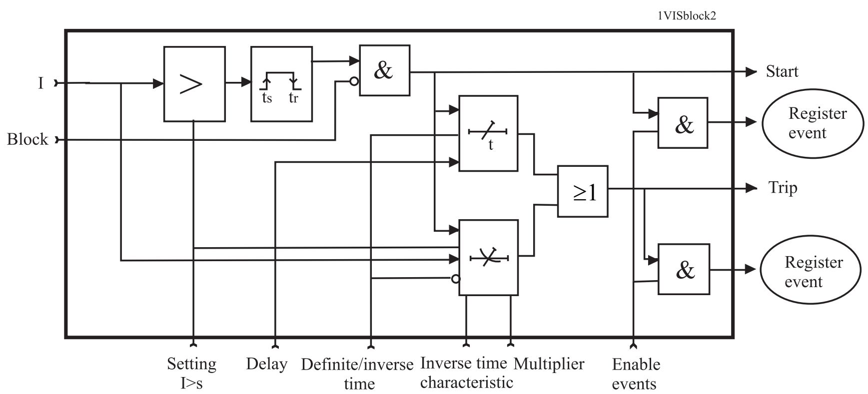


Figure 4.3: Block diagram of a basic protection function

5 Protection functions

Each protection stage can independently be enabled or disabled according to the requirements of the intended application.

5.1 Maximum number of protection stages in one application

The device limits the maximum number of enabled stages to about 30, depending of the type of the stages.

For more information, please see the configuration instructions in Chapter 2.4 Configuration and parameter setting.

5.2 General features of protection stages

Setting groups

Setting groups are controlled by using digital inputs, function keys or virtual inputs. When none of the assigned input/inputs is/are not active the active setting group is defined by parameter ‘SetGrp no control state’. When controlled input activates the corresponding setting group is activated as well. If multiple inputs are active at the same time the active setting group is defined by ‘SetGrp priority’. By using virtual I/O the active setting group can be controlled using the local panel display, any communication protocol or using the inbuilt programmable logic functions.

Set group 1 DI control	-			
Set group 2 DI control	-			
Set group 3 DI control	-			
Set group 4 DI control	-			
Group	1			
	Group 1	Group 2	Group 3	Group 4
Pick-up setting	480 A	480 A	480 A	480 A
Pick-up setting	1.20 xImot	1.20 xImot	1.20 xImot	1.20 xImot
Delay curve family	IEC	IEC	IEC	IEC
Delay type	NI	NI	NI	NI
Inv. time coefficient k	1.00	1.00	1.00	1.00
Inverse delay (20x)	2.26 s	2.26 s	2.26 s	2.26 s
Inverse delay (4x)	4.97 s	4.97 s	4.97 s	4.97 s
Inverse delay (1x)	600.02 s	600.02 s	600.02 s	600.02 s
	Common settings			
Include harmonics	Off			

Example

Any digital input could be used to control setting groups but in this example DI1, DI2, DI3 and DI4 are chosen to control setting groups 1 to 4. This setting is done with a parameter “Set group x DI control” where x refers to the desired setting group.

Set group 1 DI control	DI1			
Set group 2 DI control	DI2			
Set group 3 DI control	DI3			
Set group 4 DI control	DI4			
Group	2			
	Group 1	Group 2	Group 3	Group 4
Pick-up setting	1500 A	3600 A	3600 A	3600 A
Pick-up setting	0.50 xIn	1.20 xIn	1.20 xIn	1.20 xIn
Delay curve family	DT	IEC	IEC	IEC
Delay type	DT	NI	NI	NI
Operation delay	0.30 s	0.30 s	0.30 s	0.30 s
Inv. time coefficient k	1.00	1.00	1.00	1.00
Inverse delay (20x)	- s	2.26 s	2.26 s	2.26 s
Inverse delay (4x)	- s	4.97 s	4.97 s	4.97 s
Inverse delay (1x)	- s	600.02 s	600.02 s	600.02 s

Figure 5.1: DI1, DI2, DI3, DI4 are configured to control Groups 1 to 4 respectively.

“SetGrp priority” is used to give a condition to a situation where two or more digital inputs, controlling setting groups, are active and at a same time . SetGrp priority could have vales “1 to 4” or “4 to 1”.

VALID PROTECTION STAGES

Enabled stages	1
SetGrp common change	1
SetGrp no control state	1
SetGrp priority	1 to 4

Figure 5.2: SetGrp priority setting is located in the Valid Protection stages view.

Assuming that DI2 and DI3 are active at a same time and SetGrp priority is set to “1 to 4” setting group 2 will become active. In case SetGrp priority is reversed i.e. it is set to “4 to 1” setting group 3 would be active.

Forcing start or trip condition for testing

The status of a protection stage can be one of the followings:

- **Ok = ‘-‘**
  The stage is idle and is measuring the analog quantity for the protection. No fault detected.
- **Blocked**
  The stage is detecting a fault but blocked by some reason.
- **Start**
  The stage is counting the operation delay.
- **Trip**
  The stage has tripped and the fault is still on.

The blocking reason may be an active signal via the block matrix from other stages, the programmable logic or any digital input. Some stages also have inbuilt blocking logic. For more details about block matrix, see Chapter 8.6 Blocking matrix.

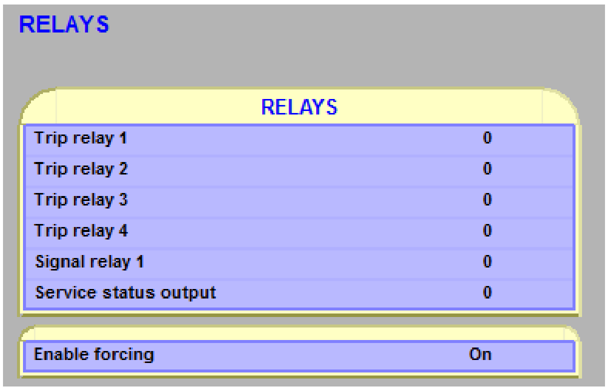
Forcing start or trip condition for testing purposes

There is a "Force flag" parameter which, when activated, allows forcing the status of any protection stage to be "start" or "trip" for a half second. By using this forcing feature any current or voltage injection to the device is not necessary to check the output matrix configuration, to check the wiring from the output relays to the circuit breaker and also to check that communication protocols are correctly transferring event information to a SCADA system.

After testing the force flag will automatically reset 5-minute after the last local panel push button activity.

The force flag also enables forcing of the output relays.

Force flag can be found in relays menu.



Start and trip signals

Every protection stage has two internal binary output signals: start and trip. The start signal is issued when a fault has been detected. The trip signal is issued after the configured operation delay unless the fault disappears before the end of the delay time.

Output matrix

Using the output matrix the user connects the internal start and trip signals to the output relays and indicators. For more details, see Chapter 8.5 Output matrix.

Blocking

Any protection function, except arc protection, can be blocked with internal and external signals using the block matrix (Chapter 8.6 Blocking matrix). Internal signals are for example logic outputs and start and trip signals from other stages and external signals are for example digital and virtual inputs.

When a protection stage is blocked, it won't pick-up in case of a fault condition is detected. If blocking is activated during the operation delay, the delay counting is frozen until the blocking goes off or the pick-up reason, i.e. the fault condition, disappears. If the stage is already tripping, the blocking has no effect.

Retardation time

Retardation time is the time a protection relay needs to notice, that a fault has been cleared during the operation time delay. This parameter is important when grading the operation time delay settings between relays.

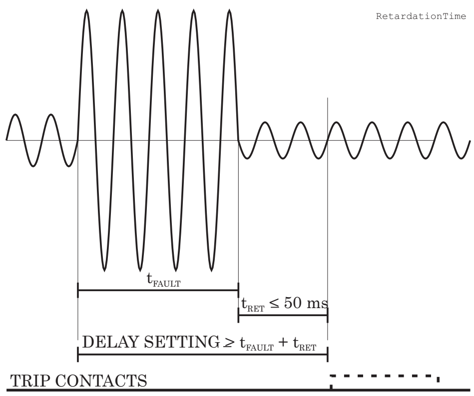


Figure 5.3: Definition for retardation time. If the delay setting would be slightly shorter, an unselective trip might occur (the dash line pulse).

For example when there is a big fault in an outgoing feeder, it might start i.e. pick-up both the incoming and outgoing feeder relay. However the fault must be cleared by the outgoing feeder relay and the incoming feeder relay must not trip. Although the operating delay setting of the incoming feeder is more than at the outgoing feeder, the incoming feeder might still trip, if the operation time difference is not big enough. The difference must be more than the retardation time of the incoming feeder relay plus the operating time of the outgoing feeder circuit breaker.

Figure 5.3 shows an overvoltage fault seen by the incoming feeder, when the outgoing feeder does clear the fault. If the operation delay setting would be slightly shorter or if the fault duration would be slightly longer than in the figure, an unselective trip might happen (the dashed 40 ms pulse in the figure). In VAMP devices the retardation time is less than 50 ms.

Reset time (release time)

Figure 5.4 shows an example of reset time i.e. release delay, when the relay is clearing an overcurrent fault. When the relay's trip contacts are closed the circuit breaker (CB) starts to open. After the CB contacts are open the fault current will still flow through an arc between the opened contacts. The current is finally cut off when the arc extinguishes at the next zero crossing of the current. This is the start moment of the reset delay. After the reset delay the trip contacts and start contact are opened unless latching is configured. The precise reset time depends on the fault size; after a big fault the reset time is longer. The reset time also depends on the specific protection stage.

The maximum reset time for each stage is specified in Chapter 12.3 Protection functions. For most stages it is less than 95 ms.

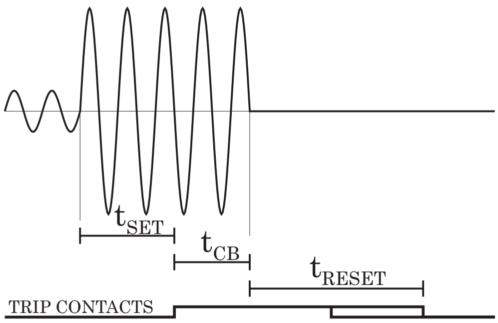


Figure 5.4: Reset time is the time it takes the trip or start relay contacts to open after the fault has been cleared.

Hysteresis or dead band

When comparing a measured value against a pick-up value, some amount of hysteresis is needed to avoid oscillation near equilibrium situation. With zero hysteresis any noise in the measured signal or any noise in the measurement itself would cause unwanted oscillation between fault-on and fault-off situations.

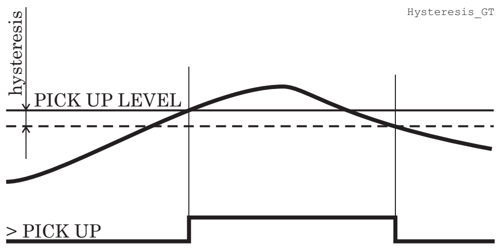


Figure 5.5: Behaviour of a greater than comparator. For example in overvoltage stages the hysteresis (dead band) acts according this figure.

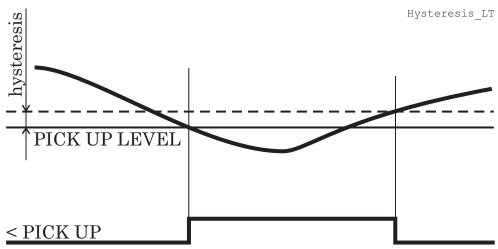


Figure 5.6: Behaviour of a less than comparator. For example in under-voltage and under frequency stages the hysteresis (dead band) acts according this figure.

5.3 Application modes

The application modes available are the feeder protection mode and the motor protection mode. In the feeder protection mode all current dependent protection functions are relative to nominal current I_N derived by CT ratios. The motor protection functions are unavailable in the feeder protection mode. In the motor protection mode all current dependent protection functions are relative to motor's nominal current I_{MOT}. The motor protection mode enables motor protection functions. All functions which are available in the feeder protection mode are also available in the motor protection mode. Default value of the application mode is the feeder protection mode.

The application mode can be changed with VAMPSET software or from CONF menu of the device. Changing the application mode requires configurator password.

5.4 Current protection function dependencies

The current based protection functions are relative to I_{MODE}, which is dependent of the application mode. In the motor, protection mode all of the current based functions are relative to I_{MOT} and in the feeder protection mode to I_N with following exceptions.

I_2> (46), I_2>> (47), I_{ST}> (48), N> (66) are always dependent on I_{MOT} and they are only available when application mode is in the motor protection.

5.5 Overcurrent protection I> (50/51)

Overcurrent protection is used against short circuit faults and heavy overloads.

The overcurrent function measures the fundamental frequency component of the phase currents. The protection is sensitive for the highest of the three phase currents. Whenever this value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation delay setting, a trip signal is issued.

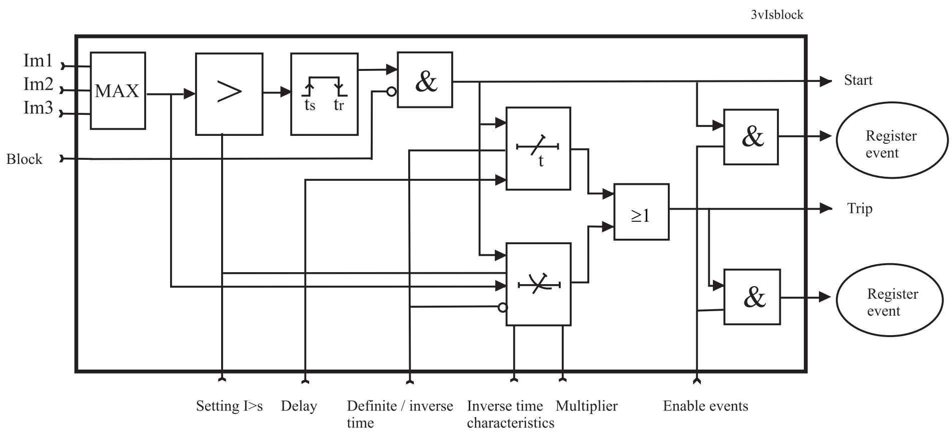


Figure 5.7: Block diagram of the three-phase overcurrent stage I>

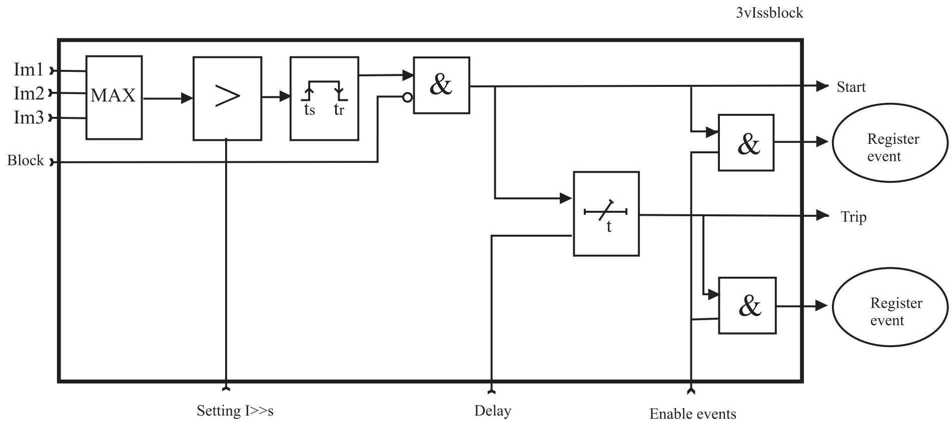


Figure 5.8: Block diagram of the three-phase overcurrent stage I>> and I>>>

Three independent stages

There are three separately adjustable overcurrent stages: I>, I>> and I>>>. The first stage I> can be configured for definite time (DT) or inverse time operation characteristic (IDMT). The stages I>> and I>>> have definite time operation characteristic. By using the definite delay type and setting the delay to its minimum, an instantaneous (ANSI 50) operation is obtained.

Figure 5.7 shows a functional block diagram of the I> overcurrent stage with definite time and inverse time operation time. Figure 5.8 shows a functional block diagram of the I>> and I>>> overcurrent stages with definite time operation delay.

Inverse operation time

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for the I> stage. The inverse delay types are described in Chapter 5.17 Inverse time operation. The device will show the currently used inverse delay curve graph on the local panel display.

Inverse time limitation

The maximum measured secondary current is 50 x I_N. This limits the scope of inverse curves with high pick-up settings. See Chapter 5.17 Inverse time operation for more information.

Cold load and inrush current handling

See Chapter 6.3 Cold load pick-up and inrush current detection.

Setting groups

There are four settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually. See Chapter 5.2 General features of protection stages for more details.

Table 5.1: Parameters of the overcurrent stage I> (50/51)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. This flag is automatically reset 5 minutes after the last front panel push button pressing.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Status			Current status of the stage	
I>		A	Pick-up value scaled to primary value	
I>		xI_N	Pick-up setting	Set
Curve	 DT IEC, IEEE, IEEE2, RI, PrgN		Delay curve family: Definite time Inverse time. See Chapter 5.17 Inverse time operation.	Set

Parameter	Value	Unit	Description	Note
Type	 DT NI, VI, EI, LTI, Parameters		Delay type Definite time Inverse time. See Chapter 5.17 Inverse time operation.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Dly20x		s	Delay at 20xImode	
Dly4x		s	Delay at 4xImode	
Dly2x		s	Delay at 2xImode	
Dly1x		s	Delay at 1xImode	
IncHarm		On/off	Include Harmonics	
Delay curves			Graphic delay curve picture (only local display)	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. Chapter 5.17 Inverse time operation.	Set
Recorded values	LOG1		Date and time of trip	
	Type		Fault type	
	Flt	xI_N	Fault current	
	Load	xI_N	Pre-fault current	
	Edly	%	Elapsed delay time	
	SetGrp		Active set group during fault	

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.20.

Table 5.2: Parameters of the overcurrent stages I>>, I>>> (50/51)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	

Parameter	Value	Unit	Description	Note
I>>, I>>>		A	Pick-up value scaled to primary value	
I>>, I>>>		xI_N	Pick-up setting	Set
t>>, t>>>		s	Definite operation time.	Set
IncHarm		On/off	Include Harmonics	Set

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.21, Table 12.22.

Recorded values of the latest eight faults

There is detailed information available of the eight latest faults: Time stamp, fault type, fault current, load current before the fault, elapsed delay and setting group.

Table 5.3: Recorded values of the overcurrent stages (8 latest faults) I>, I>>, I>>> (50/51)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type			Fault type
	1-N		Ground fault
	2-N		Ground fault
	3-N		Ground fault
	1-2		Two phase fault
	2-3		Two phase fault
	3-1		Two phase fault
	1-2-3		Three phase fault
Flt		xI_N	Maximum fault current
Load		xI_N	1 s average phase currents before the fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1, 2, 3, 4		Active setting group during fault

5.5.1 Remote controlled overcurrent scaling

Pick-up setting of the three over current stages can also be controlled remotely. In this case only two scaling coefficients are possible: 100% (the scaling is inactive) and any configured value between 10% - 200% (the scaling is active). When scaling is enabled all settings of group one are copied to group two but the pick-up value of group two is changed according the given value (10-200%).

- This feature can be enabled/disabled via VAMPSET or by using the local panel. When using VAMPSET the scaling can be activated and adjusted in the “protection stage status 2” –menu. When using the local panel similar settings can be found from the “prot” -menu.
- It is also possible to change the scaling factor remotely by using the modbus TCP –protocol. When changing the scaling factor remotely value of 1% is equal to 1. Check the correct modbus address for this application from the VAMPSET or from the communication parameter list.

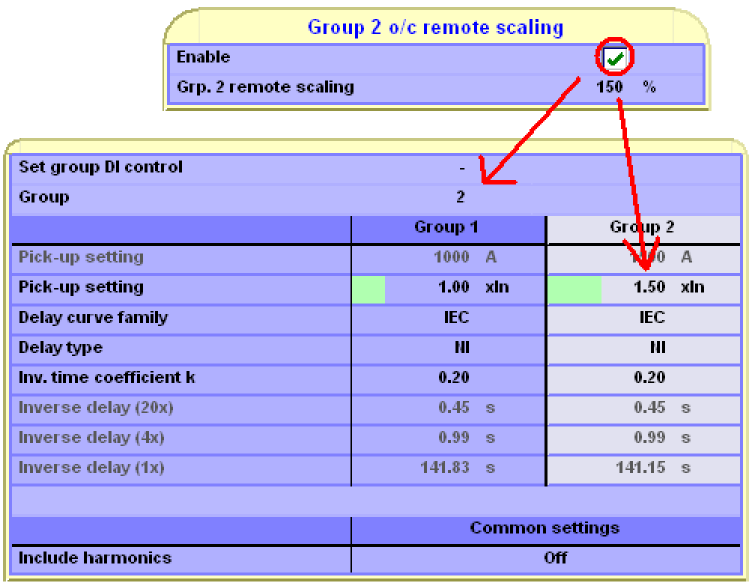


Figure 5.9: Remote scaling example.

In the Figure 5.9 can be seen the affect of remote scaling. After enabling group is changed from group one to group two and all settings from group one are copied to group two. The difference is that group two uses scaled pick-up settings.

NOTE: When remote scaling function is used, it replaces all the settings of group 2. So this function cannot be used simultaneously with normal group change.

5.6 Current unbalance stage I_2/I_1> (46)

The purpose of the unbalance stage is to detect unbalanced load conditions, for example a broken conductor of a heavy loaded overhead line in case there is no earth fault. The operation of the unbalanced load function is based on the negative phase sequence component I_2 related to the positive phase sequence component I_1. This is calculated from the phase currents using the method of symmetrical components. The function requires that the measuring inputs are connected correctly so that the rotation direction of the phase currents are as in Chapter 11.11 Connection examples. The unbalance protection has definite time operation characteristic.

$$K2 = \frac{I_2}{I_1}$$

$$I_1 = I_{L1} + aI_{L2} + a^2I_{L3}$$

$$I_2 = I_{L1} + a^2I_{L2} + aI_{L3}$$

$$\underline{a} = 1\angle 120° = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$$, a phasor rotating constant

Table 5.4: Setting parameters of the current unbalanced stage I_2/I_1> (46)

Parameter	Value	Unit	Default	Description
I2/I1>	2 – 70	%	20	Setting value, I2/I1
t>	1.0 – 600.0	s	10.0	Definite operating time
Type	DT INV	-	DT	The selection of time characteristics
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

For details of setting ranges, see Table 12.24.

Table 5.5: Measured and recorded values of the current unbalanced stage I_2/I_1> (46)

	Parameter	Value	Unit	Description
Measured value	I2/I1		%	Relative negative sequence component
Recorded values	SCntr			Cumulative start counter
	TCntr			Cumulative trip counter
	Flt		%	Maximum I_2/I_1 fault component
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

5.7 Directional earth fault protection $I_{0\varphi}$> (67N)

The directional earth fault protection is used in networks where a selective and sensitive earth fault protection is needed and in applications with varying network structure and length.

The device consists of versatile protection functions for earth fault protection in various network types.

The function is sensitive to the fundamental frequency component of the residual current and zero sequence voltage and the phase angle between them. The attenuation of the third harmonic is more than 60 dB. Whenever the size of I_0 and U_0 and the phase angle between I_0 and U_0 fulfils the pick-up criteria, the stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Polarization

The negative zero sequence voltage U_0 is used for polarization i.e. the angle reference for I_0. The $-U_0$ voltage is measured via energizing input U_0.

- 3LN+U_0: the zero sequence voltage is measured with voltage transformer(s) for example using a broken delta connection. The setting values are relative to the VT_0 secondary voltage defined in configuration.

NOTE: The U_0 signal must be connected according the connection diagram (Figure 11.8) in order to get a correct polarization.

Modes for different network types

The available modes are:

- ResCap
  This mode consists of two sub modes, Res and Cap. A digital signal can be used to dynamically switch between these two sub modes. This feature can be used with compensated networks, when the Petersen coil is temporarily switched off.
  - Res
    The stage is sensitive to the resistive component of the selected I_0 signal. This mode is used with compensated **networks** (resonant grounding) and **networks earthed with a high resistance**. Compensation is usually done with a Petersen coil between the neutral point of the main transformer and earth. In this context "high resistance" means, that the fault current is limited to be less than the rated phase current. The trip area is a half plane as drawn in Figure 5.11. The base angle is usually set to zero degrees.
  - Cap
    The stage is sensitive to the capacitive component of the selected I_0 signal. This mode is used with **unearthed networks**. The trip area is a half plane as drawn in Figure 5.11. The base angle is usually set to zero degrees.
- Sector
  This mode is used with **networks earthed with a small resistance**. In this context "small" means, that a fault current may be more than the rated phase currents. The trip area has a shape of a sector as drawn in Figure 5.12. The base angle is usually set to zero degrees or slightly on the lagging inductive side (i.e. negative angle).
- Undir
  This mode makes the stage equal to the undirectional stage I_0>. The phase angle and U_0 amplitude setting are discarded. Only the amplitude of the selected I_0 input is supervised.

Input signal selection

Each stage can be connected to supervise any of the following inputs and signals:

- Input I_0 for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3} = 3I_0$.

Intermittent earth fault detection

Short earth faults make the protection to start (to pick up), but will not cause a trip. (Here a short fault means one cycle or more. For shorter than 1 ms transient type of intermittent earth faults in compensated networks there is a dedicated stage I_{0INT}> 67NI.) When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting.

When a new start happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip.

Two independent stages

There are two separately adjustable stages: $I_{0\varphi}$> and $I_{0\varphi}$>>. Both the stages can be configured for definite time delay (DT) or inverse time delay operation time.

Inverse operation time

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for both stages $I_{0\varphi}$> and $I_{0\varphi}$>>. The inverse delay types are described in Chapter 5.17 Inverse time operation. The device will show a scaleable graph of the configured delay on the local panel display.

Inverse time limitation

The maximum measured secondary residual current is 10 x I_{0N} and maximum measured phase current is 50 x I_N. This limits the scope of inverse curves with high pick-up settings. See Chapter 5.17 Inverse time operation for more information.

Setting groups

There are four settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually. See Chapter 5.2 General features of protection stages for more details.

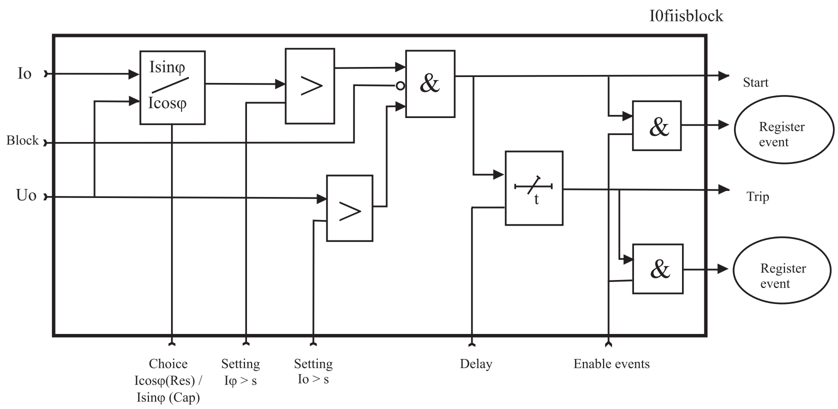


Figure 5.10: Block diagram of the directional earth fault stages $I_{0\varphi}$>, $I_{0\varphi}$>>

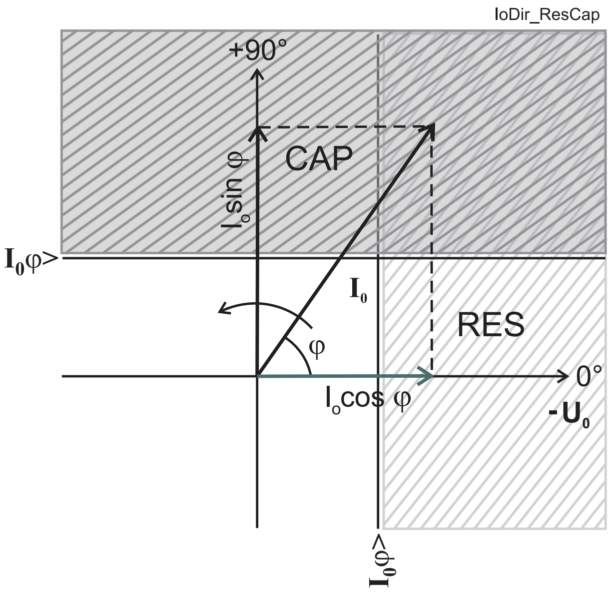


Figure 5.11: Operation characteristic of the directional earth fault protection in Res or Cap mode. Res mode can be used with compensated networks and Cap mode is used with ungrounded networks.

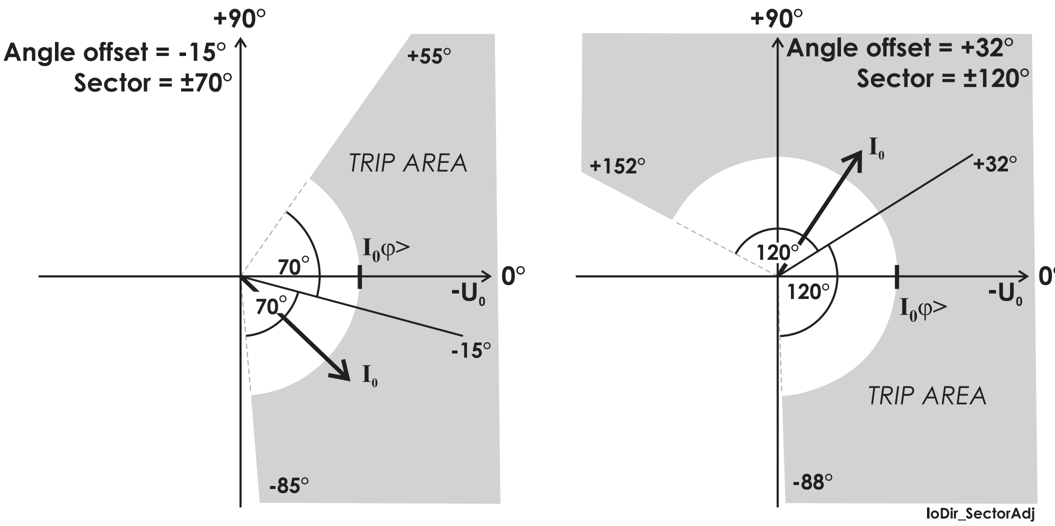


Figure 5.12: Two example of operation characteristics of the directional earth fault stages in sector mode. The drawn I_0 phasor in both figures is inside the trip area. The angle offset and half sector size are user's parameters.

Table 5.6: Parameters of the directional earth fault stages $I_{0\varphi}$>, $I_{0\varphi}$>> (67N)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io IoCalc IoPeak		pu	The supervised value according the parameter "Input" below. ($I_{0\varphi}$> only)	
IoRes		pu	Resistive part of I_0 (only when "InUse"=Res)	
IoCap		pu	Capacitive part of I_0 (only when "InUse"=Cap)	
Ioφ>		A	Pick-up value scaled to primary value	

Parameter	Value	Unit	Description	Note
Ioφ>		pu	Pick-up setting relative to the parameter “Input” and the corresponding CT value	Set
Uo>		%	Pick-up setting for U_0	Set
Uo		%	Measured U_0	
Curve			Delay curve family:	Set
	DT		Definite time	
	IEC, IEEE, IEEE2, RI, PrgN		Inverse time. Chapter 5.17 Inverse time operation.	
Type			Delay type.	Set
	DT		Definite time	
	NI, VI, EI, LTI, Parameters		Inverse time. Chapter 5.17 Inverse time operation.	
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Mode	ResCap		High impedance earthed nets	Set
	Sector		Low impedance earthed nets	
	Undir		Undirectional mode	
Offset		°	Angle offset (MTA) for RecCap and Sector modes	Set
Sector	Default = 88	±°	Half sector size of the trip area on both sides of the offset angle	Set
ChCtrl			Res/Cap control in mode ResCap	Set
	Res		Fixed to Resistive characteristic	
	Cap		Fixed to Capacitive characteristic	
	DIx		Controlled by digital input	
	VIx		Controlled by virtual input	
InUse			Selected submode in mode ResCap.	
	-		Mode is not ResCap	
	Res		Submode = resistive	
	Cap		Submode = capacitive	
Input	Io		X1:7, 8, 9. See Chapter 11 Connections.	Set
	IoCalc		IL1 + IL2 + IL3	
	IoPeak		X1:7, 8, 9 peak mode ($I_{0\varphi}$> only)	
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20xI_{0N}	
Dly4x		s	Delay at 4xI_{0N}	
Dly2x		s	Delay at 2xI_{0N}	
Dly1x		s	Delay at 1xI_{0N}	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See Chapter 5.17 Inverse time operation.	Set

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.27.

Recorded values of the latest eight faults

There is detailed information available of the eight latest earth faults: Time stamp, fault current, elapsed delay and setting group.

Table 5.7: Recorded values of the directional earth fault stages (8 latest faults) $I_{0\varphi}$>, $I_{0\varphi}$>> (67N)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Maximum earth fault current Resistive part of I_0 (only when "InUse"=Res) Capacitive part of I_0 (only when "InUse"=Cap)
EDly		%	Elapsed time of the operating time setting. 100% = trip
Angle	°		Fault angle of I_0 $-U_0$ = 0°
Uo		%	Max. U_0 voltage during the fault
SetGrp	1, 2, 3, 4		Active setting group during fault

5.8 Earth fault protection I_0> (50N/51N)

The undirectional earth fault protection is to detect earth faults in low impedance earthed networks. In high impedance earthed networks, compensated networks and isolated networks undirectional earth fault can be used as back-up protection.

The undirectional earth fault function is sensitive to the fundamental frequency component of the residual current $3I_0$. The attenuation of the third harmonic is more than 60 dB. Whenever this fundamental value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

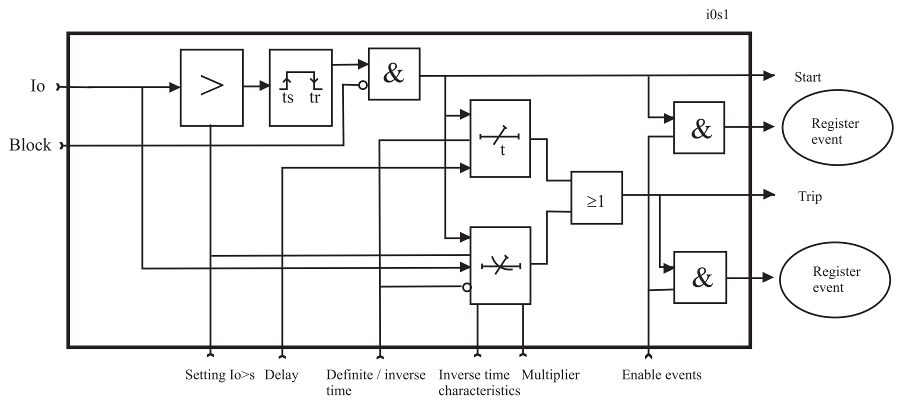


Figure 5.13: Block diagram of the earth fault stage I_0>

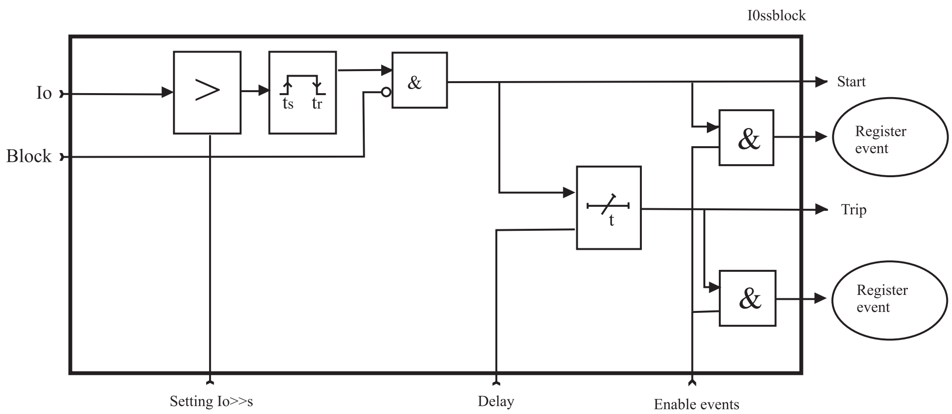


Figure 5.14: Block diagram of the earth fault stages I_0>>, I_0>>>, I_0>>>>

Figure 5.13 shows a functional block diagram of the I_0> earth overcurrent stage with definite time and inverse time operation time. Figure 5.14 shows a functional block diagram of the I_0>>, I_0>>> and I_0>>>> earth fault stages with definite time operation delay.

Input signal selection

Each stage can be connected to supervise any of the following inputs and signals:

- Input I_0 for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3}$.

Intermittent earth fault detection

Short earth faults make the protection to start (to pick up), but will not cause a trip. (Here a short fault means one cycle or more. For shorter than 1 ms transient type of intermittent earth faults in compensated networks there is a dedicated stage I_{0INT}> 67NI.) When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting.

When a new start happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip.

Four or six independent undirectional earth fault overcurrent stages

There are four separately adjustable earth fault stages: I_0>, I_0>>, I_0>>>, and I_0>>>>. The first stage I_0> can be configured for definite time (DT) or inverse time operation characteristic (IDMT). The other stages have definite time operation characteristic. By using the definite delay type and setting the delay to its minimum, an instantaneous (ANSI 50N) operation is obtained.

Using the directional earth fault stages (Chapter 5.7 Directional earth fault protection $I_{0\varphi}$> (67N)) in undirectional mode, two more stages with inverse operation time delay are available for undirectional earth fault protection.

Inverse operation time (I_0> stage only)

Inverse delay means that the operation time depends on the amount the measured current exceeds the pick-up setting. The bigger the fault current is the faster will be the operation. Accomplished inverse delays are available for the I_0> stage. The inverse delay types are described in Chapter 5.17 Inverse time operation. The device will show a scaleable graph of the configured delay on the local panel display.

Inverse time limitation

The maximum measured secondary residual current is 10 x I_{0N} and maximum measured phase current is 50 x I_N. This limits the scope of inverse curves with high pick-up settings. See Chapter 5.17 Inverse time operation for more information.

Setting groups

There are four settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually. See Chapter 5.2 General features of protection stages for more details.

Table 5.8: Parameters of the undirectional earth fault stage I_0> (50N/51N)

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io, IoCalc, IoPeak		pu	The supervised value according the parameter "Input" below.	
Io>		A	Pick-up value scaled to primary value	
Io>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
Curve			Delay curve family:	Set
	DT		Definite time	
	IEC, IEEE, IEEE2, RI, PrgN		Inverse time. Chapter 5.17 Inverse time operation.	
Type			Delay type.	Set
	DT		Definite time	
	NI, VI, EI, LTI, Parameters		Inverse time. Chapter 5.17 Inverse time operation.	
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Input	Io		X1:7, 8, 9. See Chapter 11 Connections.	Set
	IoCalc		IL1 + IL2 + IL3	
	IoPeak		X1:7, 8, 9. peak mode ($I_{0\varphi}$> only).	
Intrmt		s	Intermittent time	Set

Parameter	Value	Unit	Description	Note
Dly20x		s	Delay at 20 x I_{0N}	
Dly4x		s	Delay at 4 x I_{0N}	
Dly2x		s	Delay at 2 x I_{0N}	
Dly1x			Delay at 1 x I_{0N}	
A, B, C, D, E			User’s constants for standard equations. Type=Parameters. See Chapter 5.17 Inverse time operation.	Set

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.25.

Table 5.9: Parameters of the undirectional earth fault stage I_0>>, I_0>>>, I_0>>>> (50N/51N)

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
TripTime		s	Estimated time to trip	
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1, 2, 3, 4		Active setting group	Set
SgrpDI			Digital signal to select the active setting group	Set
	-		None	
	Dix		Digital input	
	Vix		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Io IoCalc		pu	The supervised value according the parameter “Input” below.	
Io>>, Io>>>, Io>>>>		A	Pick-up value scaled to primary value	
Io>>, Io>>>, Io>>>>		pu	Pick-up setting relative to the parameter "Input" and the corresponding CT value	Set
t>		s	Definite operation time (for definite time only)	Set
Input	Io		X1:7, 8, 9. See Chapter 11 Connections.	Set
	IoCalc		IL1 + IL2 + IL3	

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.26.

Recorded values of the latest eight faults

There is detailed information available of the eight latest earth faults: Time stamp, fault current, elapsed delay and setting group.

Table 5.10: Recorded values of the undirectional earth fault stages (8 latest faults) I_0>>, I_0>>>, I_0>>>> (50N/51N)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Maximum earth fault current
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1, 2, 3, 4		Active setting group during fault

5.8.1 Earth fault faulty phase detection algorithm

Phase recognition:

A zero sequence overcurrent has been detected.

Faulted phase/ phases are detected in 2 stage system.

1. Algorithm is using delta principle to detect the faulty phase/ phases.
2. Algorithm confirms the faulty phase with neutral current angle comparison to the suspected faulted phase.

Ideal grounded network:

When there is forward earth fault in phase L1, its current will increase creating calculated or measured zero sequence current in phase angle of 0 degrees. If there is reverse earth fault in phase L1, its current will degrease creating calculated or measured zero sequence current in phase angle of 180 degrees.

When there is forward earth fault in phase L2, its current will increase creating calculated or measured zero sequence current in phase angle of -120 degrees. If there is reverse earth fault in phase L2, its current will degrease creating calculated or measured zero sequence current in phase angle of 60 degrees.

When there is forward earth fault in phase L3, its current will increase creating calculated or measured zero sequence current in phase angle of 120 degrees. If there is reverse earth fault in phase L3 its current will degrease creating calculated or measured zero sequence current in phase angle of -60 degrees.

Implementation:

When faulty phase is recognized, it will be recorded in 50N protection fault log (also in event list and alarm screen). This faulted phase and direction recording function has a tick box for enabling/disabling in protection stage settings. For compensated network, this is not a 100% reliable algorithm because it depends on the network compensation degree. So for compensated networks this feature can be turned off so it will not cause confusion. For high impedance earthed networks, there will be drop down menu in both setting groups to choose between RES/CAP. RES is default and it is for earthed networks. When CAP is chosen, the Io angle will be corrected to inductive direction 90 degrees and after that faulty phase detection is made.

Possible outcomes and conditions for those detections:

- FWD L1
  Phase L1 increases above the set limit and two other phases remain inside the set (delta) limit. Io current angle is +/- 60 degrees from L1 phase angle.
- FDW L2
  Phase L2 increases above the set limit and two other phases remain inside the set (delta) limit. Io current angle is +/- 60 degrees from L2 phase angle.
- FDW L3
  Phase L3 increases above the set limit and two other phases remain inside the set (delta) limit. Io current angle is +/- 60 degrees from L3 phase angle.
- FWD L1-L2
  Phase L1 and L2 increase above the set limit and phase L3 remains inside the set (delta) limit. Io current angle is between L1 and L2 phase angles.
- FWD L2-L3
  Phase L2 and L3 increase above the set limit and phase L1 remains inside the set (delta) limit. Io current angle is between L2 and L3 phase angles.
- FWD L3-L1
  Phase L3 and L1 increase above the set limit and phase L2 remains inside the set (delta) limit. Io current angle is between L3 and L3 phase angles.
- FWD L1-L2-L3
  All three phase currents increase above the set delta limit.
- REV 1 (any one phase)
  One phase decreases below the set delta limit and other two phases remain inside the delta limit.
- REV 2 (any two phase)
  Two phases decrease below the set delta limit and third phase remains inside the delta limit.
- REV 3 (all three phases)
  All three phase currents decrease below the set delta limit.

Below are simulated different fault scenarios:

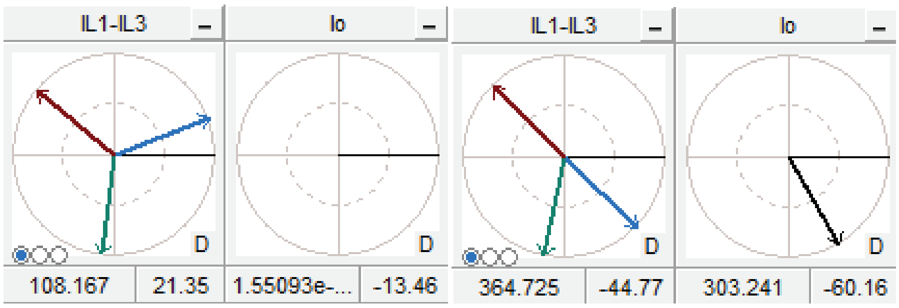


Figure 5.15: Phase L1 forward

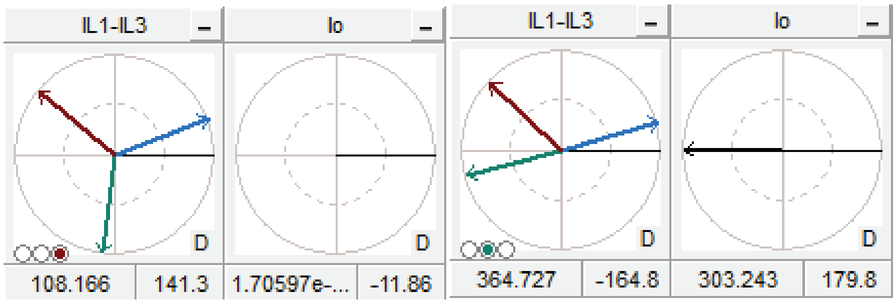


Figure 5.16: Phase L2 forward

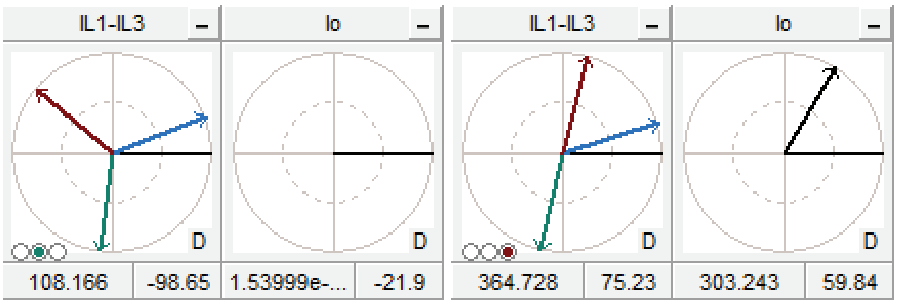


Figure 5.17: Phase L3 forward

5.9 Zero sequence voltage protection U_0> (59N)

The zero sequence voltage protection is used as unselective backup for earth faults and also for selective earth fault protections for motors having a unit transformer between the motor and the busbar.

This function is sensitive to the fundamental frequency component of the zero sequence voltage. The attenuation of the third harmonic is more than 60 dB. This is essential, because 3rd harmonics exist between the neutral point and earth also when there is no earth fault.

Whenever the measured value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Measuring the zero sequence voltage

The zero sequence voltage is either measured with three voltage transformers (e.g. broken delta connection), one voltage transformer between the motor's neutral point and earth or calculated from the measured phase-to-neutral voltages according to the selected voltage measurement mode (see Chapter 7.7 Voltage measurement modes):

- U_0: The zero sequence voltage is measured with voltage transformer(s) for example using a broken delta connection. The setting values are relative to the VT_0 secondary voltage defined in configuration.

NOTE: The U_0 signal must be connected according the connection diagram (Figure 11.8) in order to get a correct polarization.

Two independent stages

There are two separately adjustable stages: U_0> and U_0>>. Both stages can be configured for definite time (DT) operation characteristic.

The zero sequence voltage function comprises two separately adjustable zero sequence voltage stages (stage U_0> and U_0>>).

Setting groups

There are four settings groups available for both stages. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually. See Chapter 5.2 General features of protection stages for more details.

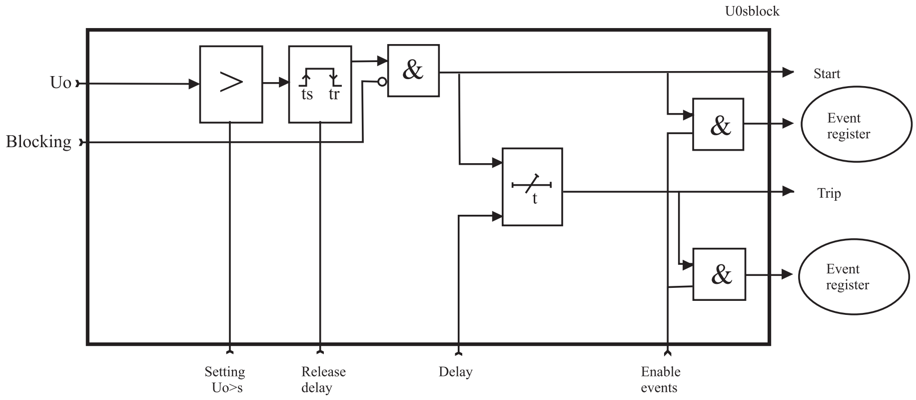


Figure 5.18: Block diagram of the zero sequence voltage stages U_0>, U_0>>

Table 5.11: Parameters of the residual overvoltage stages U_0>, U_0>>

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Uo		%	The supervised value relative to Un/ $\sqrt{3}$	
Uo>, Uo>>		%	Pick-up value relative to Un/ $\sqrt{3}$	Set
t>, t>>		s	Definite operation time.	Set

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp, fault voltage, elapsed delay and setting group.

Table 5.12: Recorded values of the residual overvoltage stages U_0>, U_0>>

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		%	Fault voltage relative to Un/ $\sqrt{3}$
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1, 2, 3, 4		Active setting group during fault

5.10 Thermal overload protection T> (49)

The thermal overload function protects cables against excessive heating.

Thermal model

The temperature is calculated using rms values of phase currents and a thermal model according IEC 60255-8. The rms values are calculated using harmonic components up to the 15th.

Trip time: $t = \tau \cdot \ln \frac{I^2 - I_P^2}{I^2 - a^2}$, τ unit: second

Alarm: $a = k \cdot k_\Theta \cdot I_N \cdot \sqrt{alarm}$ (Alarm 60% = 0.6)

Trip: $a = k \cdot k_\Theta \cdot I_N$

Release time: $t = \tau \cdot C_\tau \cdot \ln \frac{I_P^2}{a^2 - I^2}$, τ unit: second

Trip release: $a = \sqrt{0.95} \times k \times I_N$

Start release: $a = \sqrt{0.95} \times k \times I_N \times \sqrt{alarm}$ (Alarm 60% = 0.6)

T =	Operation time
τ =	Thermal time constant tau (Setting value)
ln =	Natural logarithm function
I =	Measured rms phase current (the max. value of three phase currents)
Ip =	Preload current, $I_P = \sqrt{\theta} \times k \times I_N$ (If temperature rise is 120%(θ = 1.2). This parameter is the memory of the algorithm and corresponds to the actual temperature rise.
k =	Overload factor (Maximum continuous current), i.e. service factor.(Setting value)
kΘ =	Ambient temperature factor (Permitted current due to tamb).
I_N =	The rated current
C_τ =	Relay cooling time constant (Setting value)

Time constant for cooling situation

If the feeder's fan is stopped, the cooling will be slower than with an active fan. Therefore there is a coefficient C_T for thermal constant available to be used as cooling time constant, when current is less than 0.3 x I_N.

Heat capacitance, service factor and ambient temperature

The trip level is determined by the maximum allowed continuous current I_{MAX} corresponding to the 100 % temperature rise Θ_{TRIP} i.e. the heat capacitance of the cable. I_{MAX} depends of the given service factor k and ambient temperature Θ_{AMB} and settings I_{MAX40} and I_{MAX70} according the following equation.

$$I_{MAX} = k \cdot k_{\Theta} \cdot I_N$$

The value of ambient temperature compensation factor kΘ depends on the ambient temperature Θ_{AMB} and settings I_{MAX40} and I_{MAX70}. See Figure 5.19. Ambient temperature is not in use when kΘ = 1. This is true when

- I_{MAX40} is 1.0
- Samb is “n/a” (no ambient temperature sensor)
- TAMB is +40 °C.

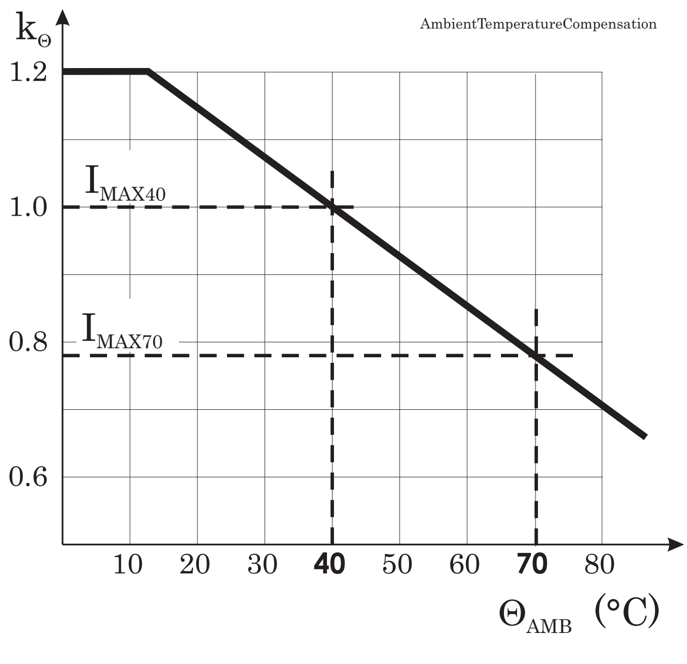


Figure 5.19: Ambient temperature correction of the overload stage T>.

Example of a behaviour of the thermal model

Figure 5.19 shows an example of the thermal model behaviour. In this example τ = 30 minutes, k = 1.06 and kΘ = 1 and the current has been zero for a long time and thus the initial temperature rise is 0 %. At time = 50 minutes the current changes to 0.85 x I_N and the temperature rise starts to approach value $(0.85/1.06)^2$ = 64 % according the time constant. At time = 300 min, the temperature is about stable, and the current increases to 5 % over the maximum defined by the rated current and the service factor k. The temperature rise starts to approach value 110 %. At about 340 minutes the temperature rise is 100 % and a trip follows.

Initial temperature rise after restart

When the device is switched on, an initial temperature rise of 70 % is used. Depending of the actual current, the calculated temperature rise then starts to approach the final value.

Alarm function

The thermal overload stage is provided with a separately settable alarm function. When the alarm limit is reached the stage activates its start signal.

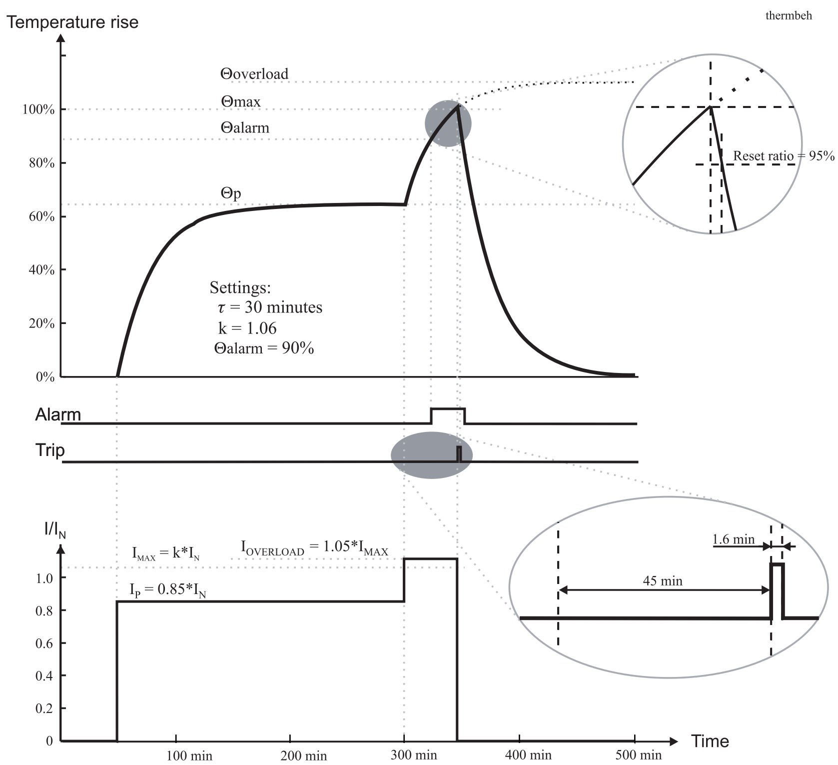


Figure 5.20: Example of the thermal model behaviour.

Table 5.13: Parameters of the thermal overload stage T> (49)

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
Time	hh:mm:ss		Estimated time to trip	
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
T		%	Calculated temperature rise. Trip limit is 100 %.	F
MaxRMS		Arms	Measured current. Highest of the three phases.	
Imax		A	k x I_N. Current corresponding to the 100 % temperature rise.	
k>		xI_N	Allowed overload (service factor)	Set
Alarm		%	Alarm level	Set
tau		min	Thermal time constant	Set
ctau		xtau	Coefficient for cooling time constant. Default = 1.0	Set
kTamb		xI_N	Ambient temperature corrected max. allowed continuous current	
Imax40		$\%I_N$	Allowed load at Tamb +40 °C. Default = 100 %.	Set
Imax70		$\%I_N$	Allowed load at Tamb +70 °C.	Set
Tamb		°C	Ambient temperature. Editable Samb=n/a. Default = +40 °C	Set
Samb			Sensor for ambient temperature	Set
	n/a		No sensor in use for Tamb	
	ExtAI1 – 16		External Analogue input 1 – 16	

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.23.

5.11 Magnetishing inrush I_{f2} > (68F2)

This stage is mainly used to block other stages. The ratio between the second harmonic component and the fundamental frequency component is measured on all the phase currents. When the ratio in any phase exceeds the setting value, the stage gives a start signal. After a settable delay, the stage gives a trip signal.

The start and trip signals can be used for blocking the other stages.

The trip delay is irrelevant if only the start signal is used for blocking.

The trip delay of the stages to be blocked must be more than 60 ms to ensure a proper blocking.

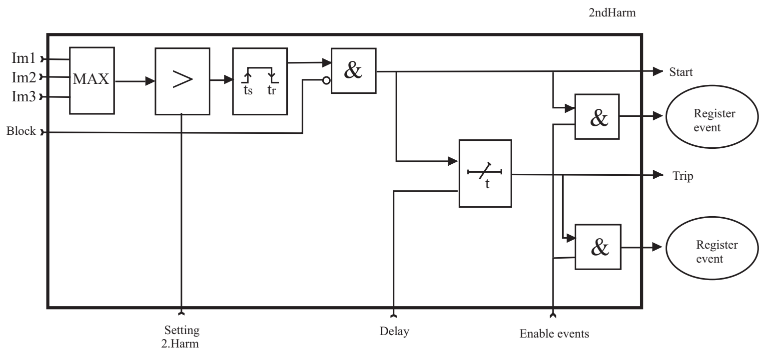


Figure 5.21: Block diagram of the magnetishing inrush stage.

Table 5.14: Setting parameters of magnetishing inrush blocking (68F2)

Parameter	Value	Unit	Default	Description
If2>	10 – 100	%	10	Setting value If2/Ifund
t_f2	0.05 – 300.0	s	0.05	Definite operating time
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

For details of setting ranges, see Table 12.29.

Table 5.15: Measured and recorded values of magnetishing inrush blocking (68F2)

	Parameter	Value	Unit	Description
Measured values	IL1H2.		%	2. harmonic of IL1, proportional to the fundamental value of IL1
	IL2H2.		%	2. harmonic of IL2
	IL3H2.		%	2. harmonic of IL3
Recorded values	Flt		%	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

5.12 Transformer over excitation I_{f5}> (68F5)

Overexiting for example a transformer creates odd harmonics. This over excitation stage can be used detect overexcitation. This stage can also be used to block some other stages.

The ratio between the over excitation component and the fundamental frequency component is measured on all the phase currents. When the ratio in any phase exceeds the setting value, the stage gives a start signal. After a settable delay, the stage gives a trip signal.

The trip delay of the stages to be blocked must be more than 60 ms to ensure a proper blocking.

Table 5.16: Setting parameters of over exicitation blocking (68F5)

Parameter	Value	Unit	Default	Description
If5>	10 – 100	%	10	Setting value If5/Ifund
t_f5	0.05 – 300.0	s	0.05	Definite operating time
S_On	Enabled; Disabled	-	Enabled	Start on event
S_Off	Enabled; Disabled	-	Enabled	Start off event
T_On	Enabled; Disabled	-	Enabled	Trip on event
T_Off	Enabled; Disabled	-	Enabled	Trip off event

For details of setting ranges, see Table 12.30.

Table 5.17: Measured and recorded values of over exicitation blocking (68F5)

	Parameter	Value	Unit	Description
Measured values	IL1H5.		%	5. harmonic of IL1, proportional to the fundamental value of IL1
	IL2H5.		%	5. harmonic of IL2
	IL3H5.		%	5. harmonic of IL3
Recorded values	Flt		%	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

5.13 Circuit breaker failure protection CBFP (50BF)

The circuit breaker failure protection can be used to trip any upstream circuit breaker (CB), if the fault has not disappeared within a given time after the initial trip command. A different output contact of the device must be used for this backup trip.

The operation of the circuit-breaker failure protection (CBFP) is based on the supervision of the signal to the selected trip relay and the time the fault remains on after the trip command.

If this time is longer than the operating time of the CBFP stage, the CBFP stage activates another output relay, which will remain activated until the primary trip relay resets.

The CBFP stage is supervising all the protection stages using the same selected trip relay, since it supervises the control signal of this device. See Chapter 8.5 Output matrix

Table 5.18: Parameters of the circuit breaker failure stage CBFP (50BF)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Cbrelay			The supervised output relay*).	Set
	1		Relay T1	
	2		Relay T2	
t>		s	Definite operation time.	Set

*) This setting is used by the circuit breaker condition monitoring, too. See Chapter 6.5 Circuit breaker condition monitoring.

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Table 12.28.

Recorded values of the latest eight faults

There are detailed information available of the eight latest faults: Time stamp and elapsed delay.

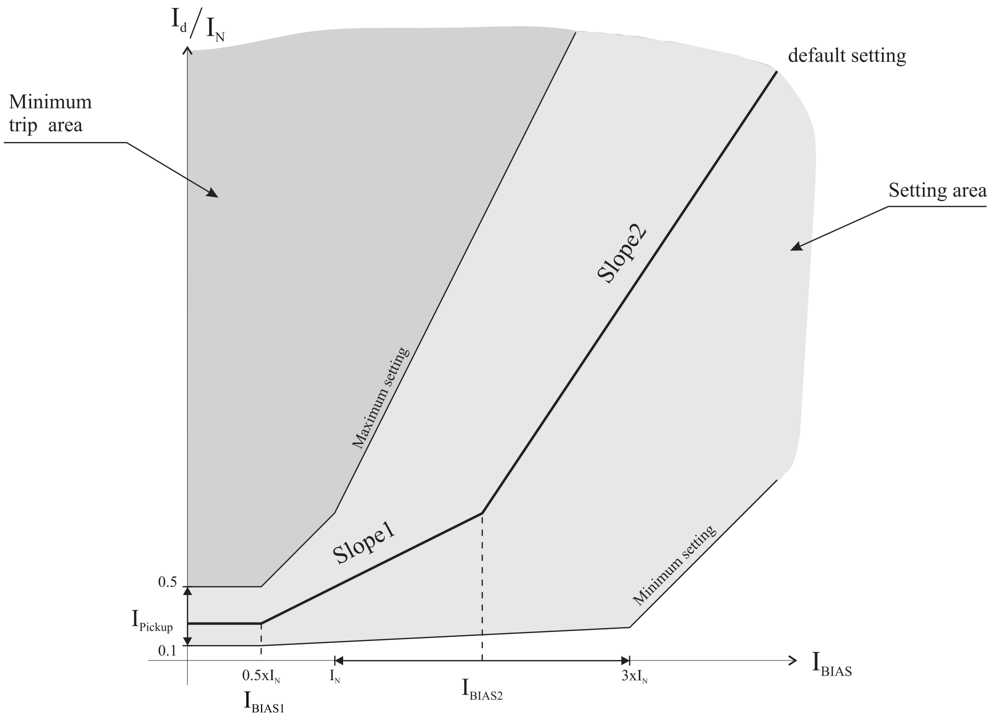
Table 5.19: Recorded values of the circuit breaker failure stage (8 latest faults) CBFP (50BF)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
EDly		%	Elapsed time of the operating time setting. 100% = trip

5.14 Line differential protection LdI> (87L)

VAMP 59 is a differential protection device mainly designed for sub-transmission overhead lines, medium voltage cables and transformers. Two line ends may lie within the protection zone.

Phase segregated protection is based on current (vector) differential. Combination of both phase and magnitude differential is used to determine operation. The differential element takes a sampled version of the instantaneous current waveform as its local input and compares it with a corresponding current from the remote end. The signal is converted to magnitude and angle information for comparison. The threshold characteristics is biased for CT saturation as presented in Figure 5.22.



Settings:

$I_{Pick\text{-}Up}$ = 20 – 50%

Start of slope1 = 0.5 – 1.0 x I_N

Slope1 = 0 – 100%

Start of slope2 = 1.0 – 3.0 x I_N

Slope2 = 50 – 200%

Figure 5.22: Tripping threshold characteristics

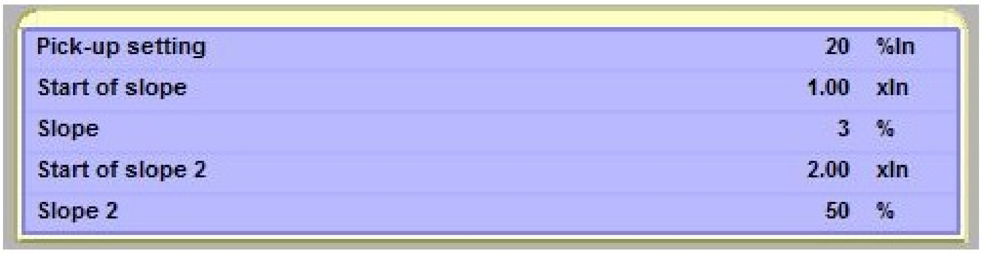
Bias current calculation is only used in protection stage LdI>. Bias current describes the average current flow in transformer. Bias and differential currents are calculated individually for each phase.

Equation 5.1: Bias current

$$I_b = \frac{\left|\overline{I}_{RELAY1}\right| + \left|\overline{I}_{RELAY2}\right|}{2}$$

Equation 5.2: Differential current

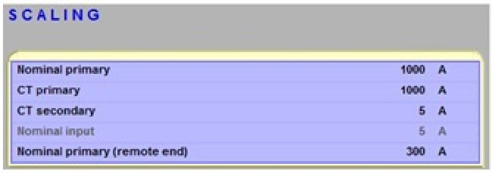
$$I_d = \left|\overline{I}_{RELAY1} - \overline{I}_{RELAY2}\right|$$



Pick-up setting	20	%In
Start of slope	1.00	xIn
Slope	3	%
Start of slope 2	2.00	xIn
Slope 2	50	%

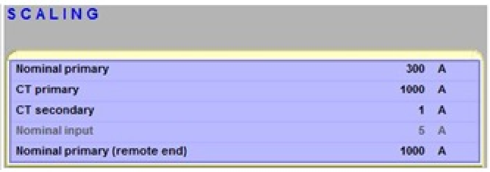
Figure 5.23: Setting example

Example 1: Normal situation from relay 1 point of view



SCALING

Nominal primary	1000	A
CT primary	1000	A
CT secondary	5	A
Nominal input	5	A
Nominal primary (remote end)	300	A



SCALING

Nominal primary	300	A
CT primary	1000	A
CT secondary	1	A
Nominal input	5	A
Nominal primary (remote end)	1000	A

Relay1: measured phase current I_{L1} = 1000A / 0°

Relay2: measured phase current I_{L1} = 300A / -180°

CT scaling of relay1 is 1000A / 5A and nominal current is 1000A.

CT scaling of relay2 is 1000A / 1A and the nominal current is 300A.

Relay2 sends primary current measurement information to relay1.

Relay1 swaps the angle of received current by 180 degrees (relay2 phase current I_{L1} = 300A / -180° ⇒ 300A / 0°).

In BIAS-calculation the measured current amplitude is divided by the nominal primary current of both ends (might be different like now).

Relay1: $I_{PRIMARY\ MEASURED} / I_{NOMINAL}$ = 1000A / 1000A = 1

Relay2: $I_{PRIMARY\ RECEIVED} / I_{NOMINAL\ REMOTE}$ = 300A / 300A = 1

$$I_b = \frac{|1| + |1|}{2} = 1 \times I_N$$

$$I_d = |1\angle 0° - 1\angle 0°| = 0 \times I_N$$

Example 2: Fault situation from relay 1 point of view

Relay1: measured phase current I_{L1} = 2400A / -30°

Relay2: measured phase current I_{L1} = 2100A / -45°

CT scaling of relay1 is 1000A / 5A and nominal current is 1000A.

CT scaling of relay2 is 1000A / 1A and the nominal current is 300A.

Relay2 sends primary current measurement information to relay1.

Relay1 swaps the angle of received current by 180 degrees (relay2 phase current I_{L1} = 2100A / -45° ⇒ 2100A / 135°).

In BIAS-calculation the measured current amplitude is divided by the nominal primary current of both ends (might be different like now).

Relay1: $I_{PRIMARY\ MEASURED} / I_{NOMINAL}$ = 2400A / 1000A = 2.4

Relay2: $I_{PRIMARY\ RECEIVED} / I_{NOMINAL\ REMOTE}$ = 2100A / 300A = 7

$$I_b = \frac{|2.4| + |7|}{2} = 4.7 \times I_N$$

$$I_d = |2.4\angle -35° - 7\angle 135°| = 9.37 \times I_N$$

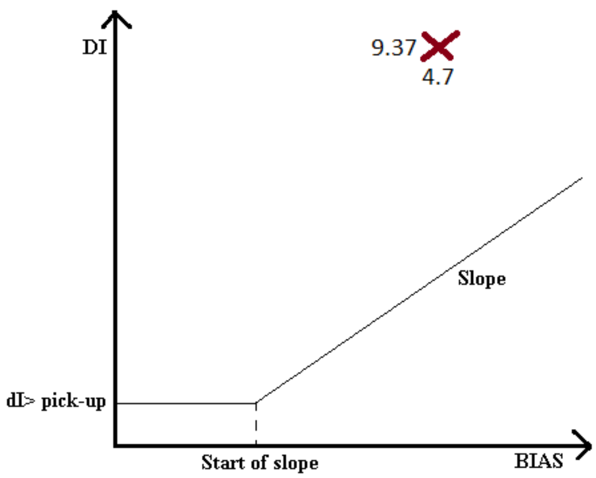


Figure 5.24: Example BIAS and differential calculation

Data communication for differential current measurement is functioned via fibre-optic cables. Single-mode fibre provides communication up till 120 km with external communication modules.

Relay has special setting called “Line distance”. This setting compensates the time delay between the relay caused by the optic fiber. In case that the length of the fibre is 90 km the setting has to be 90km as well.

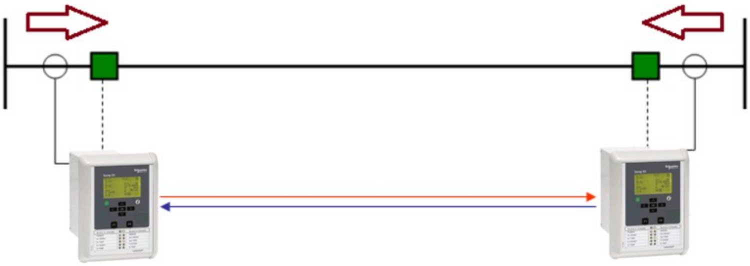


Figure 5.25: CT wiring towards the line

The starting times of the phase currents calculation tasks in two relays are synchronized. Function will block tripping until the synchronization is achieved. The default communication speed is 64000 bps.

Serial remote port of the relay (RS-232) is used by line differential protection. The recommended solution for the communication channel is the supervised fibre optic wiring. With multimode fibre cables and VSE001-GG fibre optic modems the communication distance can be up to 1 km. When using single mode fibre cables and third party converters the distance can be up to tens of kilometres.

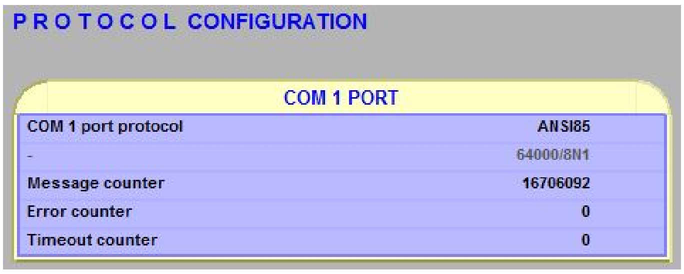


Figure 5.26: Enabling line differential communication

Line differential protection has no operation delay. When the difference between phase currents has been greater than the threshold for two task cycles, the device will trip. Typical tripping time in fault situation is 35 ms.

In case of the communication channel failure the line differential protection is inactive.

Line differential trip signal as well as communication channel failure status are available as inputs in the output matrix and blocking matrix of the relay.

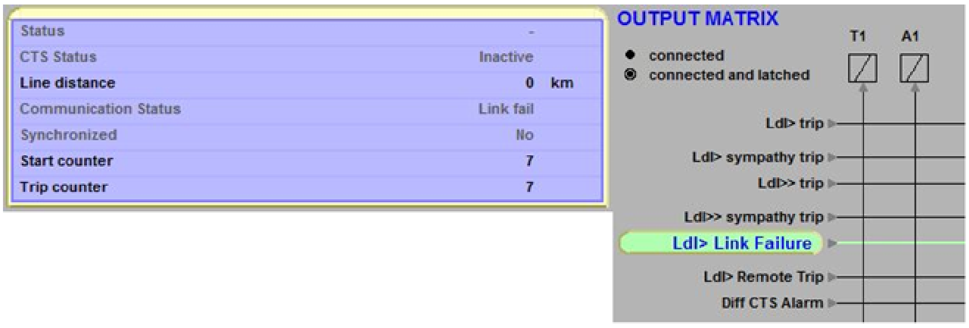
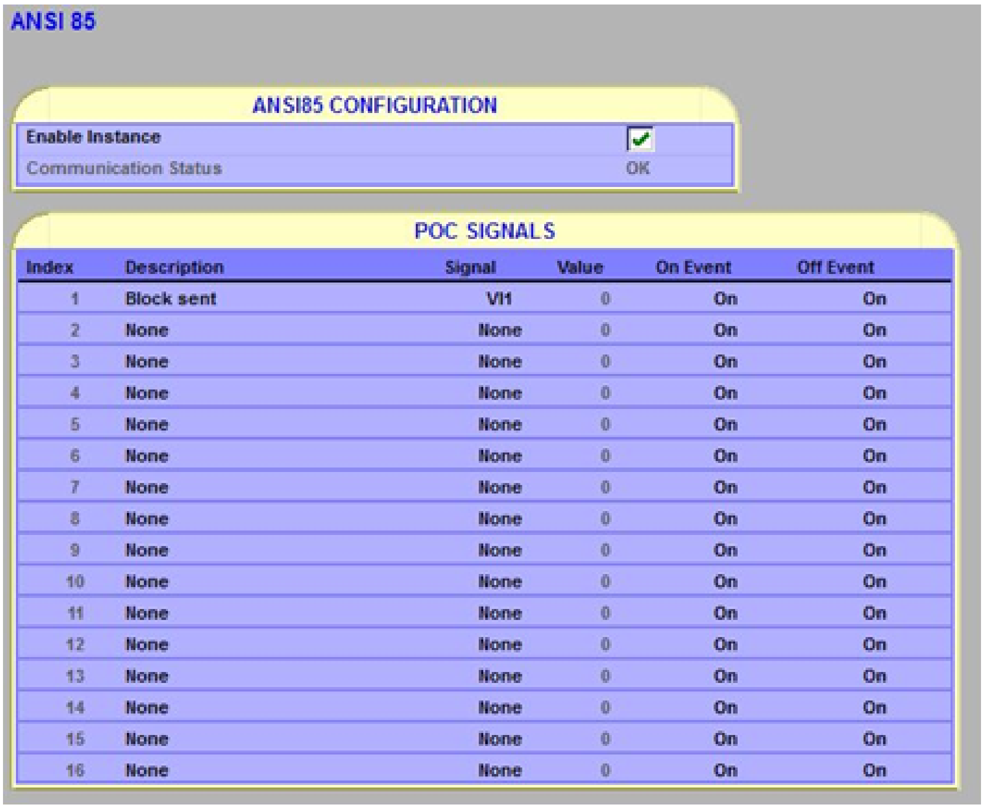


Figure 5.27: Communication failure

The communication channel between two line differential protection relays carries also binary signals in both directions: the status of LDP trip signals, and the remote trip command signal which is an output from the output logic matrix of the sending relay. Remote trip signal can be processed as an input in the output matrix and blocking matrix of the receiving relay. Up to 16 binary signals can be sent between the relays. Signals are updated every 10 ms. POC-signals are tied to line differential algorithm which is operating after every half cycle (50Hz).



ANSI 85

ANSI85 CONFIGURATION

Enable Instance	✓
Communication Status	OK

POC SIGNALS

Index	Description	Signal	Value	On Event	Off Event
1	Block sent	VI1	0	On	On
2	None	None	0	On	On
3	None	None	0	On	On
4	None	None	0	On	On
5	None	None	0	On	On
6	None	None	0	On	On
7	None	None	0	On	On
8	None	None	0	On	On
9	None	None	0	On	On
10	None	None	0	On	On
11	None	None	0	On	On
12	None	None	0	On	On
13	None	None	0	On	On
14	None	None	0	On	On
15	None	None	0	On	On
16	None	None	0	On	On

Figure 5.28: Up to 16 event stamped binary signals

In VAMP 59 current comparison is based to nominal primary currents of both ends in this unit. In line or cable differential protection “nominal primary” value should be the same the “CT primary” value.

When it comes to transformer protection it is normal that nominal current of the transformer differs of the CT nominal which is higher. To ensure correct differential calculation it is important to know the nominal current of the other end as well.

When there is transformer on the line or the VAMP 59 is used mainly to transformer differential protection, it is possible to select correct connection group and whether the relay is on high voltage (HV) or low voltage side (LV).

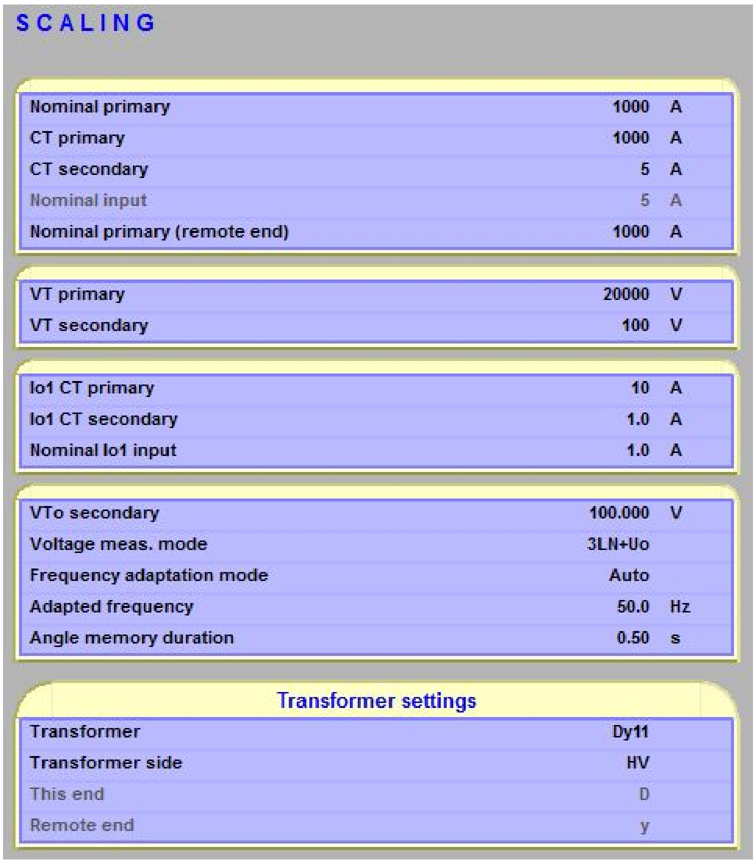


Figure 5.29: CT – and transformer settings

If transformer is earthed, e.g. connection group Dyn11, then zero current must be compensated before differential and bias current calculation. Zero current compensation can be selected individually for own and remote side.

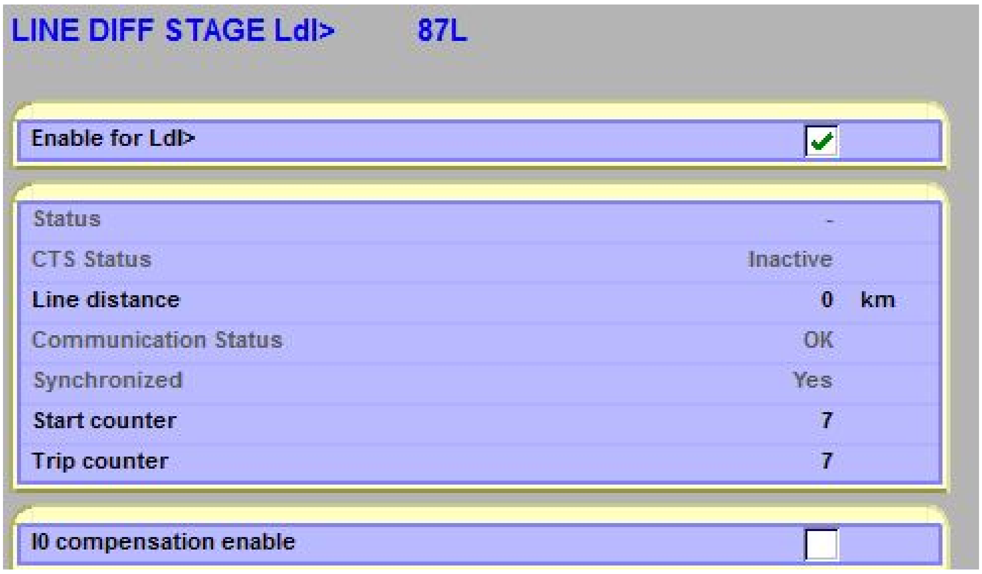


Table 5.20: Zero current compensation in transformer applications

Transformator	Relay setting		
Connection group	**ConnGrp**	**Io cmps**	**I'o cmps**
YNy0	Yy0	ON	OFF
YNyn0	Yy0	ON	ON
Yy0	Yy0	OFF	OFF
Yyn0	Yy0	OFF	ON
YNy6	Yy6	ON	OFF
YNyn6	Yy6	ON	ON
Yy6	Yy6	OFF	OFF
Yyn6	Yy6	OFF	ON
Yd1	Yd1	OFF	OFF
YNd1	Yd1	ON	OFF
Yd5	Yd5	OFF	OFF
YNd5	Yd5	ON	OFF
Yd7	Yd7	OFF	OFF
YNd7	Yd7	ON	OFF
Yd11	Yd11	OFF	OFF
YNd11	Yd11	ON	OFF
Dy1	Dy1	OFF	OFF
Dyn1	Dy1	OFF	ON
Dy5	Dy5	OFF	OFF
Dyn5	Dy5	OFF	ON
Dy7	Dy7	OFF	OFF
Dyn7	Dy7	OFF	ON
Dy11	Dy11	OFF	OFF
Dyn11	Dy11	OFF	ON

For details of setting ranges, see Table 12.17, Table 12.18, Table 12.19.

Testing mode

Test mode for commissioning can be enabled from the protection stage also. When protection stage in test mode does not receive currents from the other relay, this way the tests can be carried out without interference from the other relay. In test mode, the relay still sends it’s measurements to the other relay. When test mode is activated, it is shown in the protection stage.

Figure 5.30: When VI1 was activated, “Operation mode” changed from normal to test.

The other end relay tripping should be blocked during testing. This can be achieved by sending block signal with POC-messages to the other side and activating blocking for differential protection from that signal.

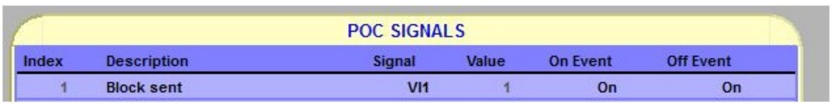


Figure 5.31: Sending the Block signal

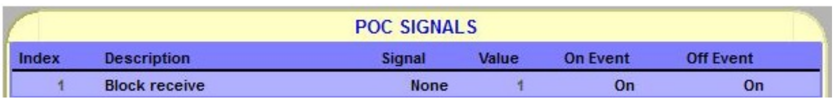


Figure 5.32: Receiving the Block signal in other relay

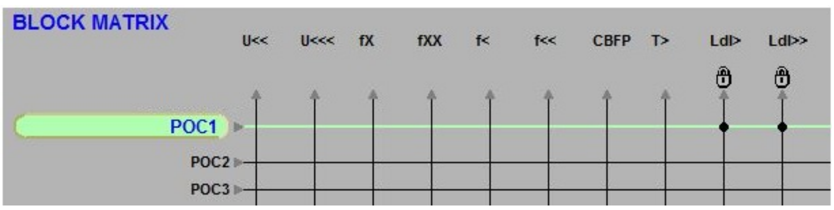


Figure 5.33: Using the block signal for differential protection blocking

Current transformer supervision

The current transformer supervision feature is used to detect failure of one or more of the phase current inputs to the relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the current circuit causes dangerous CT secondary voltages being generated.

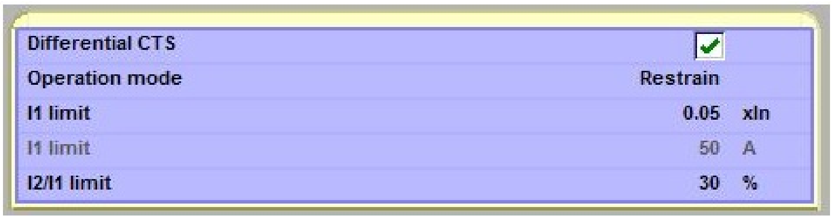


Figure 5.34: Current transformer supervision settings

Differential CTS method uses the ratio between positive and negative sequence currents in both ends of the protected line to determine CT failure. This algorithm relies on ANSI85 communication and is inbuilt to LdI> stage.

When this ratio is small (zero), one of four conditions is present:

- The system is unloaded – both I2 and I1 are zero
- The system is loaded but balanced – I2 is zero
- The system has three phase fault – I2 is zero
- There is 3-phase CT failure – Unlikely to happen

When the ratio in non-zero one of the two conditions is present:

- The system has an asymmetric fault – both I2 and I1 are non-zero
- There is a 1 or 2 phase CT fault – both I2 and I1 are non-zero

I2 to I1 ratio is calculated in both ends of the protected line. Both relays calculate their own ratio and other end ratio from the own measurements and via ANSI85 received measurements. With this information we can assume:

- If the ratio is non-zero in both ends we have real fault in the network and the CTS should not operate.
- If the ratio is non-zero only in one end there is a change of CT failure and CTS should operate.

A second criteria for CTS is to check whether the differential system is loaded or not. For this purpose the positive sequence current I1 is checked at both ends. If load current is detected only in one end, it is assumed that there is internal fault condition and CTS is prevented from operating, but if load current is detected at both line ends, CTS operation is permitted.

There will be three modes of operation: Indication, restrain, block. In indication mode CTS alarm is raised but no effect on tripping. In restrain mode alarm is raised and differential current settings are raised 100% which is theoretically the maximum amount of differential current what CT failure can produce in normal full load condition. In block mode alarm is raised and differential protection is inhibited to trip.

Differential CTS block mode is not recommended for following two reasons:

- If there is real fault during CT failure differential protection would not protected the line at all.
- Blocking protection could slow down operation time of differential protection due transients in beginning of fault in protected line.

5.14.1 Capacitive charging current

Major charging currents can be expected on cable or hybrid feeders. The charging current of the cable will increase according the lengt of the circuit. The capacitive charging current leads the feeder load current and therefore is causing differential (phase and magnitude) to the protected feeder. Steady state difference in currents will have an impact on the minimum differential settings that may be used.

Equation 5.3: Capacitive charging current

$$I_C = l2\pi fCU \cdot 10^{-3}$$

l =	Cable length (km)
I_C =	Charging current (amperes)
f =	Frequency
C =	Cable capacitance (μF / km)
U =	Voltage to neutral (kV)

Example: 32km of certain 15kV cable:

$$I_C = 32km \cdot 2 \cdot 3.14 \cdot 50Hz \cdot 0.23\frac{\mu F}{km} \cdot \frac{15kV}{\sqrt{3}} \cdot 10^{-3}$$

will cause about 20A of constant charging current. In this case differential stage should be set above 20A.

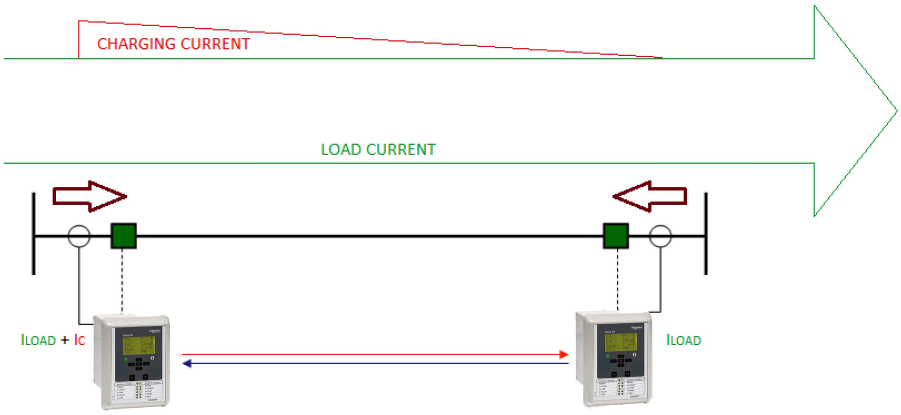


Figure 5.35: Behaviour of constant charging current

NOTE: When cable feeder is energized there will be significant transient charging current. The frequency of this transient is above basic component and does not effect to the differential calculation.

5.14.2 ANSI 85 communication (POC –signals)

Total of 16 signals can be sent between two VAMP 59 line differential relays via ANSI 85 communication. Basically it means when relay is using 8 of the signals there is still 8 more signals left for the other end. Signal status is updated every 10 ms.

Table 5.21: List of POC –signals between the relays (ANSI 85 communication)

Index	Description	Signal	Value	On event	Off event
1 – 16	User selectable name for the signal (None as a default)	None DI1 – n VI1 – 4 VO1 – 6 Logic1 – 20	0 – 1	on – off	on – off

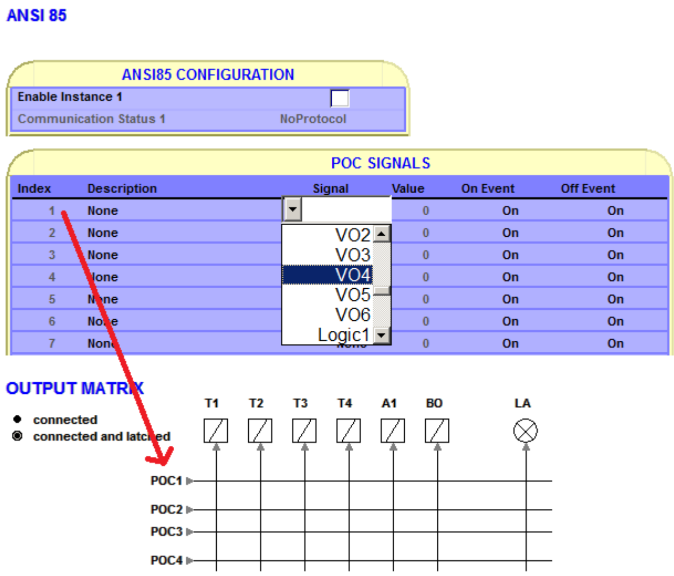


Figure 5.36: Selecting POC – signals

ANSI 85 communication has to be enabled between the relays to transfer POC –signals. This is done by activating "Enable instance 1". When for example DI1 is selected as a signal it's value remains 0 as long as DI1 is acticated. Activated signal in index 1 activates the POC1 of the other relay in output matrix. Signal is also visible in logic and other matrixes.

Communication status is "NoProtocol" when ANSI 85 is not selected to remote port in protocol configuration –menu, "Disable" when not activated and "OK" when instance 1 is enabled.

5.14.3 Frequency adaptation

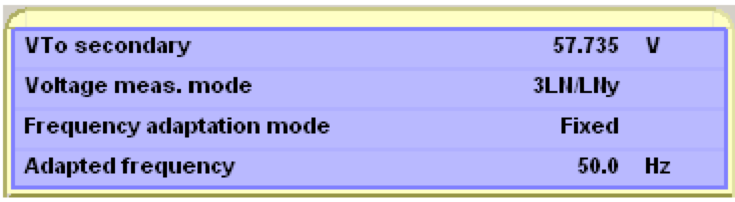


Figure 5.37: Frequency adaptation mode has to be set as "Fixed" when line differential protection is used

The frequency adaptation mode should be set as fixed when using the line differential protection stages. Adapted frequency should be set to same as the frequency of the grid.

NOTE: Frequency protection stages cannot be used while frequency adaptation mode is set as "Fixed".

5.14.4 Second harmonic blocking

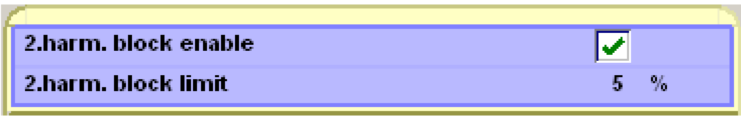


Figure 5.38: Second harmonic blocking can be enabled in the LdI menus

Second harmonic blocking might be needed when there is a transformer inside the protected line. Transformer can cause great magnetizing current to the side of incomer. Big through faults outside the protected zone might cause saturation to the CT and this might cause false tripping as well. Second harmonic blocking can be used to avoid this type of false trips.

5.14.5 Fifth harmonic blocking

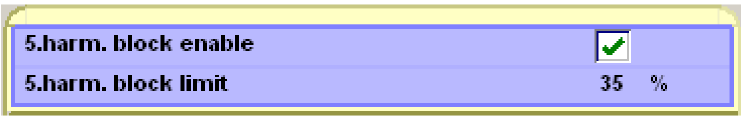


Figure 5.39: Fifth harmonic blocking can be enabled in the LdI> and LdI>> menus.

Sudden load drop might cause overvoltage situation. Overvoltage causes over-excitation to the transformer. Transformer over-excitation is another possible cause of differential relay undesired operation. The use of an additional fifth-harmonic restraint can prevent such operations. Transformer over-excitation causes about 20 – 50% of fifth harmonic component to the measured phase currents.

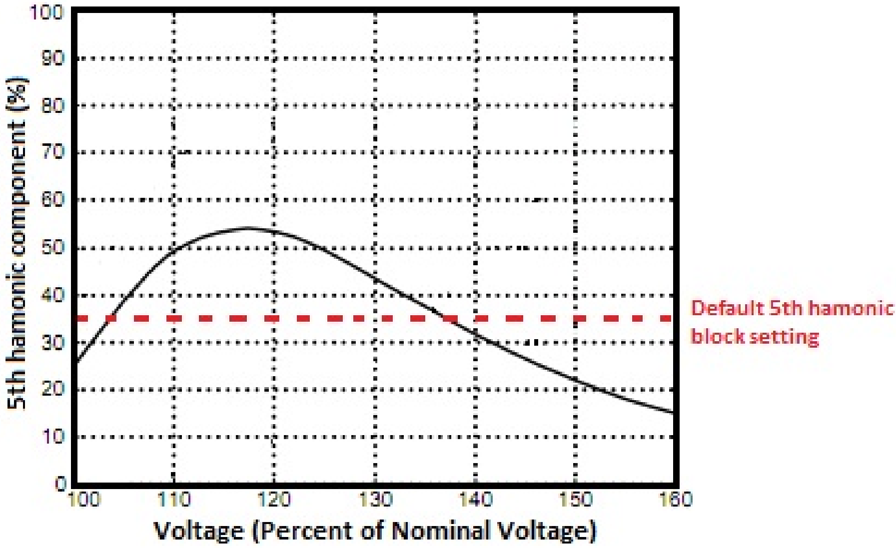


Figure 5.40: Harmonic content of transformer exciting current as a function of the applied voltage

5th harmonic blocking limit is set to 35% of the fundamental component as a default. This value can be used in most of the applications.

5.15 Programmable stages (99)

For special applications the user can built own protection stages by selecting the supervised signal and the comparison mode.

The following parameters are available:

- **Priority**
  If operation times less than 80 milliseconds are needed select 10 ms. For operation times under one second 20 ms is recommended. For longer operation times and THD signals 100 ms is recommended.
- **Coupling A**
  The name of the supervised signal in “>” and “<” modes (see table below). Also the name of the supervised signal 1 in “Diff” and “AbsDiff” modes.
- **Coupling B**
  The name of the supervised signal 2 in “Diff” and “AbsDiff” modes.
- **Compare condition**
  Compare mode. ‘>’ for over or ‘<’ for under comparison, “Diff” and “AbsDiff” for comparing Coupling A and Coupling B.
- **Pick-up**
  Limit of the stage. The available setting range and the unit depend on the selected signal.
- **Operation delay**
  Definite time operation delay
- **Hysteresis**
  Dead band (hysteresis)
- **No Compare limit for mode <**
  Only used with compare mode under (‘<’). This is the limit to start the comparison. Signal values under NoCmp are not regarded as fault.

Table 5.22: Available signals to be supervised by the programmable stages

IL1, IL2, IL3	Phase currents
IL1REM, IL2REM, IL3REM	Remote end phase currents
Io	Residual current input
Uo	Zero sequence voltage
f	Frequency
IoCalc	Phasor sum $\underline{I}_{L1} + \underline{I}_{L2} + \underline{I}_{L3}$
I1	Positive sequence current
I2	Negative sequence current
I2/I1	Relative negative sequence current
I2/In	Negative sequence current in pu
T	Thermal status
IL	Average $(I_{L1} + I_{L2} + I_{L3)}$ / 3
THDIL1	Total harmonic distortion of I_{L1}
THDIL2	Total harmonic distortion of I_{L2}
THDIL3	Total harmonic distortion of I_{L3}
IL1RMS	IL1 RMS for average sampling
IL2RMS	IL2 RMS for average sampling
IL3RMS	IL3 RMS for average sampling
ILmin, ILmax	Minimum and maximum of phase currents
Io1RMS	RMS current of input Io
VAI1, VAI2, VAI3, VAI4, VAI5	Virtual analog inputs 1, 2, 3, 4, 5 (GOOSE)

Eight independent stages

The device has eight independent programmable stages. Each programmable stage can be enabled or disabled to fit the intended application.

Setting groups

There are four settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (mimic display, communication, logic) and manually.

There are four identical stages available with independent setting parameters.

See Chapter 5.2 General features of protection stages for more details.

Table 5.23: Parameters of the programmable stages PrgN (99)

Parameter	Value	Unit	Description	Note
Enable for Prg"n"	Enaled Disabled		Activation of the programmable stage	Set
Priority		ms	Software task priority of the protected stage	Set

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Blocked			
	Start			F
	Trip			F
SetGrp	1, 2, 3, 4		Active setting group	Set
SGrpDI			Digital signal to select the active setting group	Set
	-		None	
	DIx		Digital input	
	VIx		Virtual input	
	LEDx		LED indicator signal	
	VOx		Virtual output	
	Fx		Function key	
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
Timebase for input value			cycletime of the selected protection signal	Set
Coupling			Selected protection signal	Set
Value			Current primary value of the selected protection signal	Set
Cmp			Mode of comparison	Set
	>		Over protection	
	<		Under protection	
	Diff		Difference	
	AbsDiff		Absolut difference	
Pickup			Pick up value scaled to primary level	
Pickup		pu	Pick up setting in pu	Set
t		s	Definite operation time.	Set
Hyster		%	Dead band setting	Set
NoCmp		pu	Minimum value to start under comparison. (Mode='<')	Set

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

Recorded values of the latest eight faults

There is detailed information available of the eight latest faults: Time stamp, fault value and elapsed delay.

Table 5.24: Recorded values of the programmable stages PrgN (99)

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Flt		pu	Fault value
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1, 2, 3, 4		Active setting group during fault

5.16 Arc fault protection (optional)

5.16.1 2S+BIO

Delayed light indication signal

Relay output matrix has a delayed light indication output signal (Delayed Arc L>) available for building selective arc protection systems. Any light source combination and a delay can be configured starting from 0.01 s to 0.15 s. The resulting signal is available in the output matrix to be connected to BO, output relays etc.

Pick up scaling

The per unit (pu) values for pick up setting are based on the current transformer values.

ArcI>: 1 pu = 1 x I_N = rated phase current CT value

ArcI_0>: 1 pu = 1 x I_{0N} = rated residual current CT value for input I_0.

Table 5.25: Parameters of arc protection stages ArcI>, ArcI$_0$> (50ARC/50NARC)

Parameter	Value	Unit	Description	Note
Status	-		Current status of the stage	
	Start		Light detected according ArcI_N	F
	Trip		Light and overcurrent detected	F
LCntr			Cumulative light indication counter. S1, S2 or BI.	C
SCntr			Cumulative light indication counter for the selected inputs according parameter ArcI_N	C
TCntr			Cumulative trip counter	C
Force	Off On		Force flag for status forcing for test purposes. This is a common flag for all stages and output relays, too. Automatically reset by a 5-minute timeout.	Set
			Value of the supervised signal	
ILmax			Stage ArcI>	
Io>			Stage ArcI_0>	
ArcI>		pu	Pick up setting xI_N	Set
ArcIn			Light indication source selection	Set
	–		No sensor selected	
	S1/S2		Sensor in terminals 1 and 2	
	S1/BI		Sensor 1 and BI in use	
	S2/BI		Sensor 2 and BI in use	
	S1/S2/BI		Sensor 1, 2 and BI in use	
Delayed light signal output				
Ldly		s	Delay for delayed light output signal	Set

Parameter	Value	Unit	Description	Note
LdlyCn			Light indication source selection	Set
	–		No sensor selected	
	S1/S2		Sensor in terminals 1 and 2	
	S1/BI		Sensor 1 and BI in use	
	S2/BI		Sensor 2 and BI in use	
	S1/S2/BI		Sensor 1, 2 and BI in use	

Set = An editable parameter (password needed). C = Can be cleared to zero. F = Editable when force flag is on.

For details of setting ranges, see Chapter 12.3.8 Arc fault protection (option).

Recorded values of the latest eight faults

There is detailed information available of the eight latest faults: Time stamp, fault type, fault value, load current before the fault and elapsed delay.

Table 5.26: Recorded values of the arc protection stages

Parameter	Value	Unit	Description
	yyyy-mm-dd		Time stamp of the recording, date
	hh:mm:ss.ms		Time stamp, time of day
Type		pu	Fault type value. Only for ArcI> stage.
Flt		pu	Fault value
Load		pu	Pre fault current. Only for ArcI> stage.
EDly		%	Elapsed time of the operating time setting. 100% = trip

5.16.2 3S+BIO

The arc option card is inserted in the upper option card slot in the back of the device. The card is fastened to the relay with two screws.

The optional arc protection card includes three arc sensor channels for light detection and fast overcurrent detection for combined phase currents and Io. The arc sensors are connected to the terminals 6 – 7, 8 9, and 10 – 11.

The arc information can be transmitted and/or received through digital input and output channels BIO. The output signal is 30 V dc when active. The input signal has to be 12 – 40 V dc to be activated.

1	Binary output +
2	Binary output GND
3	Binary input +
4	Binary input GND
5	no connection
6-7	Arc sensor 1 (VA 1 DA)
8-9	Arc sensor 2 (VA 1 DA)
9-10	Arc sensor 3 (VA 1 DA)

When devices are connected together using binary channel the ground wires must also be connected.

The option card has two fast arc outputs: the binary output and direct control of relay T1. The behaviour of the arc protection is determined by the 3S+BIO output matrix that is described in more detail later in this chapter.

Binary input

The binary input (BI) on the arc option card can be used to get either light or current indication from another relay to build selective arc protection systems. The BI signal can also be routed to BO or T1 from 3S+BIO output matrix. BI is a dry input for signal from binary outputs of other VAMP relays or dedicated arc protection devices by VAMP.

Binary output

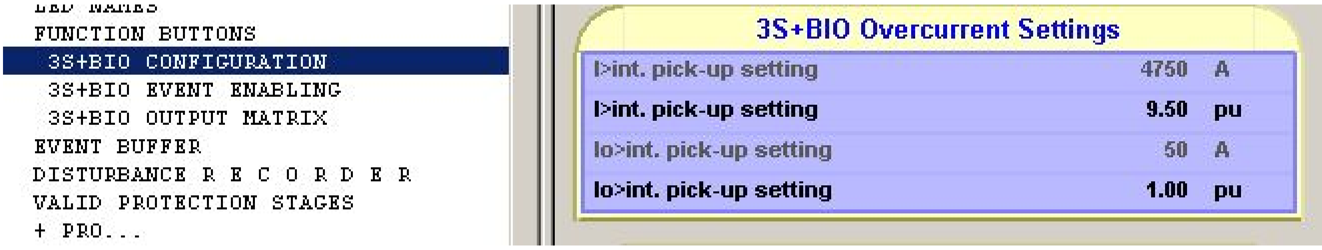
The binary output (BO) on the arc option card (see Chapter 11.6 Arc protection card C = Arc (2 x Arc sensor + BIO)) can be used to give the light indication signal or any other signal or signals to another relay's binary input to build selective arc protection systems. Selection of the BO connected signal(s) is done with the 3S+BIO output matrix. BO is an internally wetted 30 Vdc signal for BI of other VAMP relays or dedicated arc protection devices by VAMP.

Pick up scaling for 3S+BIO arc current

The per unit (pu) values for pick up setting are based on the current transformer values.

ArcI>: 1 pu = $1xI_N$ = rated phase current CT value

$ArcI_0$>: 1 pu = $1xI_{0N}$ = rated residual current CT value for input I_0.



The greyed current values indicate the corresponding actual current values after scaling factors from the “scaling”-menu have been applied.

3S+BIO output matrix

The functionality of the 3S+BIO option card is controlled mostly by the card’s dedicated output matrix (Figure 5.41). All the connections made in this matrix are a lot faster than the device’s normal output matrix connections and are handled separately from the relay’s other processes.

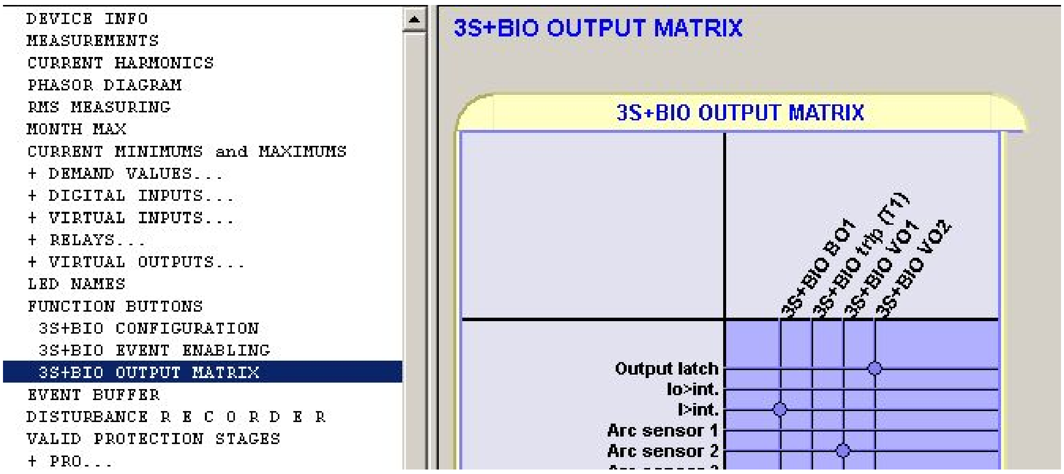


Figure 5.41: 3S+BIO output matrix

In the matrix all inputs are on left hand side and can be connected to outputs on top of each column by placing dots to the matrix. It should be noted that “Output latch” isn’t a real input. Instead, a dot in that line indicates that the corresponding output is latched on activation.

Arc events

There are number of events that can be set to trigger on changes in arc protection signals. For each signal there is separately selectable on and off event. Those events can be enabled or disabled from the 3S+BIO event matrix shown in Figure 5.42.

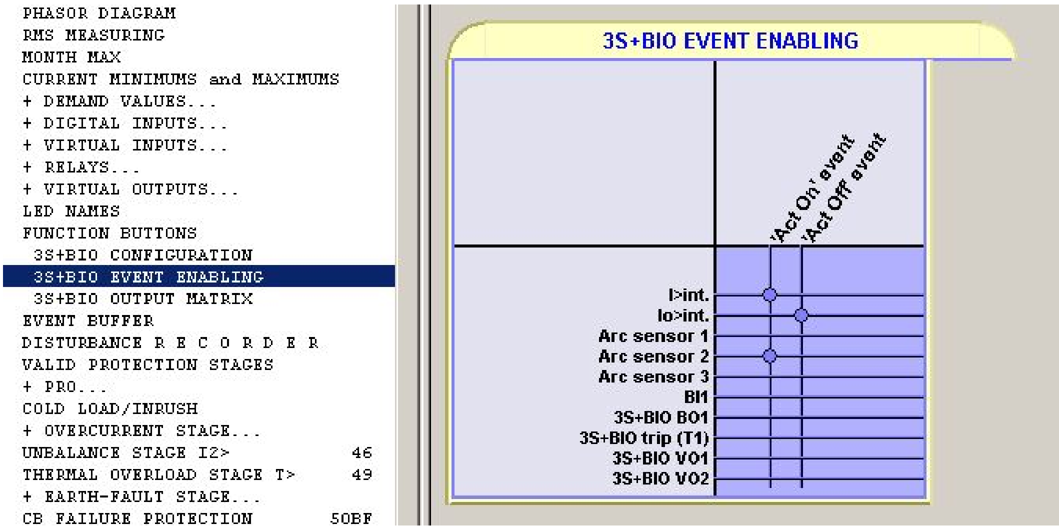


Figure 5.42: 3S+BIO event enabling

When triggered the event shows up normally in the device’s event buffer along with time stamp.

5.17 Inverse time operation

The inverse time operation - i.e. inverse definite minimum time (IDMT) type of operation - is available for several protection functions. The common principle, formulae and graphic representations of the available inverse delay types are described in this chapter.

Inverse delay means that the operation time depends on the measured real time process values during a fault. For example with an overcurrent stage using inverse delay a bigger a fault current gives faster operation. The alternative to inverse delay is definite delay. With definite delay a preset time is used and the operation time does not depend on the size of a fault.

Stage specific inverse delay

Some protection functions have their own specific type of inverse delay. Details of these dedicated inverse delays are described with the appropriate protection function.

Operation modes

There are three operation modes to use the inverse time characteristics:

- Standard delays
  Using standard delay characteristics by selecting a curve family (IEC, IEEE, IEEE2, RI) and a delay type (Normal inverse, Very inverse etc). See Chapter 5.17.1 Standard inverse delays IEC, IEEE, IEEE2, RI.
- Standard delay formulae with free parameters
  selecting a curve family (IEC, IEEE, IEEE2) and defining one's own parameters for the selected delay formula. This mode is activated by setting delay type to ‘Parameters’, and then editing the delay function parameters A – E. See Chapter 5.17.2 Free parameterization using IEC, IEEE and IEEE2 equations.
- Fully programmable inverse delay characteristics
  Building the characteristics by setting 16 [current, time] points. The relay interpolates the values between given points with 2nd degree polynomials. This mode is activated by setting curve family to ‘PrgN''. There are maximum three different programmable curves available at the same time. Each programmed curve can be used by any number of protection stages. See Chapter 5.17.3 Programmable inverse time curves.

Local panel graph

The device will show a graph of the currently used inverse delay on the local panel display. Up and down keys can be used for zooming. Also the delays at 20 x I_{SET}, 4 x I_{SET} and 2 x I_{SET} are shown.

Inverse time setting error signal

If there are any errors in the inverse delay configuration the appropriate protection stage will use definite time delay.

There is a signal 'Setting Error' available in output matrix, which indicates three different situations:

1. Settings are currently changed with VAMPSET or local panel, and there is temporarily an illegal combination of curve/delay/points. For example if previous settings were IEC/NI and then curve family is changed to IEEE, the setting error will active, because there is no NI type available for IEEE curves. After changing valid delay type for IEEE mode (for example MI), the 'Setting Error' signal will release.
2. There are errors in formula parameters A – E, and the device is not able to build the delay curve
3. There are errors in the programmable curve configuration and the device is not able to interpolate values between the given points.

Limitations

The maximum measured secondary phase current is 50 x I_N and the maximum directly measured earth fault current is 10 x I_{0N} for residual current input. The full scope of inverse delay curves goes up to 20 times the setting. At high setting the maximum measurement capability limits the scope of inverse curves according the following table.

Current input	Maximum measured secondary current	Maximum secondary scaled setting enabling inverse delay times up to full 20x setting
I_{L1}, I_{L2}, I_{L3} and I_{0Calc}	250 A	12.5 A
I_0 = 5 A	50 A	2.5 A
I_0 = 1 A	10 A	0.5 A
I_{01} = 0.2 A I_0 = 0.2 A	2 A	0.1 A

1. **Example of limitation**

   CT = 750 / 5

   CT_0= 100 / 1 (cable CT is used for residual current)

   The CT_0 is connected to a 1 A terminals of input I_0.

   For overcurrent stage I> the table above gives 12.5 A. Thus the maximum setting for I> stage giving full inverse delay range is 12.5 A / 5 A = 2.5 xI_N = 1875 $A_{Primary}$.

   For earth fault stage I_0> the table above gives 0.5 A. Thus the maximum setting for I_0> stage giving full inverse delay range is 0.5 A / 1 A = 0.5 xI_{0N} = 50 $A_{Primary}$.

5.17.1 Standard inverse delays IEC, IEEE, IEEE2, RI

The available standard inverse delays are divided in four categories IEC, IEEE, IEEE2 and RI called delay curve families. Each category of family contains a set of different delay types according the following table.

Inverse time setting error signal

The inverse time setting error signal will be activated, if the delay category is changed and the old delay type doesn't exist in the new category. See Chapter 5.17 Inverse time operation for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. Chapter 5.17 Inverse time operation for more details.

Table 5.27: Available standard delay families and the available delay types within each family.

Delay type		**Curve family**				
		DT	**IEC**	**IEEE**	**IEEE2**	**RI**
DT	Definite time	X				
NI	Normal inverse		X		X	
VI	Very inverse		X	X	X	
EI	Extremely inverse		X	X	X	
LTI	Long time inverse		X	X		
LTEI	Long time extremely inverse			X		
LTVI	Long time very inverse			X		
MI	Moderately inverse			X	X	
STI	Short time inverse			X		
STEI	Short time extremely inverse			X		
RI	Old ASEA type					X
RXIDG	Old ASEA type					X

IEC inverse time operation

The operation time depends on the measured value and other parameters according Equation 5.4. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.4:

$$t = \frac{k\ A}{\left(\frac{I}{I_{PICKUP}}\right)^{B} - 1}$$

t = Operation delay in seconds

k = User's multiplier

I = Measured value

I_{PICKUP} = User's pick up setting

A, B = Constants parameters according Table 5.28.

There are three different delay types according IEC 60255-3, Normal inverse (NI), Extremely inverse (EI), Very inverse (VI) and a VI extension. Additional there is a de facto standard Long time inverse (LTI).

Table 5.28: Constants for IEC inverse delay equation

Delay type		Parameter	
		A	B
NI	Normal inverse	0.14	0.02
EI	Extremely inverse	80	2
VI	Very inverse	13.5	1
LTI	Long time inverse	120	1

Example for Delay type "Normal inverse (NI)":

k = 0.50

I = 4 pu (constant current)

I_{PICKUP} = 2 pu

A = 0.14

B = 0.02

$$t = \frac{0.50 \cdot 0.14}{\left(\frac{4}{2}\right)^{0.02} - 1} = 5.0$$

The operation time in this example will be 5 seconds. The same result can be read from Figure 5.43.

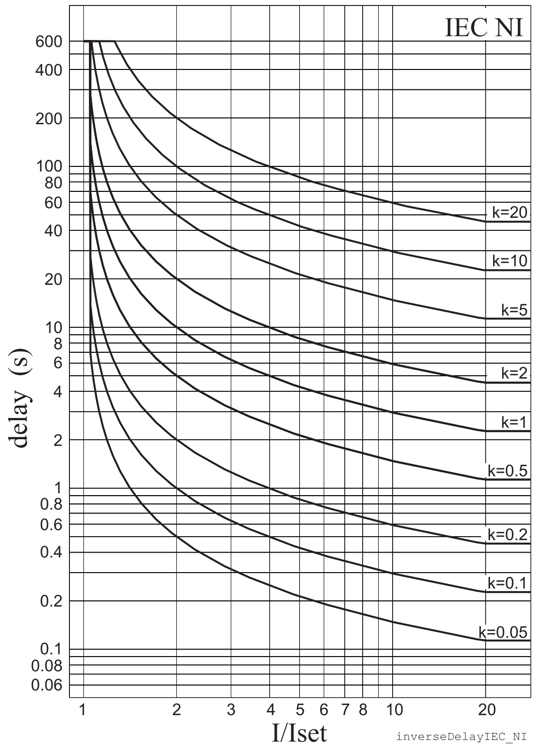


Figure 5.43: IEC normal inverse delay.

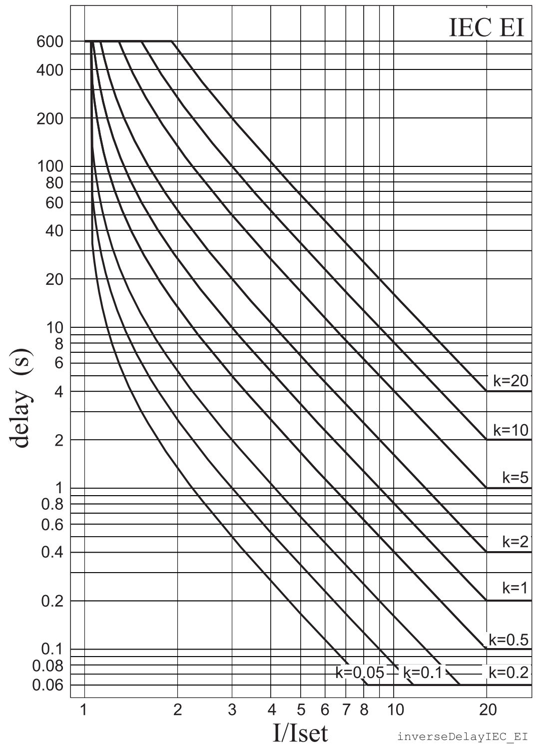


Figure 5.44: IEC extremely inverse delay.

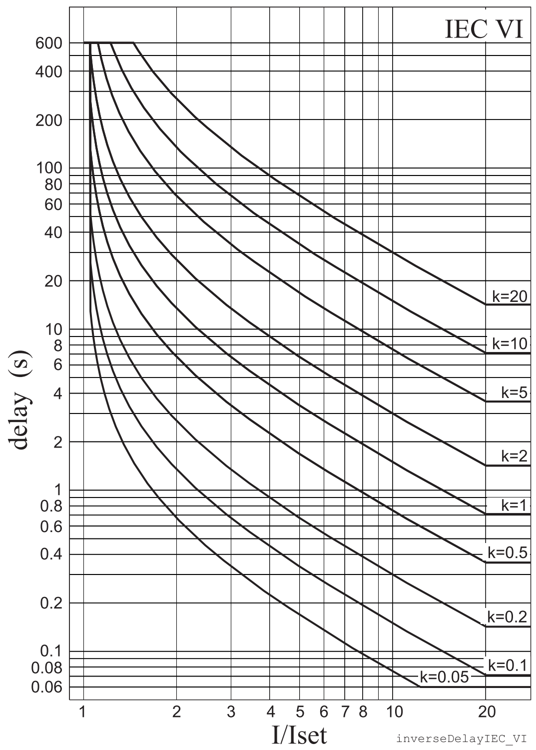


Figure 5.45: IEC very inverse delay.

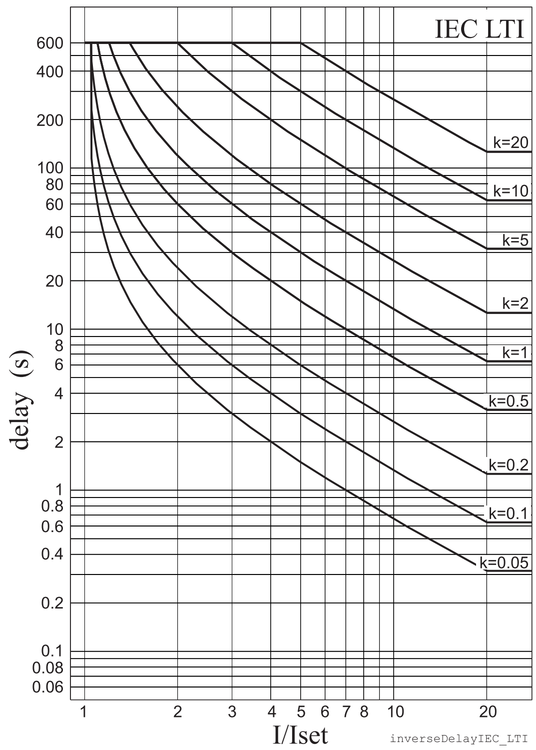


Figure 5.46: IEC long time inverse delay.

IEEE/ANSI inverse time operation

There are three different delay types according IEEE Std C37.112-1996 (MI, VI, EI) and many de facto versions according Table 5.29. The IEEE standard defines inverse delay for both trip and release operations. However, in the VAMP relay only the trip time is inverse according the standard but the release time is constant.

The operation delay depends on the measured value and other parameters according Equation 5.5. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.5:

$$t = k \left[\frac{A}{\left(\frac{I}{I_{PICKUP}} \right)^{C} - 1} + B \right]$$

t = Operation delay in seconds

k = User's multiplier

I = Measured value

I_{PICKUP} = User's pick up setting

A,B,C = Constant parameter according Table 5.29.

Table 5.29: Constants for IEEE/ANSI inverse delay equation

Delay type		Parameter		
		A	B	C
LTI	Long time inverse	0.086	0.185	0.02
LTVI	Long time very inverse	28.55	0.712	2
LTEI	Long time extremely inverse	64.07	0.250	2
MI	Moderately inverse	0.0515	0.1140	0.02
VI	Very inverse	19.61	0.491	2
EI	Extremely inverse	28.2	0.1217	2
STI	Short time inverse	0.16758	0.11858	0.02
STEI	Short time extremely inverse	1.281	0.005	2

Example for Delay type "Moderately inverse (MI)":

k = 0.50

I = 4 pu

I_{PICKUP} = 2 pu

A = 0.0515

B = 0.114

C = 0.02

$$t = 0.50 \cdot \left[\frac{0.0515}{\left(\frac{4}{2}\right)^{0.02} - 1} + 0.1140 \right] = 1.9$$

The operation time in this example will be 1.9 seconds. The same result can be read from Figure 5.50.

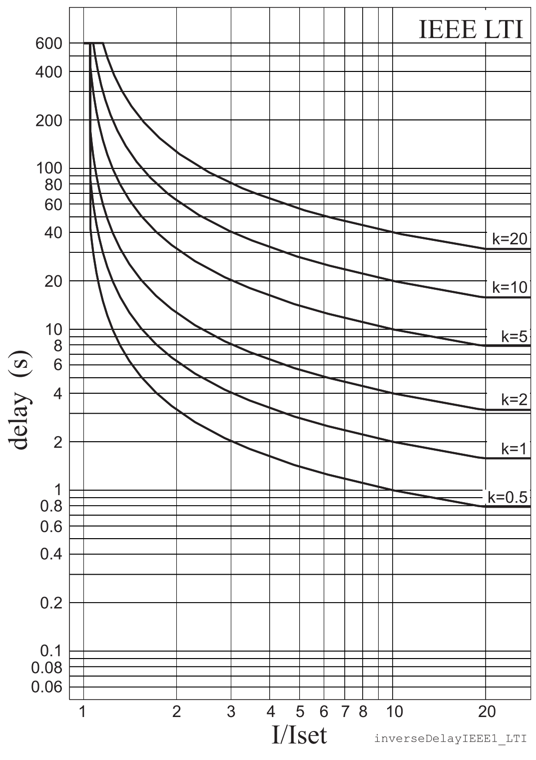


Figure 5.47: ANSI/IEEE long time inverse delay

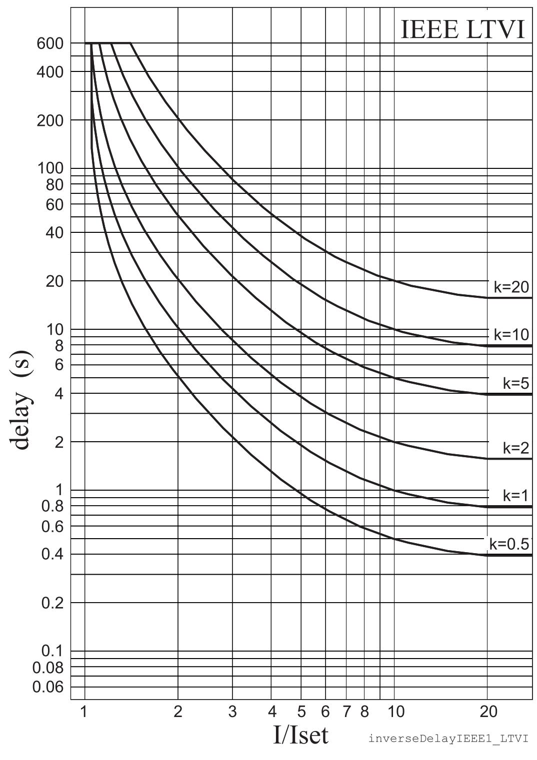


Figure 5.48: ANSI/IEEE long time very inverse delay

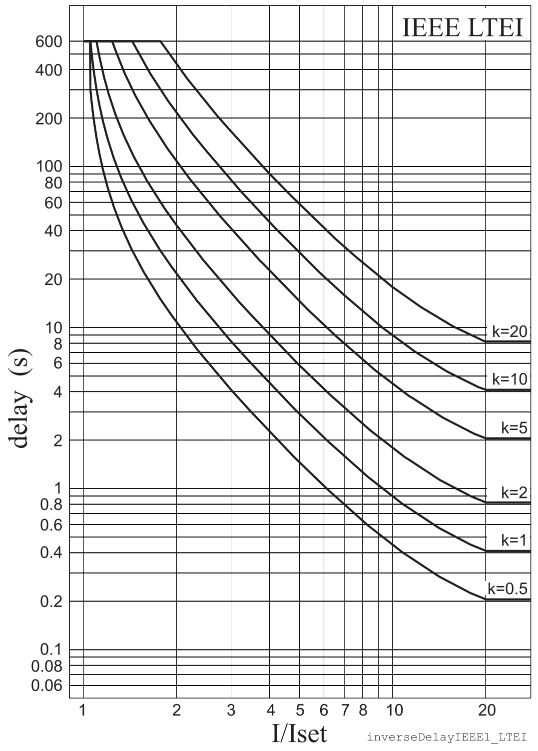


Figure 5.49: ANSI/IEEE long time extremely inverse delay

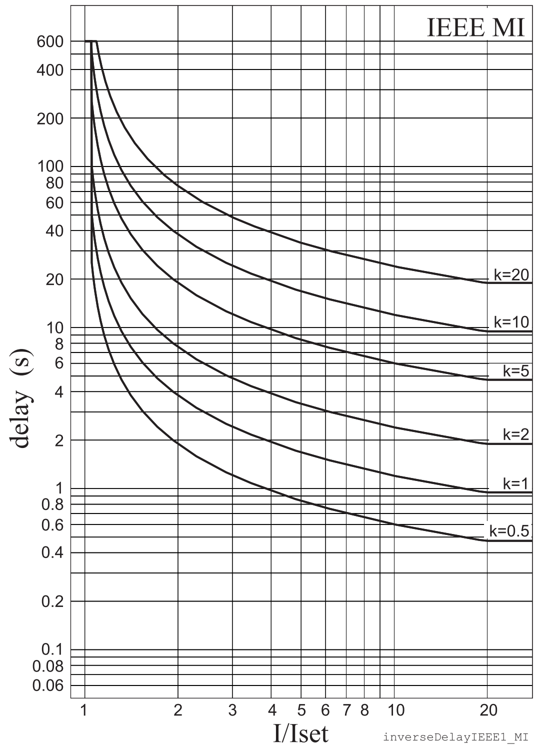


Figure 5.50: ANSI/IEEE moderately inverse delay

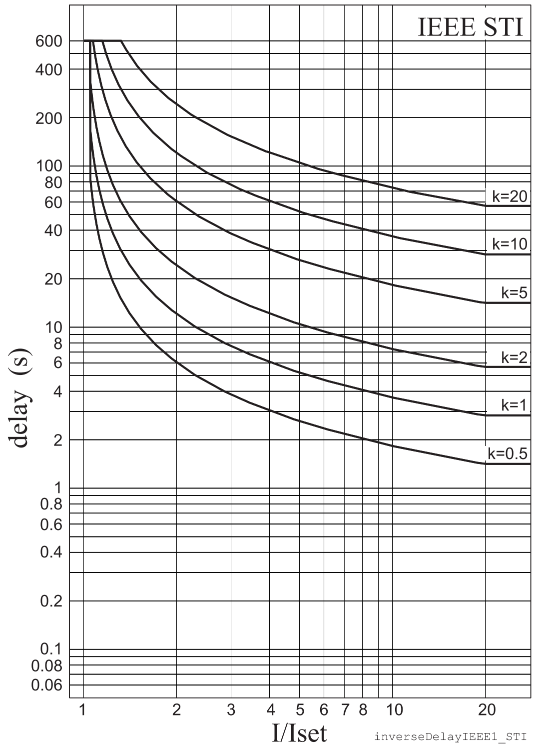


Figure 5.51: ANSI/IEEE short time inverse delay

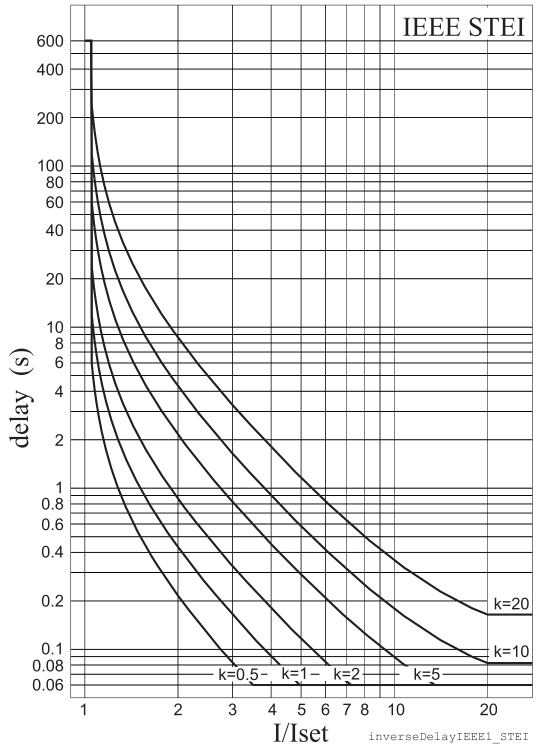


Figure 5.52: ANSI/IEEE short time extremely inverse delay

IEEE2 inverse time operation

Before the year 1996 and ANSI standard C37.112 microprocessor relays were using equations approximating the behaviour of various induction disc type relays. A quite popular approximation is Equation 5.6, which in VAMP relays is called IEEE2. Another name could be IAC, because the old General Electric IAC relays have been modeled using the same equation.

There are four different delay types according Table 5.30. The old electromechanical induction disc relays have inverse delay for both trip and release operations. However, in VAMP relays only the trip time is inverse the release time being constant.

The operation delay depends on the measured value and other parameters according Equation 5.6. Actually this equation can only be used to draw graphs or when the measured value I is constant during the fault. A modified version is implemented in the relay for real time usage.

Equation 5.6:

$$t = k\left[A + \frac{B}{\left(\frac{I}{I_{PICKUP}} - C\right)} + \frac{D}{\left(\frac{I}{I_{PICKUP}} - C\right)^2} + \frac{E}{\left(\frac{I}{I_{PICKUP}} - C\right)^3}\right]$$

t = Operation delay in seconds

k = User’s multiplier

I = Measured value

I_{PICKUP} = User’s pick up setting

A, B, C, D = Constant parameter according Table 5.30.

Table 5.30: Constants for IEEE2 inverse delay equation

Delay type		Parameter				
		A	B	C	D	E
MI	Moderately inverse	0.1735	0.6791	0.8	-0.08	0.1271
NI	Normally inverse	0.0274	2.2614	0.3	-0.1899	9.1272
VI	Very inverse	0.0615	0.7989	0.34	-0.284	4.0505
EI	Extremely inverse	0.0399	0.2294	0.5	3.0094	0.7222

Example for Delay type "Moderately inverse (MI)":

k = 0.50

I = 4 pu

I_{PICKUP} = 2 pu

A = 0.1735

B = 0.6791

C = 0.8

D = -0.08

E = 0.127

$$t = 0.5 \cdot \left[0.1735 + \frac{0.6791}{\left(\frac{4}{2} - 0.8\right)} + \frac{-0.08}{\left(\frac{4}{2} - 0.8\right)^2} + \frac{0.127}{\left(\frac{4}{2} - 0.8\right)^3} \right] = 0.38$$

The operation time in this example will be 0.38 seconds. The same result can be read from Figure 5.53.

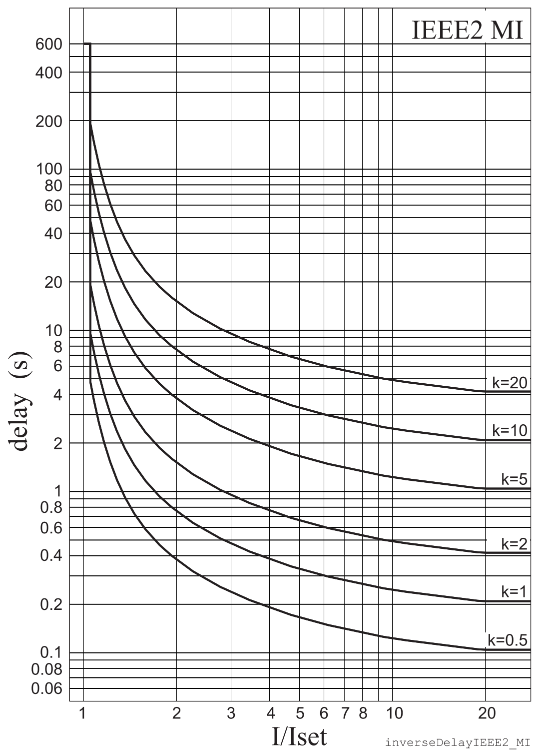


Figure 5.53: IEEE2 moderately inverse delay

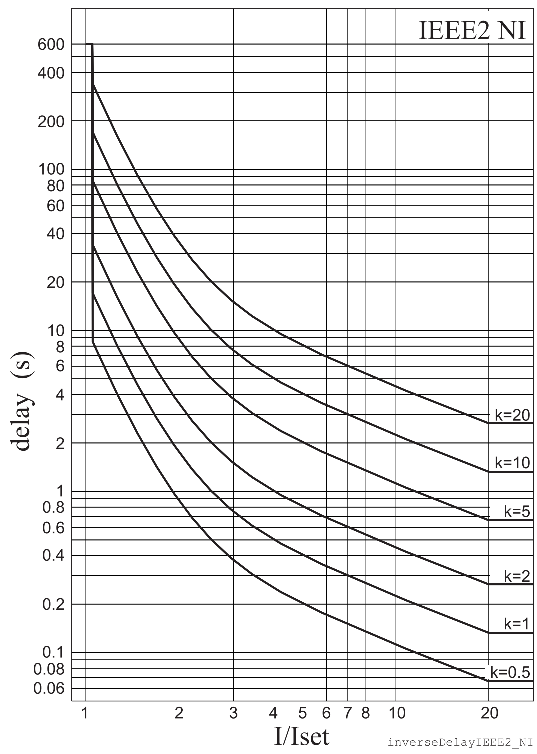


Figure 5.54: IEEE2 normal inverse delay

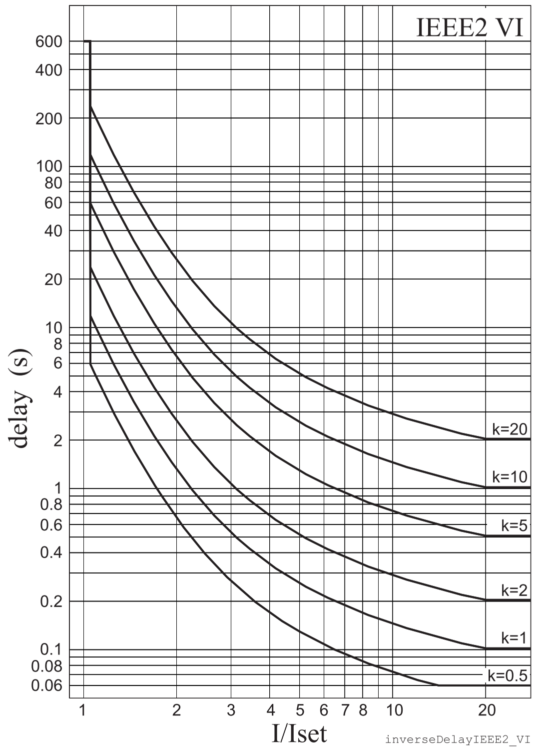


Figure 5.55: IEEE2 very inverse delay

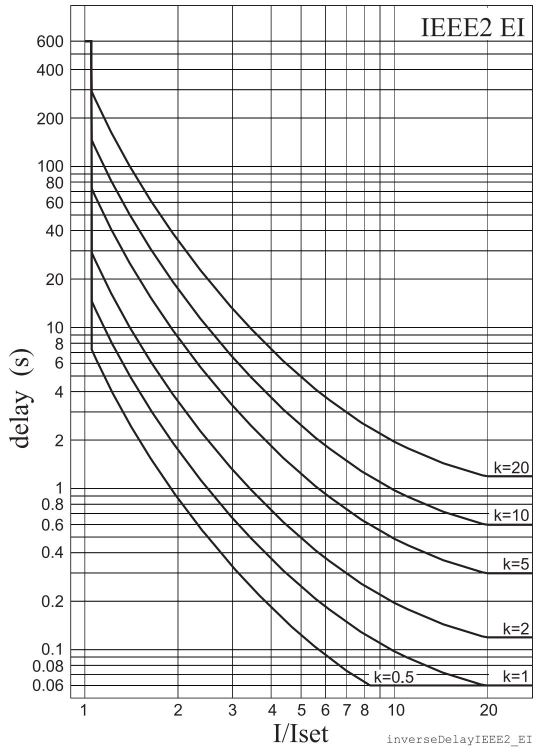


Figure 5.56: IEEE2 extremely inverse delay

RI and RXIDG type inverse time operation

These two inverse delay types have their origin in old ASEA (nowadays ABB) earth fault relays.

The operation delay of types RI and RXIDG depends on the measured value and other parameters according Equation 5.7 and Equation 5.8. Actually these equations can only be used to draw graphs or when the measured value I is constant during the fault. Modified versions are implemented in the relay for real time usage.

Equation 5.7: RI

$$t_{RI} = \frac{k}{0.339 - \frac{0.236}{\left(\frac{I}{I_{PICKUP}}\right)}}$$

Equation 5.8: RXIDG

$$t_{RXIDG} = 5.8 - 1.35 \ln \frac{I}{k\, I_{PICKUP}}$$

t = Operation delay in seconds

k = User's multiplier

I = Measured value

I_{PICKUP} = User's pick up setting

Example for Delay type RI

k = 0.50

I = 4 pu

I_{PICKUP} = 2 pu

$$t_{RI} = \frac{0.5}{0.339 - \frac{0.236}{\left(\frac{4}{2}\right)}} = 2.3$$

The operation time in this example will be 2.3 seconds. The same result can be read from Figure 5.57.

Example for Delay type RXIDG

k = 0.50

I = 4 pu

I_{PICKUP} = 2 pu

$$t_{RXIDG} = 5.8 - 1.35 \ln \frac{4}{0.5 \cdot 2} = 3.9$$

The operation time in this example will be 3.9 seconds. The same result can be read from Figure 5.58.

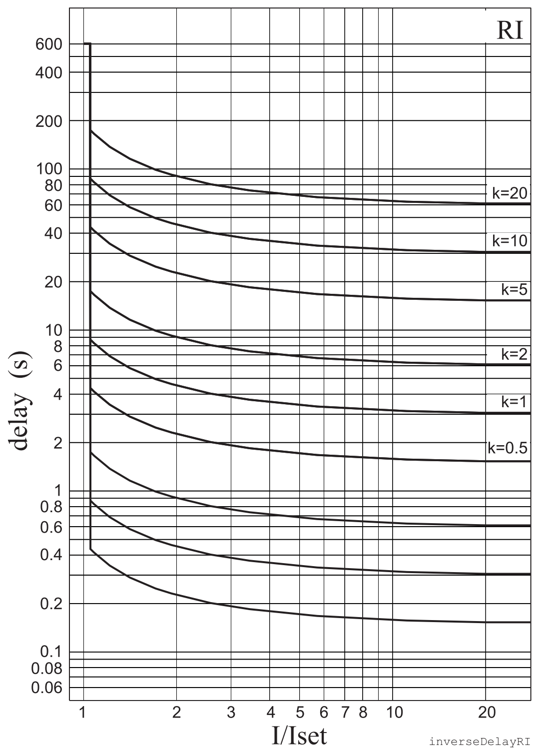


Figure 5.57: Inverse delay of type RI.

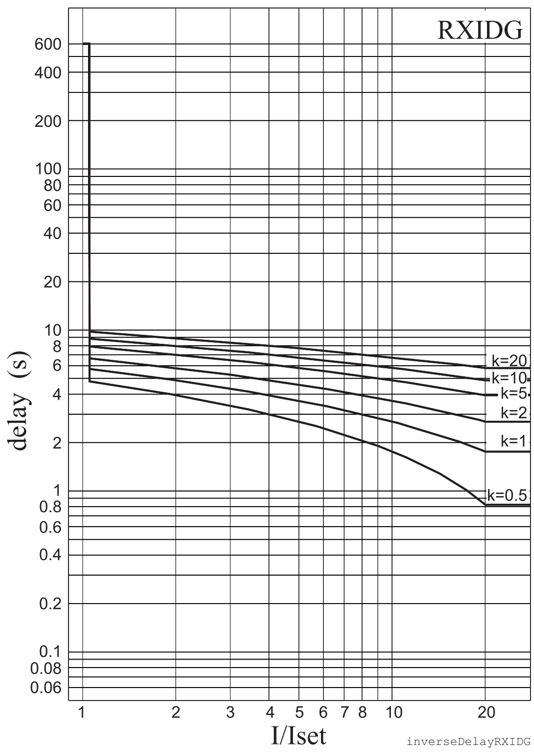


Figure 5.58: Inverse delay of type RXIDG.

5.17.2 Free parameterization using IEC, IEEE and IEEE2 equations

This mode is activated by setting delay type to ‘Parameters’, and then editing the delay function constants, i.e. the parameters A – E. The idea is to use the standard equations with one’s own constants instead of the standardized constants as in the previous chapter.

Example for GE-IAC51 delay type inverse:

k = 0.50

I = 4 pu

I_{PICKUP} = 2 pu

A = 0.2078

B = 0.8630

C = 0.8000

D = - 0.4180

E = 0.1947

$$t = 0.5 \cdot \left[0.2078 + \frac{0.8630}{\left(\frac{4}{2} - 0.8\right)} + \frac{-0.4180}{\left(\frac{4}{2} - 0.8\right)^2} + \frac{0.1947}{\left(\frac{4}{2} - 0.8\right)^3} \right] = 0.37$$

The operation time in this example will be 0.37 seconds.

The resulting time/current characteristic of this example matches quite well with the characteristic of the old electromechanical IAC51 induction disc relay.

Inverse time setting error signal

The inverse time setting error signal will become active, if interpolation with the given parameters is not possible. See Chapter 5.17 Inverse time operation for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See Chapter 5.17 Inverse time operation for more details.

5.17.3 Programmable inverse time curves

Only with VAMPSET, requires rebooting.

The [current, time] curve points are programmed using VAMPSET PC program. There are some rules for defining the curve points:

- configuration must begin from the topmost line
- line order must be as follows: the smallest current (longest operation time) on the top and the largest current (shortest operation time) on the bottom
- all unused lines (on the bottom) should be filled with [1.00 0.00s]

Here is an example configuration of curve points:

Point	Current I/I_{PICKUP}	Operation delay
1	1.00	10.00 s
2	2.00	6.50 s
3	5.00	4.00 s
4	10.00	3.00 s
5	20.00	2.00 s
6	40.00	1.00 s
7	1.00	0.00 s
8	1.00	0.00 s
9	1.00	0.00 s
10	1.00	0.00 s
11	1.00	0.00 s
12	1.00	0.00 s
13	1.00	0.00 s
14	1.00	0.00 s
15	1.00	0.00 s
16	1.00	0.00 s

Inverse time setting error signal

The inverse time setting error signal will be activated, if interpolation with the given points fails. See Chapter 5.17 Inverse time operation for more details.

Limitations

The minimum definite time delay start latest, when the measured value is twenty times the setting. However, there are limitations at high setting values due to the measurement range. See Chapter 5.17 Inverse time operation for more details.

6 Supporting functions

6.1 Event log

Event log is a buffer of event codes and time stamps including date and time. For example each start-on, start-off, trip-on or trip-off of any protection stage has a unique event number code. Such a code and the corresponding time stamp is called an event.

As an example of information included with a typical event a programmable stage trip event is shown in the following table.

EVENT	Description	Local panel	Communication protocols
Code: 01E02	Channel 1, event 2	Yes	Yes
I> trip on	Event text	Yes	No
2.7 x In	Fault value	Yes	No
2007-01-31	Date	Yes	Yes
08:35:13.413	Time	Yes	Yes
Type: 1-N, 2-N, 3-N	Fault type	Yes	No

Events are the major data for a SCADA system. SCADA systems are reading events using any of the available communication protocols. Event log can also be scanned using the front panel or using VAMPSET. With VAMPSET the events can be stored to a file especially in case the relay is not connected to any SCADA system.

Only the latest event can be read when using communication protocols or VAMPSET. Every reading increments the internal read pointer to the event buffer. (In case of communication interruptions, the latest event can be reread any number of times using another parameter.) On the local panel scanning the event buffer back and forth is possible.

Event enabling/masking

In case of an uninteresting event, it can be masked, which prevents the particular event(s) to be written in the event buffer. As a default there is room for 200 latest events in the buffer. Event buffer size can be modified from 50 to 2000.

All events are stored in non-volatile memory.

Indication screen (popup screen) can also be enabled in this same menu when VAMPSET –setting tool is used. The oldest one will be overwritten, when a new event does occur. The shown resolution of a time stamp is one millisecond, but the actual resolution depends of the particular function creating the event. For example most protection stages create events with 5ms, 10 ms or 20 ms resolution. The absolute accuracy of all time stamps depends on the time synchronizing of the relay. See Chapter 6.6 System clock and synchronization for system clock synchronizing.

Event buffer overflow

The normal procedure is to poll events from the device all the time. If this is not done then the event buffer could reach its limits. In such case the oldest event is deleted and the newest displayed with OVF code in HMI.

Table 6.1: Setting parameters for events

Parameter	Value	Description	Note
Count		Number of events	
ClrEn	- Clear	Clear event buffer	Set
Order	Old-New New-Old	Order of the event buffer for local display	Set
FVSca		Scaling of event fault value	Set
	PU	Per unit scaling	
	Pri	Primary scaling	
Display Alarms	On Off	Indication dispaly is enabled No indication display	Set
FORMAT OF EVENTS ON THE LOCAL DISPLAY			
Code: CHENN		CH = event channel, NN=event code	
Event description		Event channel and code in plain text	
yyyy-mm-dd		Date (for available date formats, see Chapter 6.6 System clock and synchronization)	
hh:mm:ss.nnn		Time	

6.2 Disturbance recorder

The disturbance recorder can be used to record all the measured signals, that is, currents, voltage and the status information of digital inputs (DI) and digital outputs (DO).

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Triggering the recorder

The recorder can be triggered by any start or trip signal from any protection stage or by a digital input. The triggering signal is selected in the output matrix (vertical signal DR). The recording can also be triggered manually. All recordings are time stamped.

Reading recordings

The recordings can be uploaded, viewed and analysed with the VAMPSET program. The recording is in COMTRADE format. This also means that other programs can be used to view and analyse the recordings made by the relay.

For more details, please see a separate VAMPSET manual.

Number of channels

At the maximum, there can be 12 recordings, and the maximum selection of channels in one recording 12 (limited in wave form) and digital inputs reserve one channel (includes all the inputs). Also the digital outputs reserve one channel (includes all the outputs). If digital inputs and outputs are recorded, there will be still 10 channels left for analogue waveforms.

Table 6.2: Disturbance recorder waveform

Channel	Description	Available for waveform		
		Voltage measurement mode		
		1LN	1LL	U_0
IL1, IL2, IL3	Phase current	Yes	Yes	Yes
Io1, Io2	Measured residual current	Yes	Yes	Yes
U12	Line-to-line voltage	-	Yes (*	-
U23	Line-to-line voltage	-	-	-
U31	Line-to-line voltage	-	-	-

Channel	Description	Available for waveform		
		Voltage measurement mode		
		1LN	1LL	U_0
UL1	Phase-to-neutral voltage	Yes (*	-	-
UL2	Phase-to-neutral voltage	-	-	-
UL3	Phase-to-neutral voltage	-	-	-
Uo	Zero sequence voltage	-	-	Yes
f	Frequency	-	-	-
P, Q, S	Active, reactive, apparent power	-	-	-
P.F.	Power factor	-	-	-
CosFii	cosφ	-	-	-
IoCalc	Phasor sum Io = (IL1+IL2+IL3)/3	-	-	-
I1	Positive sequence current	-	-	-
I2	Negative sequence current	-	-	-
I2/I1	Relative current unbalance	-	-	-
I2/Imode	Current unbalance [xImode]	-	-	-
U1	Positive sequence voltage	-	-	-
U2	Negative sequence voltage	-	-	-
U2/U1	Relative voltage unbalance	-	-	-
IL	Average (IL1 + IL2 + IL3)/3	-	-	-
Uphase	Average (UL1 + UL2 + UL3) / 3	-	-	-
Uline	Average (U12 + U23 + U31) / 3	-	-	-
DO	Digital outputs	Yes	Yes	Yes
DI	Digital inputs	Yes	Yes	Yes
TanFii	tanφ	-	-	-
THDIL1	Total harmonic distortion of I_{L1}	-	-	-
THDIL2	Total harmonic distortion of I_{L2}	-	-	-
THDIL3	Total harmonic distortion of I_{L3}	-	-	-
THDUa	Total harmonic distortion of Ua	-	-	-
THDUb	Total harmonic distortion of Ub	-	-	-
THDUc	Total harmonic distortion of Uc	-	-	-
DI_2	Digital inputs 21 – 32	-	-	-
Prms	Active power rms value	-	-	-
Qrms	Reactive power rms value	-	-	-
Srms	Apparent power rms value	-	-	-
IL1RMS	IL1 RMS for average sampling	-	-	-
IL2RMS	IL2 RMS for average sampling	-	-	-
IL3RMS	IL3 RMS for average sampling	-	-	-
IL1Rem	IL1 Remote current	-	-	-
IL2Rem	IL2 Remote current	-	-	-
IL3Rem	IL3 Remote current	-	-	-

Table 6.3: Disturbance recorder parameters

Parameter	Value	Unit	Description	Note
Mode			Behavior in memory full situation:	Set
	Saturated		No more recordings are accepted	
	Overflow		The oldest recorder will be overwritten	
SR			Sample rate	Set
	32/cycle		Waveform	
	16/cycle		Waveform	
	8/cycle		Waveform	
	1/10ms		One cycle value *)	
	1/20ms		One cycle value **)	
	1/200ms		Average	
	1/1s		Average	
	1/5s		Average	
	1/10s		Average	
	1/15s		Average	
	1/30s		Average	
	1/1min		Average	
Time		s	Recording length	Set
PreTrig		%	Amount of recording data before the trig moment	Set
MaxLen		s	Maximum time setting. This value depends on sample rate, number and type of the selected channels and the configured recording length.	
Status			Status of recording	
	-		Not active	
	Run		Waiting a triggering	
	Trig		Recording	
	FULL		Memory is full in saturated mode	
ManTrig	-, Trig		Manual triggering	Set
ReadyRec	n/m		n = Available recordings / m = maximum number of recordings The value of 'm' depends on sample rate, number and type of the selected channels and the configured recording length.	

Parameter	Value	Unit	Description	Note
AddCh			Add one channel. Maximum simultaneous number of channels is 12.	Set
	IL1, IL2, IL3		Phase current	
	Io		Measured residual current	
	U12, U23, U31		Line-to-line voltage	
	UL1, UL2, UL3		Phase-to-neutral voltage	
	Uo		Zero sequence voltage	
	f		Frequency	
	CosFii		cosφ	
	IoCalc		Phasor sum Io = (IL1+IL2+IL3)/3	
	I1		Positive sequence current	
	I2		Negative sequence current	
	I2/I1		Relative current unbalance	
	I2/In		Current unbalance [x I_N]	
	IL		Average (IL1 + IL2 + IL3) / 3	
	DI, DO		Digital inputs, Digital outputs	
	TanFii		tanφ	
	THDIL1, THDIL2, THDIL3		Total harmonic distortion of IL1, IL2 or IL3	
	IL1RMS, IL2MRS, IL3RMS		IL1, IL2, IL3 RMS for average sampling	
	IL1Rem, IL2Rem, IL3Rem		Remote currents	
	Starts		Protection stage start signals	
	Trips		Protection stage trip signals	
Delete recorder channel			Delete selected channel	
ClrCh	-, Clear		Remove all channels	Set
(Ch)			List of selected channels	

Set = An editable parameter (password needed).

*) This is the fundamental frequency rms value of one cycle updated every 10 ms.

**) This is the fundamental frequency rms value of one cycle updated every 20 ms.

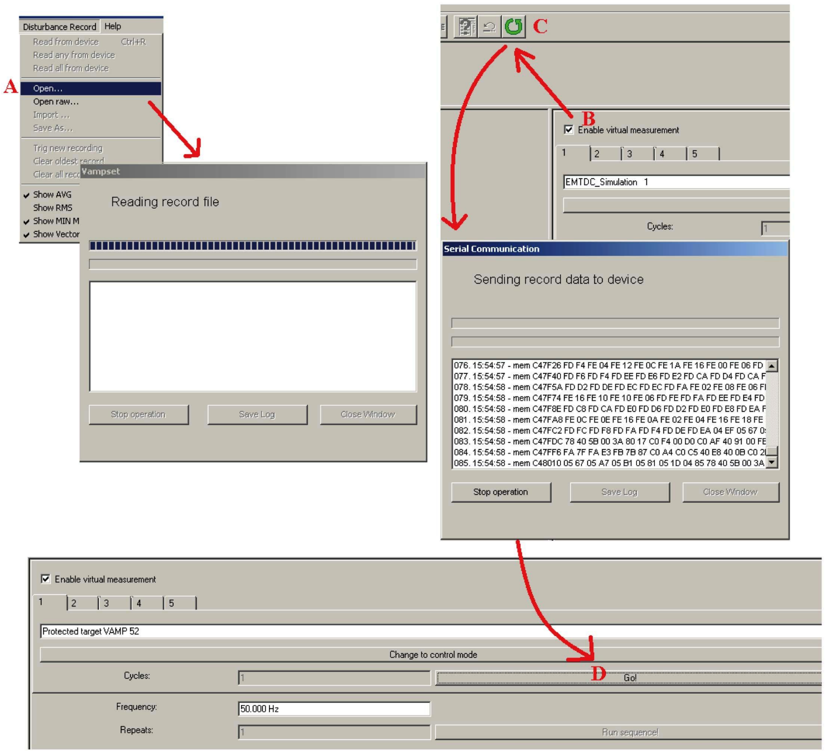
For details of setting ranges, see Table 12.34.

6.2.1 Running virtual comtrade files

Virtual comtrade files can be run with VAMP relays with the v.10.74 software or a later version. Relay behaviour can be analysed by playing the recorder data over and over again in the relay memory.

Steps of opening the VAMPSET setting tool:

1. Go to “Disturbance record” and select Open… (A).
2. Select the comtrade file from you hard disc or equivalent. VAMPSET is now ready to read the recording.
3. The virtual measurement has to be enabled (B) in order to send record data to the relay (C).
4. Sending the file to the device’s memory takes a few seconds. Initiate playback of the file by pressing the Go! button (D). The “Change to control mode” button takes you back to the virtual measurement.



NOTE: The sample rate of the comtrade file has to be 32/cycle (625 micro seconds when 50 Hz is used). The channel names have to correspond to the channel names in VAMP relays: I_{L1}, I_{L2}, I_{L3}, I_0, U_{12}, U_{23}, U_{L1}, U_{L2}, U_{L3} and U_0.

6.3 Cold load pick-up and inrush current detection

Cold load pick-up

A situation is regarded as cold load when all the three phase currents have been less than a given idle value and then at least one of the currents exceeds a given pick-up level within 80 ms. In such case the cold load detection signal is activated for a given time. This signal is available for output matrix and blocking matrix. Using virtual outputs of the output matrix setting group control is possible.

Application for cold load detection

Right after closing a circuit breaker a given amount of overload can be allowed for a given limited time to take care of concurrent thermostat controlled loads. Cold load pick-up function does this for example by selecting a more coarse setting group for over-current stage(s). It is also possible to use the cold load detection signal to block any set of protection stages for a given time.

Inrush current detection

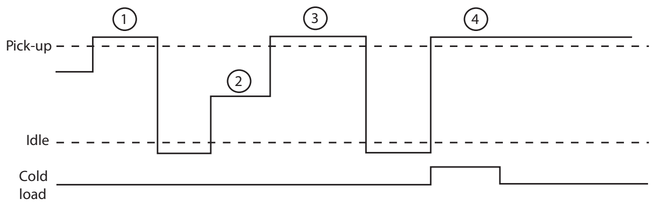
Inrush current detection is quite similar with the cold load detection but it does also include a condition for second harmonic relative content of the currents. When all phase currents have been less than a given idle value and then at least one of them exceeds a given pick-up level within 80 ms and the ratio 2nd harmonic ratio to fundamental frequency, I_{f2}/I_{f1}, of at least one phase exceeds the given setting, the inrush detection signal is activated. This signal is available for output matrix and blocking matrix. Using virtual outputs of the output matrix setting group control is possible.

By setting the 2nd harmonic pickup parameter for I_{f2}/I_{f1} to zero, the inrush signal will behave equally with the cold load pick-up signal.

Application for inrush current detection

The inrush current of transformers usually exceeds the pick-up setting of sensitive overcurrent stages and contains a lot of even harmonics. Right after closing a circuit breaker the pick-up and tripping of sensitive overcurrent stages can be avoided by selecting a more coarse setting group for the appropriate over-current stage with inrush detect signal. It is also possible to use the detection signal to block any set of protection stages for a given time.

NOTE: Inrush detection is based on FFT - calculation which recuires full cycle of data for analyzing the harmonic content. Therefore when using inrush blocking function the cold load pick up starting conditions are used for activating the inrush blocking when the current rise is noticed. If in the signal is found a significant ratio of second harmonic component after 1st cycle the blocking is continued, otherwise 2nd harmonic based blocking signal is released. Inrush blocking is recommended to be used into time delayed overcurrent stages while non blocked instant overcurrent stage is set to 20 % higher than expected inrush current. By this scheme fast reaction time in short circuit faults during the energization can be achieved while time delayed stages are blocked by inrush function.



1. No activation because the current has not been under the set I_{DLE} current.
2. Current dropped under the I_{DLE} current level but now it stays between the I_{DLE} current and the pick-up current for over 80ms.
3. No activation because the phase two lasted longer than 80ms.
4. Now we have a cold load activation which lasts as long as the operation time was set or as long as the current stays above the pick-up setting.

Figure 6.1: Functionality of cold load / inrush current feature.

Table 6.4: Parameters of the cold load & inrush detection function

Parameter	Value	Unit	Description	Note
ColdLd	- Start Trip		Status of cold load detection: Cold load situation is active Timeout	
Inrush	- Start Trip		Status of inrush detection: Inrush is detected Timeout	
ILmax		A	The supervised value. Max. of IL1, IL2 and IL3	
Pickup		A	Primary scaled pick-up value	
Idle		A	Primary scaled upper limit for idle current	
MaxTime		s		Set
Idle		xImode	Current limit setting for idle situation	Set
Pickup		xImode	Pick-up setting for minimum start current	Set
	80	ms	Maximum transition time for start recognition	
Pickupf2		%	Pick-up value for relative amount of 2nd harmonic, I_{f2}/I_{f1}	Set

Set = An editable parameter (password needed).

For details of setting ranges, see Table 12.35.

6.4 Current transformer supervision

The relay supervise the external wiring between the relay terminals and current transformers (CT) and the CT themselves. Furthermore, this is a safety function as well, since an open secondary of a CT, causes dangerous voltages.

The CT supervisor function measures phase currents. If one of the three phase currents drops below I_{MIN}< setting, while another phase current is exceeding the I_{MAX}> setting, the function will issue an alarm after the operation delay has elapsed.

Table 6.5: Setting parameters of CT supervisor CTSV

Parameter	Value	Unit	Default	Description
Imax>	0.0 – 10.0	xIn	2.0	Upper setting for CT supervisor current scaled to primary value, calculated by relay
Imin<	0.0 – 10.0	xIn	0.2	Lower setting for CT supervisor current scaled to primary value, calculated by relay
t>	0.02 – 600.0	s	0.10	Operation delay
CT on	On; Off	-	On	CT supervisor on event
CT off	On; Off	-	On	CT supervisor off event

Table 6.6: Measured and recorded values of CT supervisor CTSV

	Parameter	Value	Unit	Description
Measured value	ILmax		A	Maximum of phase currents
	ILmin		A	Minimum of phase currents
Display	Imax>, Imin<		A	Setting values as primary values
Recorded values	Date		-	Date of CT supervision alarm
	Time		-	Time of CT supervision alarm
	Imax		A	Maximum phase current
	Imin		A	Minimum phase current

For details of setting ranges, see Table 12.36.

6.5 Circuit breaker condition monitoring

The relay has a condition monitoring function that supervises the wearing of the circuit-breaker. The condition monitoring can give alarm for the need of CB maintenance well before the CB condition is critical.

The CB wear function measures the breaking current of each CB pole separately and then estimates the wearing of the CB accordingly the permissible cycle diagram. The breaking current is registered when the trip relay supervised by the circuit breaker failure protection (CBFP) is activated. (See Chapter 5.13 Circuit breaker failure protection CBFP (50BF) for CBFP and the setting parameter "CBrelay".)

Breaker curve and its approximation

The permissible cycle diagram is usually available in the documentation of the CB manufacturer (Figure 6.2). The diagram specifies the permissible number of cycles for every level of the breaking current. This diagram is parameterised to the condition monitoring function with maximum eight [current, cycles] points. See Table 6.7. If less than eight points needed, the unused points are set to [I_{BIG}, 1], where I_{BIG} is more than the maximum breaking capacity.

If the CB wearing characteristics or part of it is a straight line on a log/log graph, the two end points are enough to define that part of the characteristics. This is because the relay is using logarithmic interpolation for any current values falling in between the given current points 2 – 8.

The points 4 – 8 are not needed for the CB in Figure 6.2. Thus they are set to 100 kA and one operation in the table to be discarded by the algorithm.

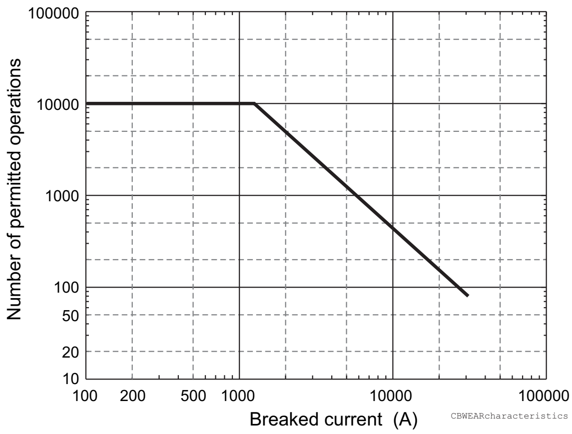


Figure 6.2: An example of a circuit breaker wearing characteristic graph.

Table 6.7: An example of circuit breaker wearing characteristics in a table format. The values are taken from the figure above. The table is edited with VAMPSET under menu "BREAKER CURVE".

Point	Interrupted current (kA)	Number of permitted operations
1	0 (mechanical age)	10000
2	1.25 (rated current)	10000
3	31.0 (maximum breaking current)	80
4	100	1
5	100	1
6	100	1
7	100	1
8	100	1

Setting alarm points

There are two alarm points available having two setting parameters each.

- Current
  The first alarm can be set for example to nominal current of the CB or any application typical current. The second alarm can be set for example according a typical fault current.
- Operations left alarm limit
  An alarm is activated when there are less operation left at the given current level than this limit.

Any actual interrupted current will be logarithmically weighted for the two given alarm current levels and the number of operations left at the alarm points is decreased accordingly. When the "operations left" i.e. the number of remaining operations, goes under the given alarm limit, an alarm signal is issued to the output matrix. Also an event is generated depending on the event enabling.

Clearing "operations left" counters

After the breaker curve table is filled and the alarm currents are defined, the wearing function can be initialised by clearing the decreasing operation counters with parameter "Clear" (Clear oper. left cntrs). After clearing the relay will show the maximum allowed operations for the defined alarm current levels.

Operation counters to monitor the wearing

The operations left can be read from the counters "Al1Ln" (Alarm 1) and "Al2Ln" (Alarm2). There are three values for both alarms, one for each phase. The smallest of three is supervised by the two alarm functions.

Logarithmic interpolation

The permitted number of operations for currents in between the defined points are logarithmically interpolated using equation

Equation 6.1:

$$C = \frac{a}{I^n}$$

C = permitted operations

I = interrupted current

a = constant according Equation 6.2

n = constant according Equation 6.3

Equation 6.2:

$$n = \frac{\ln \frac{C_k}{C_{k+1}}}{\ln \frac{I_{k+1}}{I_k}}$$

Equation 6.3:

$$a = C_k I_k^2$$

ln =	natural logarithm function
C_k, C_{k+1} =	permitted operations. k = row 2 – 7 in Table 6.7.
I_k, I_{k+1} =	corresponding current. k = row 2 – 7 in Table 6.7.

Example of the logarithmic interpolation

Alarm 2 current is set to 6 kA. What is the maximum number of operations according Table 6.7.

The current 6 kA lies between points 2 and 3 in the table. That gives value for the index k. Using

k = 2

C_k = 10000

C_{k+1} = 80

I_{k+1} = 31 kA

I_k = 1.25 kA

and the Equation 6.2 and Equation 6.3, the relay calculates

$$n = \frac{\ln \frac{10000}{80}}{\ln \frac{31000}{1250}} = 1.5038$$

$$a = 10000 \cdot 1250^{1.5038} = 454 \cdot 10^6$$

Using Equation 6.1 the relay gets the number of permitted operations for current 6 kA.

$$C = \frac{454 \cdot 10^6}{6000^{1.5038}} = 945$$

Thus the maximum number of current breaking at 6 kA is 945. This can be verified with the original breaker curve in Figure 6.2. Indeed, the figure shows that at 6 kA the operation count is between 900 and 1000. A useful alarm level for operation-left, could be in this case for example 50 being about five per cent of the maximum.

Example of operation counter decrementing when the CB is breaking a current

Alarm2 is set to 6 kA. CBFP is supervising trip relay T1 and trip signal of an overcurrent stage detecting a two phase fault is connected to this trip relay T1. The interrupted phase currents are 12.5 kA, 12.5 kA and 1.5 kA. How many are Alarm2 counters decremented?

Using Equation 6.1 and values n and a from the previous example, the relay gets the number of permitted operation at 10 kA.

$$C_{10kA} = \frac{454 \cdot 10^6}{12500^{1.5038}} = 313$$

At alarm level 2, 6 kA, the corresponding number of operations is calculated according

Equation 6.4:

$$\Delta = \frac{C_{AlarmMax}}{C}$$

$$\Delta_{L1} = \Delta_{L2} = \frac{945}{313} = 3$$

Thus Alarm2 counters for phases L1 and L2 are decremented by 3. In phase L1 the currents is less than the alarm limit current 6 kA. For such currents the decrement is one.

$\Delta_{L3} = 1$

Table 6.8: Local panel parameters of CBWEAR function

Parameter	Value	Unit	Description	Set
CBWEAR STATUS				
			Operations left for	
Al1L1			- Alarm 1, phase L1	
Al1L2			- Alarm 1, phase L2	
Al1L3			- Alarm 1, phase L3	
Al2L1			- Alarm 2, phase L1	
Al2L2			- Alarm 2, phase L2	
Al2L3			- Alarm 2, phase L3	
Latest trip				
Date time			Time stamp of the latest trip operation	
IL1		A	Broken current of phase L1	
IL2		A	Broken current of phase L2	
IL3		A	Broken current of phase L3	
CBWEAR SET				
Alarm1				
Current	0.00 – 100.00	kA	Alarm1 current level	Set
Cycles	100000 – 1		Alarm1 limit for operations left	Set
Alarm2				
Current	0.00 – 100.00	kA	Alarm2 current level	Set
Cycles	100000 – 1		Alarm2 limit for operations left	Set
CBWEAR SET2				
Al1On	On ; Off		'Alarm1 on' event enabling	Set
Al1Off	On ; Off		'Alarm1 off' event enabling	Set
Al2On	On ; Off		'Alarm2 on' event enabling	Set
Al2Off	On ; Off		'Alarm2 off' event enabling	Set
Clear	-; Clear		Clearing of cycle counters	Set

Set = An editable parameter (password needed).

The breaker curve table is edited with VAMPSET.

6.6 System clock and synchronization

The internal clock of the relay is used to time stamp events and disturbance recordings.

The system clock should be externally synchronised to get comparable event time stamps for all the relays in the system.

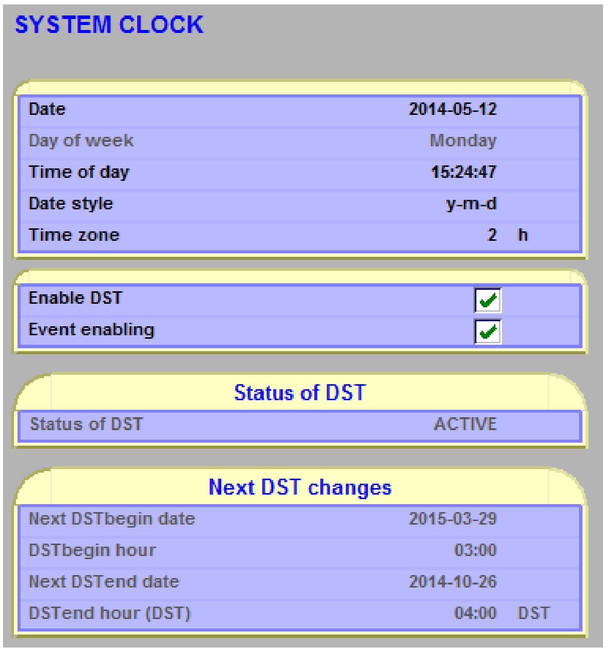
The synchronizing is based on the difference of the internal time and the synchronising message or pulse. This deviation is filtered and the internal time is corrected softly towards a zero deviation.

Time zone offsets

Time zone offset (or bias) can be provided to adjust the local time for IED. The Offset can be set as a Positive (+) or Negative (-) value within a range of -15.00 to +15.00 hours and a resolution of 0.01/h. Basically quarter hour resolution is enough.

Daylight saving time (DST)

IED provides automatic daylight saving adjustments when configured. A daylight savings time (summer time) adjustment can be configured separately and in addition to a time zone offset.



Daylight time standards vary widely throughout the world. Traditional daylight/summer time is configured as one (1) hour positive bias. The new US/Canada DST standard, adopted in the spring of 2007 is: one (1) hour positive bias, starting at 2:00am on the second Sunday in March, and ending at 2:00am on the first Sunday in November. In the European Union, daylight change times are defined relative to the UTC time of day instead of local time of day (as in U.S.) European customers, please carefully find out local country rules for DST.

The daylight saving rules for Finland are the IED defaults (24-hour clock):

- Daylight saving time start: Last Sunday of March at 03.00

- Daylight saving time end: Last Sunday of October at 04.00

DSTbegin rule		
DSTbegin month	Mar	
Ordinal of day of week	Last	
Day of week	Sunday	
DSTbegin hour	3	

DSTend rule		
DSTend month	Oct	
Ordinal of day of week	Last	
Day of week	Sunday	
DSTend hour (DST)	4	DST

To ensure proper hands-free year-around operation, automatic daylight time adjustments must be configured using the “Enable DST” and not with the time zone offset option.

Adapting auto adjust

During tens of hours of synchronizing the device will learn its average deviation and starts to make small corrections by itself. The target is that when the next synchronizing message is received, the deviation is already near zero. Parameters "AAIntv" and "AvDrft" will show the adapted correction time interval of this ±1 ms auto-adjust function.

Time drift correction without external sync

If any external synchronizing source is not available and the system clock has a known steady drift, it is possible to roughly correct the clock deviation by editing the parameters "AAIntv" and "AvDrft". The following equation can be used if the previous "AAIntv" value has been zero.

$$AAIntv = \frac{604.8}{DriftInOneWeek}$$

If the auto-adjust interval "AAIntv" has not been zero, but further trimming is still needed, the following equation can be used to calculate a new auto-adjust interval.

$$AAIntv_{NEW} = \frac{1}{\frac{1}{AAIntv_{PREVIOUS}} + \frac{DriftInOneWeek}{604.8}}$$

The term *DriftInOneWeek*/604.8 may be replaced with the relative drift multiplied by 1000, if some other period than one week has been used. For example if the drift has been 37 seconds in 14 days, the relative drift is 37*1000/(14*24*3600) = 0.0306 ms/s.

Example 1

If there has been no external sync and the relay's clock is leading sixty-one seconds a week and the parameter AAIntv has been zero, the parameters are set as

$$AvDrft = Lead$$

$$AAIntv = \frac{604.8}{61} = 9.9s$$

With these parameter values the system clock corrects itself with –1 ms every 9.9 seconds which equals –61.091 s/week.

Example 2

If there is no external sync and the relay's clock has been lagging five seconds in nine days and the AAIntv has been 9.9 s, leading, then the parameters are set as

$$AAIntv_{NEW} = \frac{1}{\frac{1}{9.9} - \frac{5000}{9 \cdot 24 \cdot 3600}} = 10.6$$

$$AvDrft = Lead$$

When the internal time is roughly correct – deviation is less than four seconds – any synchronizing or auto-adjust will never turn the clock backwards. Instead, in case the clock is leading, it is softly slowed down to maintain causality.

Table 6.9: System clock parameters

Parameter	Value	Unit	Description	Note
Date			Current date	Set
Time			Current time	Set
Style			Date format	Set
	y-d-m		Year-Month-Day	
	d.m.y		Day.Month.Year	
	m/d/y		Month/Day/Year	
SyncDI	-		DI not used for synchronizing	***)
	DI1, DI2		Minute pulse input	
TZone	-15.00 – +15.00 *)		UTC time zone for SNTP synchronization. Note: This is a decimal number. For example for state of Nepal the time zone 5:45 is given as 5.75	Set
DST	No; Yes		Daylight saving time for SNTP	Set
SySrc			Clock synchronisation source	
	Internal		No sync recognized since 200s	
	DI		Digital input	
	SNTP		Protocol sync	
	SpaBus		Protocol sync	
	ModBus		Protocol sync	
	ModBus TCP		Protocol sync	
	ProfibusDP		Protocol sync	
	IEC101		Protocol sync	
	IEC103		Protocol sync	
	DNP3		Protocol sync	
	IRIG-B003		IRIG timecode B003 ****)	
MsgCnt	0 – 65535, 0 – etc.		The number of received synchronisation messages or pulses	
Dev	±32767	ms	Latest time deviation between the system clock and the received synchronization	
SyOS	±10000.000	s	Synchronisation correction for any constant deviation in the synchronizing source	Set
AAIntv	±1000	s	Adapted auto adjust interval for 1 ms correction	Set**)
AvDrft	Lead; Lag		Adapted average clock drift sign	Set**)
FilDev	±125	ms	Filtered synchronisation deviation	

Set = An editable parameter (password needed).

*) A range of -11 h – +12 h would cover the whole Earth but because the International Date Line does not follow the 180° meridian, a more wide range is needed.

**) If external synchronization is used this parameter will be set automatically.

***) Set the DI delay to its minimum and the polarity such that the leading edge is the synchronizing edge.

****) Relay needs to be equipped with suitable hardware option module to receive IRIG-B clock synchronization signal. (Chapter 14 Order information).

Synchronisation with DI

Clock can be synchronized by reading minute pulses from digital inputs, virtual inputs or virtual outputs. Sync source is selected with **SyncDI** setting. When rising edge is detected from the selected input, system clock is adjusted to the nearest minute. Length of digital input pulse should be at least 50 ms. Delay of the selected digital input should be set to zero.

Synchronisation correction

If the sync source has a known offset delay, it can be compensated with **SyOS** setting. This is useful for compensating hardware delays or transfer delays of communication protocols. A positive value will compensate a lagging external sync and communication delays. A negative value will compensate any leading offset of the external synch source.

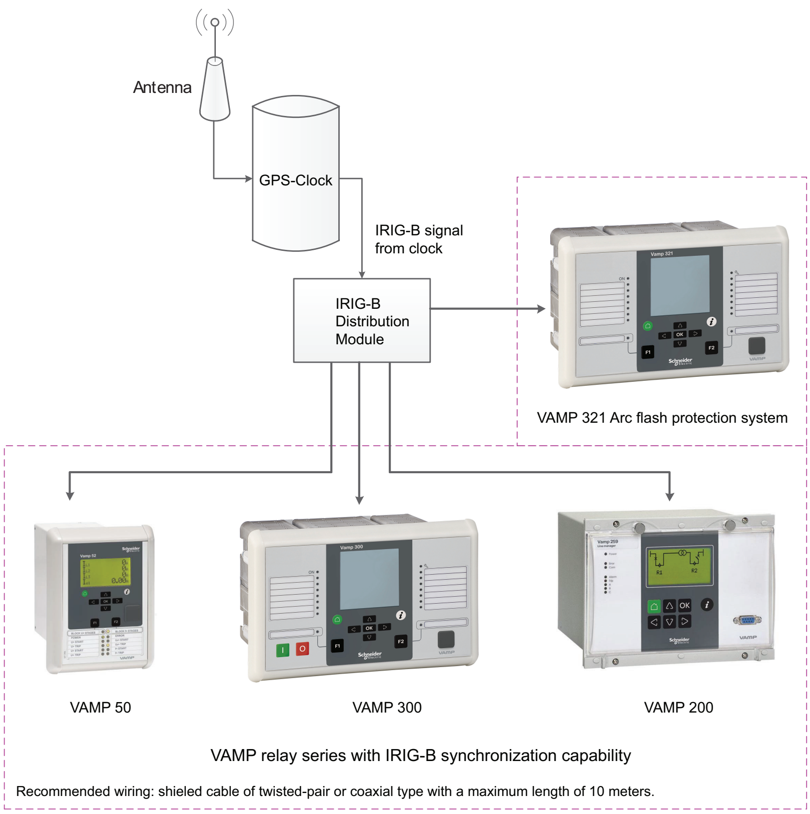
Sync source

When the device receives new sync message, the sync source display is updated. If no new sync messages are received within next 1.5 minutes, the device will change to internal sync mode.

Sync source: IRIG-B003

IRIG-B003 synchronization is supported with a dedicated communication option with either a two-pole or two pins in a D9 rear connector (See Chapter 14 Order information).

IRIG-B003 input clock signal voltage level is TLL. The input clock signal originated in the GPS receiver must be taken to multiple relays trough an IRIG-B distribution module. This module acts as a centralized unit for a point-to-multiple point connection. Note: Daisy chain connection of IRIG-B signal inputs in multiple relays must be avoided.



The recommended cable must be shielded and either of coaxial or twisted pair type. Its length should not exceed a maximum of 10 meters.

Deviation

The time deviation means how much system clock time differs from sync source time. Time deviation is calculated after receiving new sync message. The filtered deviation means how much the system clock was really adjusted. Filtering takes care of small deviation in sync messages.

Auto-lag/lead

The device synchronizes to the sync source, meaning it starts automatically leading or lagging to stay in perfect sync with the master. The learning process takes few days.

6.7 Running hour counter

This function calculates the total active time of the selected digital input, virtual I/O or output matrix output signal. The resolution is ten seconds.

Table 6.10: Running hour counter parameters

Parameter	Value	Unit	Description	Note
Runh	0 – 876000	h	Total active time, hours Note: The label text "Runh" can be edited with VAMPSET.	(Set)
Runs	0 – 3599	s	Total active time, seconds	(Set)
Starts	0 – 65535		Activation counter	(Set)
Status	Stop Run		Current status of the selected digital signal	
DI	 - DI1 – DIn, VI1 – VIn, LedA, LedB, LedC, LedD, LedE, LedF, LedG, LedDR, VO1 – VO6		Select the supervised signal None Physical inputs Virtual inputs Output matrix out signal LA Output matrix out signal LB Output matrix out signal LC Output matrix out signal LD Output matrix out signal LE Output matrix out signal LF Output matrix out signal LG Output matrix out signal DR Virtual outputs	Set
Started at			Date and time of the last activation	
Stopped at			Date and time of the last inactivation	

Set = An editable parameter (password needed).

(Set) = An informative value which can be edited as well.

6.8 Timers

The VAMP protection platform includes four settable timers that can be used together with the user's programmable logic or to control setting groups and other applications that require actions based on calendar time. Each timer has its own settings. The selected on-time and off-time is set and then the activation of the timer can be set to be as daily or according the day of week (See the setting parameters for details). The timer outputs are available for logic functions and for the block and output matrix.

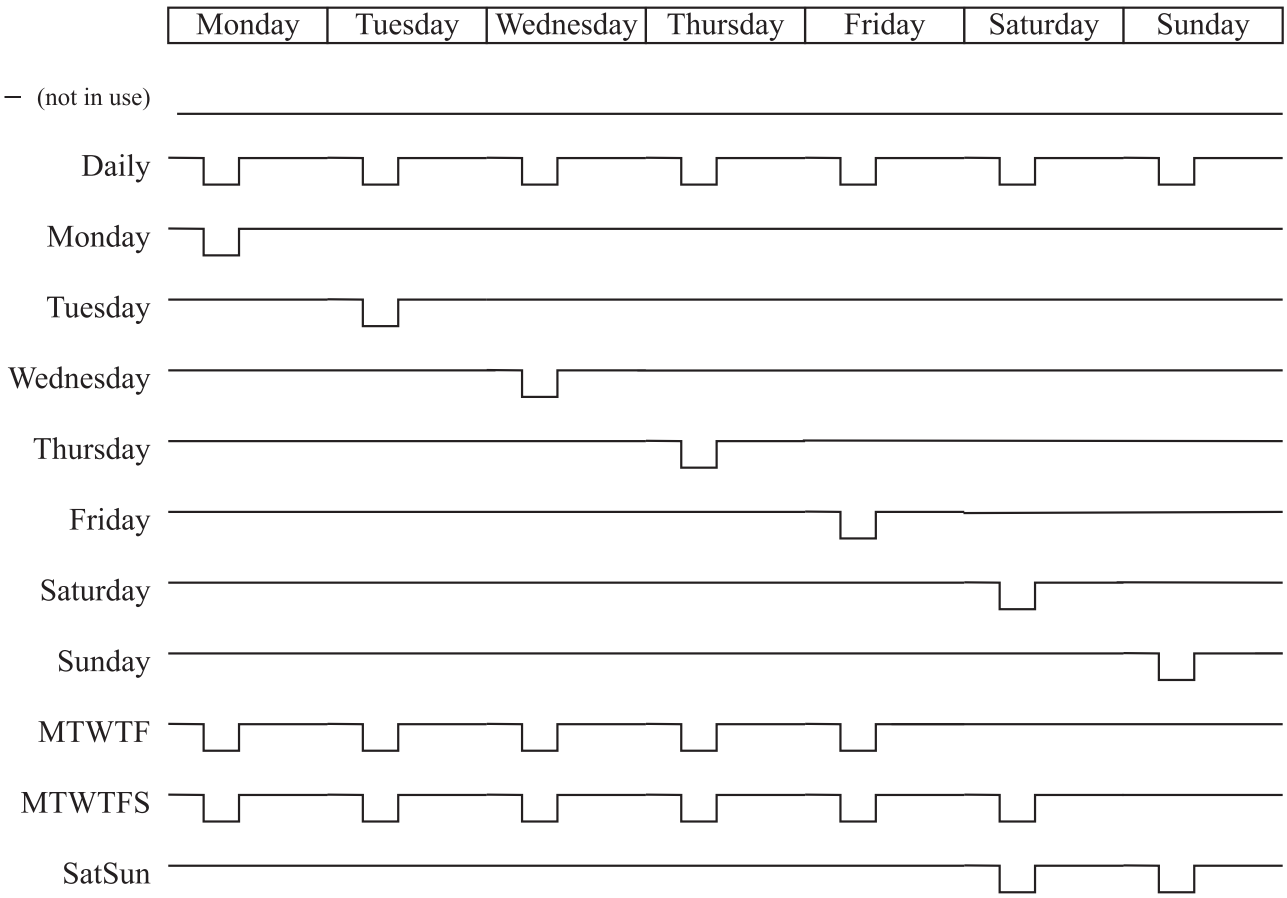


Figure 6.3: Timer output sequence in different modes.

The user can force any timer, which is in use, on or off. The forcing is done by writing a new status value. No forcing flag is needed as in forcing i.e. the output relays.

The forced time is valid until the next forcing or until the next reversing timed act from the timer itself.

The status of each timer is stored in non-volatile memory when the auxiliary power is switched off. At start up, the status of each timer is recovered.

Table 6.11: Setting parameters of timers

Parameter	Value	Description
TimerN		Timer status
	-	Not in use
	0	Output is inactive
	1	Output is active
On	hh:mm:ss	Activation time of the timer
Off	hh:mm:ss	De-activation time of the timer
Mode		For each four timers there are 12 different modes available:
	-	The timer is off and not running. The output is off i.e. 0 all the time.
	Daily	The timer switches on and off once every day.
	Monday	The timer switches on and off every Monday.
	Tuesday	The timer switches on and off every Tuesday.
	Wednesday	The timer switches on and off every Wednesday.
	Thursday	The timer switches on and off every Thursday.
	Friday	The timer switches on and off every Friday.
	Saturday	The timer switches on and off every Saturday.
	Sunday	The timer switches on and off every Sunday.
	MTWTF	The timer switches on and off every day except Saturdays and Sundays
	MTWTFS	The timer switches on and off every day except Sundays.
	SatSun	The timer switches on and off every Saturday and Sunday.

6.9 Combined overcurrent status

This function is collecting faults, fault types and registered fault currents of all enabled overcurrent stages.

Combined over current status can be used as an indication of faults. Combined o/c indicates the amplitude of the last occurred fault. Also a separate indication of the fault type is informed during the start and the trip. Active phases during the start and the trip are also activated in the output matrix. After the fault is switched off the active signals will release after the set delay “clearing delay“ has passed. The combined o/c status referres to the following over current stages: I>, I>>, I>>>.

Table 6.12: Line fault parameters

Parameter	Value	Unit	Description	Note
IFltLas		xImode	Current of the latest overcurrent fault	(Set)
LINE ALARM				
AlrL1 AlrL2 AlrL3	 0 1		Start (=alarm) status for each phase. 0 = No start since alarm ClrDly 1 = Start is on	
OCs	 0 1		Combined overcurrent start status. AlrL1 = AlrL2 = AlrL3 = 0 AlrL1 = 1 or AlrL2 = 1 or AlrL3 = 1	
LxAlarm	 On / Off		'On' Event enabling for AlrL1 – 3 Events are enabled / Events are disabled	Set
LxAlarmOff	 On / Off		'Off' Event enabling for AlrL1 – 3 Events are enabled / Events are disabled	Set
OCAlarm	 On / Off		'On' Event enabling for combined o/c starts Events are enabled / Events are disabled	Set
OCAlarmOff	 On / Off		'Off' Event enabling for combined o/c starts Events are enabled / Events are disabled	Set
IncFltEvnt	 On Off		Disabling several start and trip events of the same fault Several events are enabled *) Several events of an increasing fault is disabled **)	Set
ClrDly	0 – 65535	s	Duration for active alarm status AlrL1, Alr2, AlrL3 and OCs	Set
LINE FAULT				
FltL1 FltL2 FltL3	 0 1		Fault (=trip) status for each phase. 0 = No fault since fault ClrDly 1 = Fault is on	
OCt	 0 1		Combined overcurrent trip status. FltL1 = FltL2 = FltL3 = 0 FltL1 = 1 or FltL2 = 1 or FltL3 = 1	

Parameter	Value	Unit	Description	Note
LxTrip	 On / Off		'On' Event enabling for FltL1 – 3 Events are enabled / Events are disabled	Set
LxTripOff	 On / Off		'Off' Event enabling for FltL1 – 3 Events are enabled / Events are disabled	Set
OCTrip	 On / Off		'On' Event enabling for combined o/c trips Events are enabled / Events are disabled	Set
OCTripOff	 On / Off		'Off' Event enabling for combined o/c starts Events are enabled / Events are disabled	Set
IncFltEvnt	 On Off		Disabling several events of the same fault Several events are enabled *) Several events of an increasing fault is disabled **)	Set
ClrDly	0 – 65535	s	Duration for active alarm status FltL1, Flt2, FltL3 and OCt	Set

Set = An editable parameter (password needed).

*) Used with IEC 60870-105-103 communication protocol. The alarm screen will show the latest if it's the biggest registered fault current, too. Not used with Spabus, because Spabus masters usually don't like to have unpaired On/Off events.

**) Used with SPA-bus protocol, because most SPA-bus masters do need an off-event for each corresponding on-event.

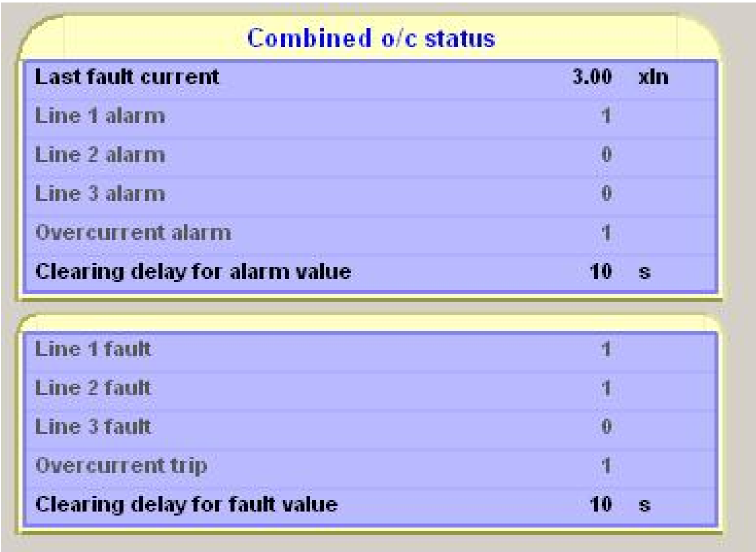


Figure 6.4: Combined o/c status.

The fault that can be seen in the Figure 6.4 was 3 times to nominal and it started as an one phase fault L1-E. At the moment when one of the protection stages tripped the fault was already increased in to a two phase short circuit L1-L2. All signals those are stated as “1” are also activated in the output matrix. After the fault disappears the activated signals will release.

Combined over current status can be found from VAMPSET menu “protection stage status 2”.

6.10 Self-supervision

The functions of the microcontroller and the associated circuitry, as well as the program execution are supervised by means of a separate watchdog circuit. Besides supervising the relay, the watchdog circuit attempts to restart the micro controller in an inoperable situation. If the micro controller does not resart, the watchdog issues a self-supervision signal indicating a permanent internal condition.

When the watchdog circuit detects a permanent fault, it always blocks any control of other output relays (except for the self-supervision output relay). In addition, the internal supply voltages are supervised. Should the auxiliary supply of the IED disappear, an indication is automatically given because the IED status inoperative (SF) output relay functions on a working current principle. This means that the SF relay is energized when the auxiliary supply is on and the arc flash protection is healthy.

6.10.1 Diagnostics

The device runs self-diagnostic tests for hardware and software in boot sequence and also performs runtime checking.

Permanent inoperative state

If permanent inoperative state has been detected, the device releases SF relay contact and status LED is set on. Local panel will also display a detected fault message. Permanet inoperative state is entered when the device is not able to handle main functions.

Temporal inoperative state

When self-diagnostic function detects a temporal inoperative state, Selfdiag matrix signal is set and an event (E56) is generated. In case the inoperative state was only temporary, an off event is generated (E57). Self diagnostic state can be reset via local HMI.

Diagnostic registers

There are four 16-bit diagnostic registers which are readable through remote protocols. The following table shows the meaning of each diagnostic register and their bits.

Register	Bit	Code	Description
SelfDiag1	0 (LSB)	T1	Potential output relay problem
	1	T2	
	2	T3	
	3	T4	
	4	A1	
SelfDiag3	0 (LSB)	DAC	Potential mA-output problem
	1	STACK	Potential stack problem
	2	MemChk	Potential memory problem
	3	BGTask	Potential background task timeout
	4	DI	Potential input problem (Remove DI1, DI2)
	5		
	6	Arc	Potential arc card problem
	7	SecPulse	Potential hardware problem
	8	RangeChk	DB: Setting outside range
	9	CPULoad	Overload
	10	+24V	Potential internal voltage problem
	11	-15V	
	12	ITemp	Internal temperature too high
	13	ADChk1	Potential A/D converter problem
	14	ADChk2	Potential A/D converter problem
	15 (MSB)	E2prom	Potential E2prom problem
SelfDiag4	1	ComBuff	Potential BUS: buffer problem
	2	OrderCode	Potential order code problem

The code is displayed in self diagnostic events and on the diagnostic menu on local panel and VAMPSET.

7 Measurement functions

All the direct measurements are based on fundamental frequency values. Most protection functions are also based on the fundamental frequency values.

The figure shows a current waveform and the corresponding fundamental frequency component f1, second harmonic f2 and rms value in a special case, when the current deviates significantly from a pure sine wave.

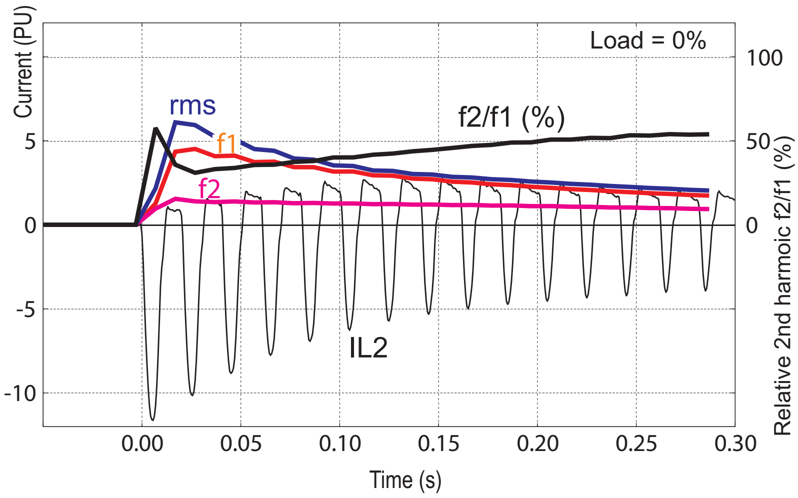


Figure 7.1: Example of various current values of a transformer inrush current

7.1 Measurement accuracy

Table 7.1: Phase current inputs I_{L1}, I_{L2}, I_{L3}

Measuring range	0.025 – 250 A
Inaccuracy:	
I ≤ 7.5 A	±0.5 % of value or ±15 mA
I > 7.5 A	±3 % of value
The specified frequency range is 45 Hz – 65 Hz.	
Squelch limit:	
Phase current inputs: 0.1% of I_{NOM} (tolerance +/- 0.05%)	
Residual current: 0.2% of I_{0NOM} (tolerance +/- 0.05%)	

Table 7.2: Residual current input I_{0N}

Measuring range	0.003 – 10 x I_{0N}
Inaccuracy: $I \le 1.5\ xI_N$ $I > 1.5\ xI_N$	 ±0.3 % of value or ±0.2 % of I_{0N} ±3 % of value
The rated input I_{0N} is 5A, 1 A or 0.2 A. It is specified in the order code of the relay. The specified frequency range is 45 Hz – 65 Hz.	

Table 7.3: THD and harmonics

Inaccuracy I, U > 0.1 PU	±2 % units
Update rate	Once a second
The specified frequency range is 45 Hz – 65 Hz.	

7.2 RMS values

RMS currents

The device calculates the RMS value of each phase current. The minimum and the maximum of RMS values are recorded and stored (see Chapter 7.5 Minimum and maximum values).

$$I_{RMS} = \sqrt{I_{f1}{}^2 + I_{f2}{}^2 + \ldots + I_{f15}{}^2}$$

7.3 Harmonics and Total Harmonic Distortion (THD)

The device calculates the THDs as a percentage of the currents and voltages values measured at the fundamental frequency. The device calculates the harmonics from the 2nd to the 15th of phase currents and voltages. (The 17th harmonic component will also be shown partly in the value of the 15th harmonic component. This is due to the nature of digital sampling.)

The harmonic distortion is calculated

$$THD = \frac{\sqrt{\sum_{i=2}^{15} h_i^2}}{h_1}$$

h_1 = Fundamental value

h_{2-15} = Harmonics

Example

h_1 = 100 A, h_3 = 10 A, h_7 = 3 A, h_{11} = 8 A

$$THD = \frac{\sqrt{10^2 + 3^2 + 8^2}}{100} = 13.2\%$$

For reference the RMS value is

$$RMS = \sqrt{100^2 + 10^2 + 3^2 + 8^2} = 100.9A$$

Another way to calculate THD is to use the RMS value as reference instead of the fundamental frequency value. In the example above the result would then be 13.0 %.

7.4 Demand values

The relay calculates average i.e. demand values of phase currents I_{L1}, I_{L2}, I_{L3} and remote currents $I_{L1Remote}$, $I_{L2Remote}$, $I_{L3Remote}$.

The demand time is configurable from 10 minutes to 30 minutes with parameter "Demand time".

Table 7.4: Demand value parameters

Parameter	Value	Unit	Description	Set
Time	10 – 30	min	Demand time (averaging time)	Set
Fundamental frequency values				
IL1da		A	Demand of phase current IL1	
IL2da		A	Demand of phase current IL2	
IL3da		A	Demand of phase current IL3	
IL1daRem		A	Demand of remote phase current IL1	
IL2daRem		A	Demand of remote phase current IL2	
IL3daRem		A	Demand of remote phase current IL3	

Set = An editable parameter (password needed).

7.5 Minimum and maximum values

Minimum and maximum values are registered with time stamps since the latest manual clearing or since the device has been restarted. The available registered min & max values are listed in the following table.

Min & Max measurement	Description
IL1, IL2, IL3	Phase current (fundamental frequency value)
IL1RMS, IL2RMS, IL3RMS	Phase current, rms value
I_0	Residual current
IL1Rem, IL2Rem, IL3Rem	Demand values of remote phase currents

The clearing parameter "ClrMax" is common for all these values.

Table 7.5: Parameters

Parameter	Value	Description	Set
ClrMax	- Clear	Reset all minimum and maximum values	Set

Set = An editable parameter (password needed).

7.6 Maximum values of the last 31 days and 12 months

Maximum and minimum values of the last 31 days and the last twelve months are stored in the non-volatile memory of the relay. Corresponding time stamps are stored for the last 31 days. The registered values are listed in the following table.

Measurement	Max	Min	Description	31 days	12 months
IL1, IL2, IL3	X		Phase current (fundamental frequency value)		
Io	X		Residual current		
IL1Rem, IL2Rem, IL3Rem	x		Remote current		

The value can be a one cycle value or an average based on the "Timebase" parameter.

Table 7.6: Parameters of the day and month registers

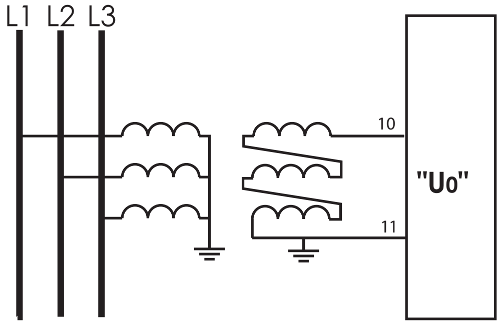
Parameter	Value	Description	Set
Timebase		Parameter to select the type of the registered values	Set
	20 ms	Collect min & max of one cycle values *	
	200 ms	Collect min & max of 200 ms average values	
	1 s	Collect min & max of 1 s average values	
	1 min	Collect min & max of 1 minute average values	
	demand	Collect min & max of demand values (Chapter 7.4 Demand values)	
ResetDays		Reset the 31 day registers	Set
ResetMon		Reset the 12 month registers	Set

Set = An editable parameter (password needed).

* This is the fundamental frequency rms value of one cycle updated every 20 ms.

7.7 Voltage measurement modes

The relay can be connected to zero-sequence voltage. The configuration parameter "Voltage measurement mode" must be set to "U_0".



U_0

The device is connected to zero sequence voltage. Directional ground fault protection is available. (see Figure 7.2 and Figure 11.8).

Figure 7.2: Broken delta connection “U_0”.

7.8 Symmetric components

In a three phase system, the voltage or current phasors may be divided in symmetric components according C. L. Fortescue (1918). The symmetric components are:

- Positive sequence 1
- Negative sequence 2
- Zero sequence 0

Symmetric components are calculated according the following equations:

$$\begin{bmatrix} \underline{S}_0 \\ \underline{S}_1 \\ \underline{S}_2 \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \underline{a} & \underline{a}^2 \\ 1 & \underline{a}^2 & \underline{a} \end{bmatrix} \begin{bmatrix} \underline{U} \\ \underline{V} \\ \underline{W} \end{bmatrix}$$

$\underline{S}_0$ = zero sequence component

$\underline{S}_1$ = positive sequence component

$\underline{S}_2$ = negative sequence component

$\underline{a} = 1\angle 120^\circ = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$, a phasor rotating constant

$\underline{U}$ = phasor of phase L1 (phase current)

$\underline{V}$ = phasor of phase L2

$\underline{W}$ = phasor of phase L3

7.9 Primary secondary and per unit scaling

Many measurement values are shown as primary values although the relay is connected to secondary signals. Some measurement values are shown as relative values - per unit or per cent. Almost all pick-up setting values are using relative scaling.

The scaling is done using the given CT in feeder mode. The following scaling equations are useful when doing secondary testing.

7.9.1 Current scaling

NOTE: The rated value of the device's current input, for example 5 A or 1A, does not have any effect in the scaling equations, but it defines the measurement range and the maximum allowed continuous current. See Table 12.1 for details.

Primary and secondary scaling

	Current scaling
secondary → primary	$I_{PRI} = I_{SEC} \cdot \frac{CT_{PRI}}{CT_{SEC}}$
primary → secondary	$I_{SEC} = I_{PRI} \cdot \frac{CT_{SEC}}{CT_{PRI}}$

For residual current to input I_0 use the corresponding CT_{PRI} and CT_{SEC} values. For ground fault stages using I_{0Calc} signals use the phase current CT values for CT_{PRI} and CT_{SEC}.

Examples:

1. **Secondary to primary**
   CT = 500 / 5
   Current to the relay's input is 4 A.
   => Primary current is I_{PRI} = 4 x 500 / 5 = 400 A
2. **Primary to secondary**
   CT = 500 / 5
   The relay displays I_{PRI} = 400 A
   => Injected current is I_{SEC} = 400 x 5 / 500 = 4 A

Per unit [pu] scaling

For phase currents

1 pu = 1 x I_{MODE} = 100 %, where

I_{MODE} is the nominal value of the feeder.

For residual currents

1 pu = 1 x CT_{SEC} for secondary side and 1 pu = 1 x CT_{PRI} for primary side.

	Phase current scaling	Residual current ($3I_0$) scaling
secondary → per unit	$I_{PU} = \frac{I_{SEC} \cdot CT_{PRI}}{CT_{SEC} \cdot I_N}$	$I_{PU} = \frac{I_{SEC}}{CT_{SEC}}$
per unit → secondary	$I_{SEC} = I_{PU} \cdot CT_{SEC} \cdot \frac{I_N}{CT_{PRI}}$	$I_{SEC} = I_{PU} \cdot CT_{SEC}$

Examples:

1. **Secondary to per unit for phase currents excluding ArcI>**

   CT = 750/5

   I_{MODE} = 525 A

   Current injected to the relay's inputs is 7 A.

   Per unit current is I_{PU} = 7 x 750 / (5 x 525) = 2.00 pu = 2.00 x I_{MODE} = 200 %

2. **Per unit to secondary for phase currents excluding ArcI>**

   CT = 750 / 5

   I_{MODE} = 525 A

   The relay setting is 2 x I_{MODE} = 2 pu = 200 %.

   Secondary current is I_{SEC} = 2 x 5 x 525 / 750 = 7 A

3. **Secondary to per unit for residual current**

   Input is I_0.

   CT_0 = 50 / 1

   Current injected to the relay's input is 30 mA.

   Per unit current is I_{PU} = 0.03 / 1 = 0.03 pu = 3 %

4. **Per unit to secondary for residual current**

   Input is I_0.

   CT_0 = 50 / 1

   The relay setting is 0.03 pu = 3 %.

   Secondary current is I_{SEC} = 0.03 x 1 = 30 mA

5. **Secondary to per unit for residual current**

   Input is I_{0Calc}.

   CT = 750 / 5

   Currents injected to the relay's I_{L1} input is 0.5 A.

   $I_{L2} = I_{L3} = 0$.

   Per unit current is I_{PU} = 0.5 / 5 = 0.1 pu = 10 %

6. **Per unit to secondary for residual current**

   Input is I_{0Calc}.

   CT = 750 / 5

   The relay setting is 0.1 pu = 10 %.

   If $I_{L2} = I_{L3} = 0$, then secondary current to I_{L1} is I_{SEC} = 0.1 x 5 = 0.5 A

7.9.2 Voltage scaling

Per unit [pu] scaling of zero sequence voltage

	Zero-sequence voltage (U_0) scaling
	Voltage measurement mode = "U_0"
secondary ->per unit	$U_{PU} = \frac{U_{SEC}}{U_{0SEC}}$
per unit -> secondary	$U_{SEC} = U_{PU} \cdot U_{0SEC}$

Examples:

1. **Secondary to per unit. Voltage measurement mode is "U_0".**

   U_{0SEC} = 110 V (This is a configuration value corresponding to U_0 at full ground fault.)

   Voltage connected to the device's input U_C is 22 V.

   Per unit voltage is U_{PU} = 22 / 110 = 0.20 pu = 20 %

7.10 Analogue output (option)

A device with the mA option has one configurable analogue output. The resolution of the analogue output is 10 bits resulting current steps less than 25 µA. The output current range is configurable allowing e.g. the following ranges: 0 – 20 mA and 4 – 20 mA. More exotic ranges like 0 – 5 mA or 10 – 2 mA can be configured freely as long as the boundary values are within 0 – 20 mA.

Available couplings to the analog output:

- IL1, IL2, IL3
- f
- IL
- Io, IoCalc
- Uo

7.10.1 mA scaling example

Example of configuration of scaling the transducer (mA) output.

Example of mA scaling for IL

Coupling = IL

Scaled minimum = 0 A

Scaled maximum = 300 mA

Analogue output minimum value = 0 mA

Analogue output maximum value = 20 mA

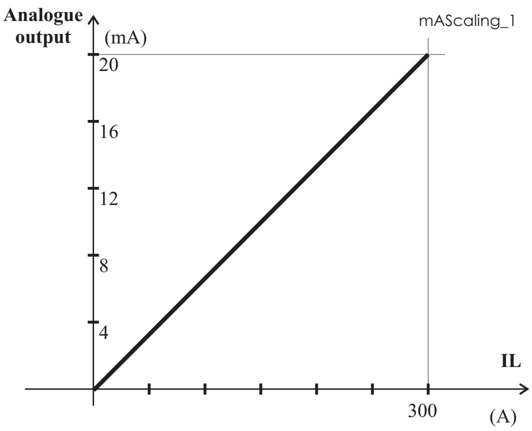


Figure 7.3: The average of the three phase currents. At 0 A the transducer ouput is 0 mA, at 300 A the output is 20 mA

8 Control functions

8.1 Output relays

The output relays are also called digital outputs. Any internal signal can be connected to the output relays using output matrix. An output relay can be configured as latched or non-latched. See Chapter 8.5 Output matrix for more details.

The difference between trip contacts and signal contacts is the DC breaking capacity. See Table 12.4 and Table 12.5 for details. The contacts are SPST normal open type (NO), except signal relay A1 which has change over contact (SPDT).

Table 8.1: Parameters of output relays

Parameter	Value	Unit	Description	Note
T1 – T4	0 1		Status of trip output relay	F
A1	0 1		Status of alarm output relay	F
SF	0 1		Status of the SF relay In VAMPSET, it is called as "Service status output"	F
Force	On Off		Force flag for output relay forcing for test purposes. This is a common flag for all output relays and detection stage status, too. Any forced relay(s) and this flag are automatically reset by a 5-minute timeout.	Set
REMOTE PULSES				
A1, T3, T4	0.00 – 99.98 or 99.99	s	Pulse length for direct output relay control via communications protocols. 99.99 s = Infinite. Release by writing "0" to the direct control parameter	Set
NAMES for OUTPUT RELAYS (editable with VAMPSET only)				
Description	String of max. 32 characters		Names for DO on VAMPSET screens. Default is "Trip relay n", n=1 – 4 or "Signal relay n", n=1	Set

F = Editable when force flag is on. Set = An editable parameter (password needed).

8.2 Digital inputs

There are two (2) digital inputs available for control purposes.

The polarity – normal open (NO) / normal closed (NC) – and a delay can be configured according the application. The signals are available for the output matrix, block matrix, user's programmable logic etc.

Selection in order code	Threshold voltage
1	24 V dc / 110 V ac
2	110 V dc / 220 V ac
3	220 V dc

The digital inputs need an external control voltage (ac or dc). The voltage nominal activation level can be selected in Chapter 14 Order information.

When 110 or 220 V ac voltage is used to activate the digital Inputs, the AC mode should be selected as shown in Figure 8.1

Figure 8.1: AC mode selection in VAMPSET

These inputs are ideal for transferring the status information of switching devices into the device.

Please note that it is possible to use two different control voltages for the inputs.

Label and description texts can be edited with VAMPSET according the application. Labels are the short parameter names used on the local panel and descriptions are the longer names used by VAMPSET.

Table 8.2: Parameters of digital inputs

Parameter	Value	Unit	Description	Note
DI1, DI2	0; 1		Status of digital input	
DI COUNTERS				
DI1, DI2	0 – 65535		Cumulative active edge counter	(Set)
DELAYS FOR DIGITAL INPUTS				
DI1, DI2	0.00 – 60.00	s	Definite delay for both on and off transitions	Set
CONFIGURATION DI1 – DI6				
Inverted	no		For normal open contacts (NO). Active edge is 0 -> 1	Set
	yes		For normal closed contacts (NC). Active edge is 1 -> 0	
Indication display	no		No pop-up display	Set
	yes		Indication display is activated at active DI edge	
On event	On		Active edge event enabled	Set
	Off		Active edge event disabled	
Off event	On		Inactive edge event enabled	Set
	Off		Inactive edge event disabled	
NAMES for DIGITAL INPUTS (editable with VAMPSET only)				
Label	String of max. 10 characters		Short name for DIs on the local display. Default is "DIn", n = 1 – 2	Set
Description	String of max. 32 characters		Long name for DIs. Default is "Digital input n", n = 1 – 2	Set

Set = An editable parameter (password needed).

8.3 Virtual inputs and outputs

There are virtual inputs and virtual outputs, which can in many places be used like their hardware equivalents, execpt that they are only located in the memory of the device. The virtual inputs acts like normal digital inputs. The state of the virtual input can be changed from display, communication bus and from VAMPSET. For example setting groups can be changed using virtual inputs.

Table 8.3: Parameters of virtual inputs

Parameter	Value	Unit	Description	Note
VI1 – VI4	0; 1		Status of virtual input	
Events	On; Off		Event enabling	Set
NAMES for VIRTUAL INPUTS (editable with VAMPSET only)				
Label	String of max. 10 characters		Short name for VIs on the local display Default is "VIn", n = 1 – 4	Set
Description	String of max. 32 characters		Long name for VIs. Default is "Virtual input n", n = 1 – 4	Set

Set = An editable parameter (password needed).

The six virtual outputs do act like output relays, but there are no physical contacts. Virtual outputs are shown in the output matrix and the block matrix. Virtual outputs can be used with the user's programmable logic and to change the active setting group etc.

8.4 Function keys / F1 & F2

There are two independent function keys, F1 and F2, available in the device front panel. As default, these keys are programmed to toggle VI1 and VI2. It is possible to change F1 & F2 to toggle other VIs or to act as object control.

8.5 Output matrix

By means of the output matrix, the output signals of the various protection stages, digital inputs, logic outputs and other internal signals can be connected to the output relays, virtual outputs, etc.

There are eight general purpose LED indicators – "A", "B", "C", "D", "E", "F", "G" and "H" – available for customer-specific indications on the front panel.

Furthermore there are two LED indicators specified for keys F1 and F2. In addition, the triggering of the disturbance recorder (DR) and virtual outputs are configurable in the output matrix.

See an example in Figure 8.2.

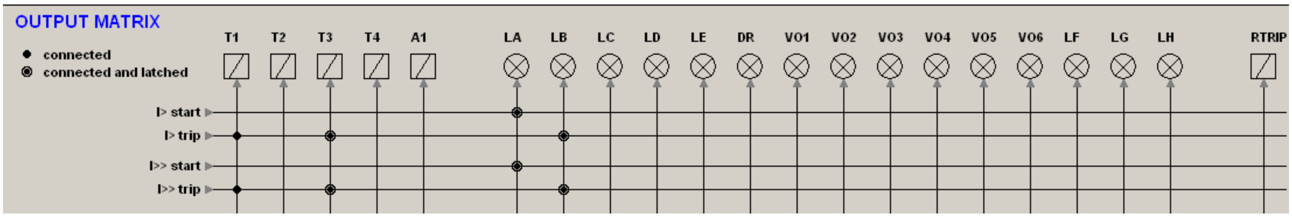


Figure 8.2: Output matrix

An output relay or indicator LED can be configured as latched or non-latched. A non-latched relay follows the controlling signal. A latched relay remains activated although the controlling signal releases.

“Auto LED release” function is designed to indicate only the latest event. When Auto LED release is enabled “old” latched LED’s will release latch when new event occurs. This way only the latest event LED’s are active. “ Auto LED release enable time” sets the time delay after the event deactivation latched LED is interpret as “old”. See an example in Figure 8.3.

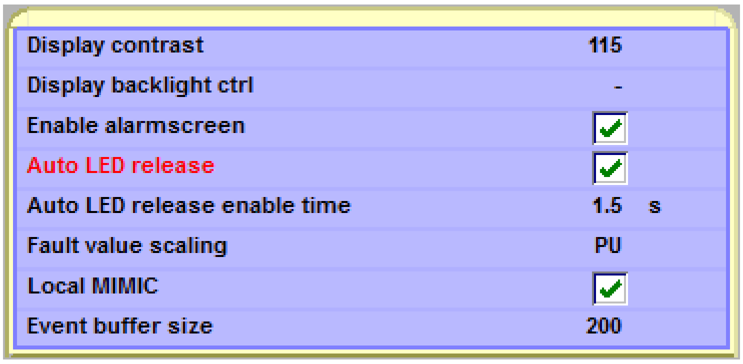


Figure 8.3: Local panel configuration menu

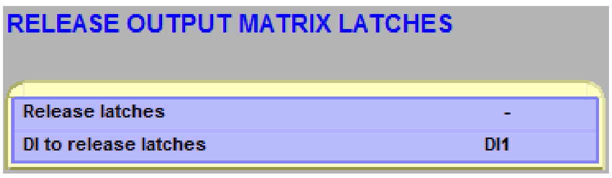


Figure 8.4: Release output matrix latches

There is a common "release all latches" signal to release all the latched relays. This release signal resets all the latched output relays and indicators with CPU and FPGA control. The reset signal can be given via a digital input, via HMI or through communication. The selection of the input is done with the VAMPSET software under the menu "Release output matrix latches". See an example in Figure 8.4.

NOTE: "Release all latches" signal clears and resets FPGA controlled latches.

8.6 Blocking matrix

By means of a blocking matrix, the operation of any protection stage can be blocked. The blocking signal can originate from the digital inputs DI1 to DI2, or it can be a start or trip signal from a protection stage or an output signal from the user's programmable logic. In the block matrix Figure 8.5 an active blocking is indicated with a black dot (•) in the crossing point of a blocking signal and the signal to be blocked.

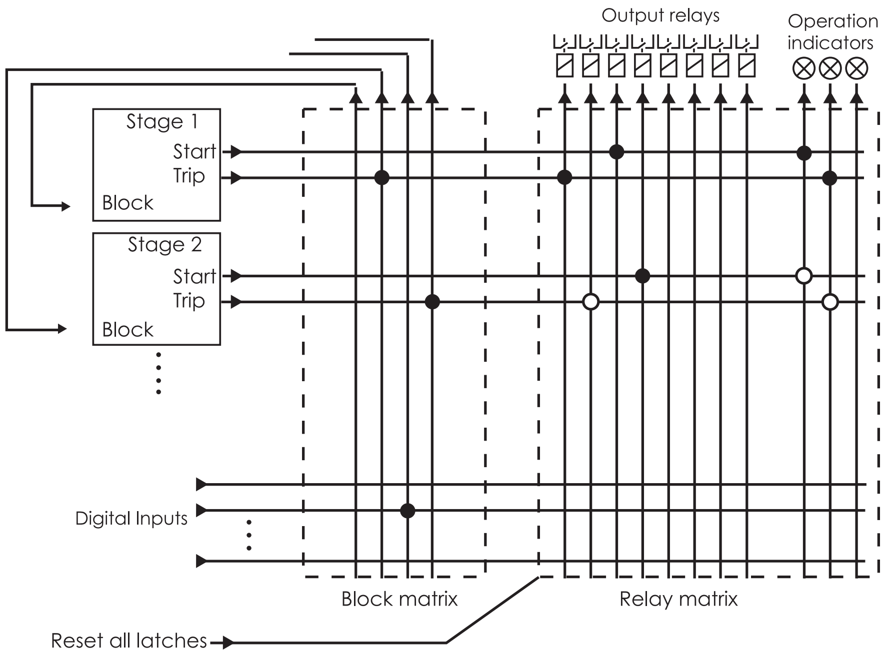


Figure 8.5: Blocking matrix and output matrix

8.7 Controllable objects

The object block matrix and logic functions can be used to configure interlocking for a safe controlling before the output pulse is issued. The objects 1 – 6 are controllable while the objects 7 – 8 are only able to show the status.

Controlling is possible by the following ways:

- through the local HMI
- through a remote communication
- through a digital input
- through the function key

The connection of an object to specific output relays is done via an output matrix (object 1 – 6 open output, object 1 – 6 close output). There is also an output signal “Object failed”, which is activated if the control of an object is not completed.

Object states

Each object has the following states:

Setting	**Value**	**Description**
Object state	Undefined (00)	Actual state of the object
	Open	
	Close	
	Undefined (11)	

Basic settings for controllable objects

Each controllable object has the following settings:

Setting	**Value**	**Description**
DI for ‘obj open’	None, any digital input, virtual input or virtual output	Open information
DI for ‘obj close’		Close information
DI for ‘obj ready’		Ready information
Max ctrl pulse length	0.02 – 600 s	Pulse length for open and close commands
Completion timeout	0.02 – 600 s	Timeout of ready indication
Object control	Open/Close	Direct object control

If changing states takes longer than the time defined by “Max ctrl pulse length” setting, object is inoperative and “Object failure” matrix signal is set. Also undefined-event is generated. “Completion timeout” is only used for the ready indication. If “DI for ‘obj ready’” is not set, completion timeout has no meaning.

Each controllable object has 2 control signals in matrix:

Output signal	Description
Object x Open	Open control signal for the object
Object x Close	Close control signal for the object

These signals send control pulse when an object is controlled by digital input, remote bus, auto-reclose etc.

Settings for read-only objects

Setting	Value	Description
DI for 'obj open'	None, any digital input, virtual input or virtual output	Open information
DI for 'obj close'		Close information
Object timeout	0.02 – 600 s	Timeout for state changes

If changing states takes longer than the time defined by "Object timeout" setting, and "Object failure" matrix signal is set. Also undefined-event is generated.

8.7.1 Controlling with DI

Objects can be controlled with digital input, virtual input or virtual output. There are four settings for each controllable object:

Setting	Active
DI for remote open / close control	In remote state
DI for local open / close control	In local state

If the device is in local control state, the remote control inputs are ignored and vice versa. Object is controlled when a rising edge is detected from the selected input. Length of digital input pulse should be at least 60 ms.

8.7.2 Local/Remote selection

In Local mode, the output relays can be controlled via a local HMI, but they cannot be controlled via a remote serial communication interface.

In Remote mode, the output relays cannot be controlled via a local HMI, but they can be controlled via a remote serial communication interface.

The selection of the Local/Remote mode is done by using a local HMI, or via one selectable digital input. The digital input is normally used to change a whole station to a local or remote mode. The selection of the L/R digital input is done in the "Objects" menu of the VAMPSET software.

NOTE: A password is not required for a remote control operation.

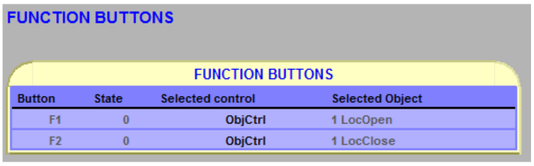
8.7.3 Controlling with F1 & F2

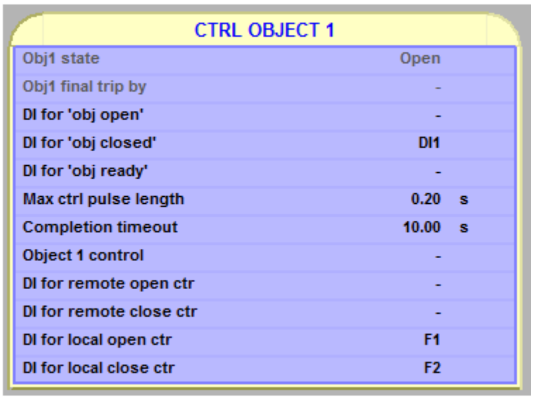
Objects can be controlled with F1 & F2.

As default these keys are programmed to toggle F1 and F2. It is possible to configure F1 & F2 to toggle VI1 – VI4 or act as object control. Selection of the F1 and F2 function is made with the VAMPSET software under the FUNCTION BUTTONS menu.

Table 8.4: Parameters of F1, F2

Parameter	Value	Unit	Description	Set
F1 – F2 VI1 – VI4	0		Function key toggles Virtual input 1 – 4 and Function button 1 – 2 between on (1) and off (0)	Set
ObjCtrl PrgFncs	1		When Object conrol in chosen F1 and F2 can be linked in OBJECTS to desired objects close/open command.	





Selected object and control is shown in VAMPSET software under the menu ”FUNCTION BUTTONS”. If no object with local control is selected ’-’ is shown. If multiple local controls are selected for one key ’?’ is shown.

8.8 Auto-reclose function (79)

The VAMP protection relays include a sophisticated Auto-reclosing (AR) function. The AR function is normally used in feeder protection relays that are protecting an overhead line. Most of the overhead line faults are temporary in nature. Even 85% can be cleared by using the AR function.

General

The basic idea is that normal protection functions will detect the fault. Then the protection function will trigger the AR function. After tripping the circuit-breaker (CB), the AR function can reclose the CB. Normally, the first reclose (or shot) is so short in time that consumers cannot notice anything. However, the fault is cleared and the feeder will continue in normal service.

Terminology

Even though the basic principle of AR is very simple; there are a lot of different timers and parameters that have to be set.

In VAMP relays, there are five shots. A shot consists of open time (so called “dead” time) and close time (so called “burning” time or discrimination time). A high-speed shot means that the dead time is less than 1 s. The time-delayed shot means longer dead times up to 2-3 minutes.

There are four AR lines. A line means an initialization signal for AR. Normally, start or trip signals of protection functions are used to initiate an AR-sequence. Each AR line has a priority. AR1 has the highest and AR4 has the lowest one. This means that if two lines are initiated at the same time, AR will follow only the highest priority line. A very typical configuration of the lines is that the instantaneous overcurrent stage will initiate the AR1 line, time-delayed overcurrent stage the AR2 line and earth-fault protection will use lines AR3 and AR4.

For more information about auto-reclosing, please refer to our application note “Auto-reclosing function in VAMP protection relays”.

The auto-reclose (AR) matrix in the following Figure 8.6 describes the start and trip signals forwarded to the auto-reclose function.

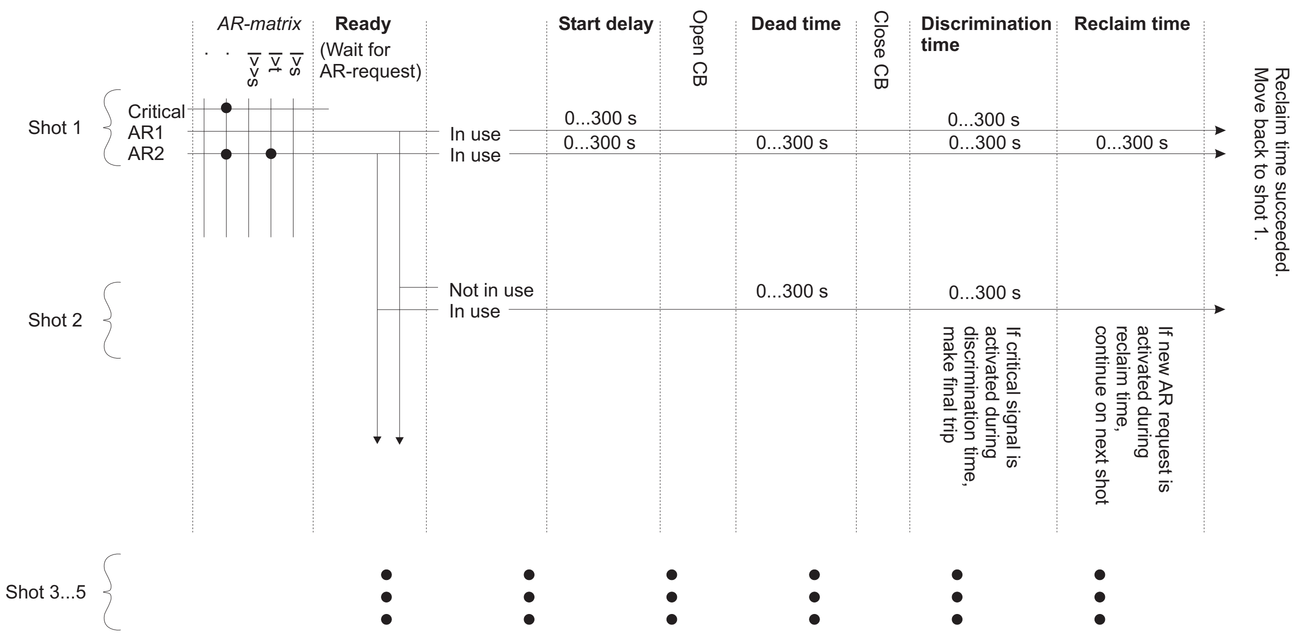


Figure 8.6: Auto-reclose matrix

The AR matrix above defines which signals (the start and trip signals from protection stages or digital input) are forwarded to the auto-reclose function. In the AR function, the AR signals can be configured to initiate the reclose sequence. Each shot from 1 to 5 has its own enabled/disabled flag. If more than one AR signal activates at the same time, AR1 has highest priority and AR2 the lowest. Each AR signal has an independent start delay for the shot 1. If a higher priority AR signal activates during the start delay, the start delay setting will be changed to that of the highest priority AR signal.

After the start delay the circuit-breaker (CB) will be opened if it is closed. When the CB opens, a dead time timer is started. Each shot from 1 to 5 has its own dead time setting.

After the dead time the CB will be closed and a discrimination time timer is started. Each shot from 1 to 5 has its own discrimination time setting. If a critical signal is activated during the discrimination time, the AR function makes a final trip. The CB will then open and the AR sequence is locked. Closing the CB manually clears the “locked” state.

After the discrimination time has elapsed, the reclaim time timer starts. If any AR signal is activated during the reclaim time or the discrimination time, the AR function moves to the next shot. The reclaim time setting is common for every shot.

If the reclaim time runs out, the auto-reclose sequence is successfully executed and the AR function moves to ready -state and waits for a new AR request in shot 1.

A trip signal from the protection stage can be used as a backup. Configure the start signal of the protection stage to initiate the AR function. If something fails in the AR function, the trip signal of the protection stage will open the CB. The delay setting for the protection stage should be longer than the AR start delay and discrimination time.

If a critical signal is used to interrupt an AR sequence, the discrimination time setting should be long enough for the critical stage, usually at least 100 ms.

Manual closing

When CB is closed manually with the local panel, remote bus, digital inputs etc, the reclaim-state is activated. Within the reclaim time all AR requests are ignored. It is up to protection stages to take care of tripping. Trip signals of protection stages must be connected to a trip relay in the output matrix.

Manual opening

Manual CB open command during AR sequence will stop the sequence and leaves the CB open.

Reclaim time setting

- Use shot specific reclaim time: No
  Reclaim time setting defines reclaim time between different shots during sequence and also reclaim time after manual closing.
- Use shot specific reclaim time: Yes
  Reclaim time setting defines reclaim time only for manual control. Reclaim time between different shots is defined by shot specific reclaim time settings.

Support for 2 circuit breakers

AR function can be configured to handle 2 controllable objects. Object 1 – 6 can be configured to CB1 and any other controllable object can be used as CB2. The object selection for CB2 is made with **Breaker 2 object** setting. Switching between the two objects is done with a digital input, virtual input, virtual output or by choosing **Auto CB selection**. AR controls CB2 when the input defined by **Input for selecting CB2** setting is active (except when using auto CB selection when operated CB 1 or 2 is that which was last in close state). Control is changed to another object only if the current object is not close.

Blocking of AR shots

Each AR shot can be blocked with a digital input, virtual input or virtual output. Blocking input is selected with **Block** setting. When selected input is active the shot is blocked. A blocked shot is treated like it doesn't exist and AR sequence will jump over it. If the last shot in use is blocked, any AR request during reclaiming of the previous shot will cause final tripping.

Starting AR sequence

Each AR request has own separate starting delay counter. The one which starting delay has elapsed first will be selected. If more than one delay elapses at the same time, an AR request of the highest priority is selected. AR1 has the highest priority and AR4 has the lowest priority. First shot is selected according to the AR request. Next AR opens the CB and starts counting dead time.

Starting sequence at shot 2 – 5 & skipping of AR shots

Each AR request line can be enabled to any combination of the 5 shots. For example making a sequence of **Shot 2** and **Shot 4** for AR request 1 is done by enabling AR1 only for those two shots.

NOTE: If AR sequence is started at shot 2 – 5 the starting delay is taken from the discrimination time setting of the previous shot. For example if Shot 3 is the first shot for AR2, the starting delay for this sequence is defined by Discrimination time of Shot 2 for AR2.

Critical AR request

Critical AR request stops the AR sequence and cause final tripping. Critical request is ignored when AR sequence is not running and also when AR is reclaiming.

Critical request is accepted during dead time and discrimination time.

Shot active matrix signals

When starting delay has elapsed, active signal of the first shot is set. If successful reclosing is executed at the end of the shot, the active signal will be reset after reclaim time. If reclosing was not successful or new fault appears during reclaim time, the active of the current shot is reset and active signal of the next shot is set (if there are any shots left before final trip).

AR running matrix signal

This signal indicates dead time. The signal is set after controlling CB open. When dead time ends, the signal is reset and CB is controlled close.

Final trip matrix signals

There are 5 final trip signals in the matrix, one for each AR request (1 to 4 and 1 critical). When final trip is generated, one of these signals is set according to the AR request which caused the final tripping. The final trip signal will stay active for 0.5 seconds and then resets automatically.

DI to block AR setting

This setting is useful with an external synchro-check device. This setting only affects re-closing the CB. Re-closing can be blocked with a digital input, virtual input or virtual output. When the blocking input is active, CB won't be closed until the blocking input becomes inactive again. When blocking becomes inactive the CB will be controlled close immediately.

Table 8.5: Setting parameters of AR function

Parameter	Value	Unit	Default	Description
ARena	ARon; ARoff	-	ARon	Enabling/disabling the autoreclose
ExtSync	None, any digital input, virtual input or virtual output	-	-	The digital input for blocking CB close. This can be used for Synchrocheck.
AR_DI	None, any digital input, virtual input or virtual output	-	-	The digital input for toggling the ARena parameter
AR2grp	ARon; ARoff	-	ARon	Enabling/disabling the autoreclose for group 2
ReclT	0.02 – 300.00	s	10.00	Reclaim time setting. This is common for all the shots.
CB	Obj1 – Obj6		Obj1	Breaker object in use
CB1	Obj1 – Obj6		Obj1	Breaker 1 object
CB2	Obj1 – Obj6		-	Breaker 2 object
AutoCBSel	On; Off		off	Enabling/disabling the auto CB selection
CB2Sel	None, any digital input, virtual input or virtual output		-	The digital input for selecting the CB2.
ARreq	On; Off	-	Off	AR request event
ShotS	On; Off	-	Off	AR shot start event
ARlock	On; Off	-	Off	AR locked event
CritAr	On; Off	-	Off	AR critical signal event
ARrun	On; Off	-	Off	AR running event
FinTrp	On; Off	-	Off	AR final trip event
ReqEnd	On; Off	-	Off	AR end of request event
ShtEnd	On; Off	-	Off	AR end of shot event
CriEnd	On; Off	-	Off	AR end of critical signal event
ARUnl	On; Off	-	Off	AR release event
ARStop	On; Off	-	Off	AR stopped event
FTrEnd	On; Off	-	Off	AR final trip ready event

Parameter	Value	Unit	Default	Description
ARon	On; Off	-	Off	AR enabled event
ARoff	On; Off	-	Off	AR disabled event
CRITri	On; Off	-	On	AR critical final trip on event
AR1Tri	On; Off	-	On	AR AR1 final trip on event
AR2Tri	On; Off	-	On	AR AR2 final trip on event
Shot settings				
DeadT	0.02 – 300.00	s	5.00	The dead time setting for this shot. This is a common setting for all the AR lines in this shot
AR1	On; Off	-	Off	Indicates if this AR signal starts this shot
AR2	On; Off	-	Off	Indicates if this AR signal starts this shot
AR3	On; Off	-	Off	Indicates if this AR signal starts this shot
AR4	On; Off	-	Off	Indicates if this AR signal starts this shot
Start1	0.02 – 300.00	s	0.02	AR1 Start delay setting for this shot
Start2	0.02 – 300.00	s	0.02	AR2 Start delay setting for this shot
Start3	0.02 – 300.00	s	0.02	AR3 Start delay setting for this shot
Start4	0.02 – 300.00	s	0.02	AR4 Start delay setting for this shot
Discr1	0.02 – 300.00	s	0.02	AR1 Discrimination time setting for this shot
Discr2	0.02 – 300.00	s	0.02	AR2 Discrimination time setting for this shot
Discr3	0.02 – 300.00	s	0.02	AR3 Discrimination time setting for this shot
Discr4	0.02 – 300.00	s	0.02	AR4 Discrimination time setting for this shot

Table 8.6: Measured and recorded values of AR function

	Parameter	Value	Unit	Description
Measured or recorded values	Obj1	UNDEFINED; OPEN; CLOSE; OPEN_REQUEST; CLOSE_REQUEST; READY; NOT_READY; INFO_NOT_AVAILABLE; FAIL	-	Object 1 state
	Status	INIT; RECLAIM_TIME; READY; WAIT_CB_OPEN; WAIT_CB_CLOSE; DISCRIMINATION_TIME; LOCKED; FINAL_TRIP; CB_FAIL; INHIBIT	-	AR-function state
	Shot#	1 – 5	-	The currently running shot
	ReclT	RECLAIMTIME; STARTTIME; DEADTIME; DISCRIMINATIONTIME	-	The currently running time (or last executed)
	SCntr		-	Total start counter
	Fail		-	The counter for failed AR shots
	Shot1*		-	Shot1 start counter
	Shot2*		-	Shot2 start counter
	Shot3*		-	Shot3 start counter
	Shot4*		-	Shot4 start counter
	Shot5*		-	Shot5 start counter

* There are 5 counters available for each one of the two AR signals.

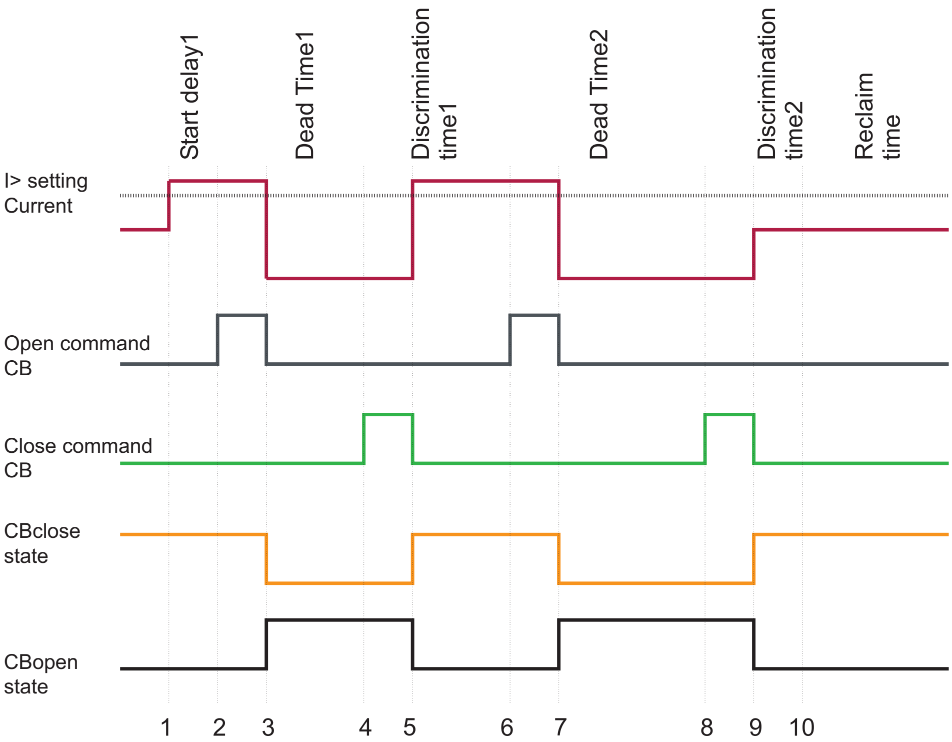


Figure 8.7: Example sequence of two shots. After shot 2 the fault is cleared.

1. Current exceeds the I> setting; the start delay from shot 1 starts.
2. After the start delay, an OpenCB relay output closes.
3. A CB opens. The dead time from shot 1 starts, and the OpenCB relay output opens.
4. The dead time from shot 1 runs out; a CloseCB output relay closes.
5. The CB closes. The CloseCB output relay opens, and the discrimination time from shot 1 starts. The current is still over the I> setting.
6. The discrimination time from the shot 1 runs out; the OpenCB relay output closes.
7. The CB opens. The dead time from shot 2 starts, and the OpenCB relay output opens.
8. The dead time from shot 2 runs out; the CloseCB output relay closes.
9. The CB closes. The CloseCB output relay opens, and the discrimination time from shot 2 starts. The current is now under I> setting.
10. Reclaim time starts. After the reclaim time the AR sequence is successfully executed. The AR function moves to wait for a new AR request in shot 1.

8.9 Logic functions

Logic is made with VAMPSET setting tool. Consumed memory is dynamically shown on the configuration view in percentage. The first value indicates amount of used inputs, second amount of gates and third values shows amount of outputs consumed.

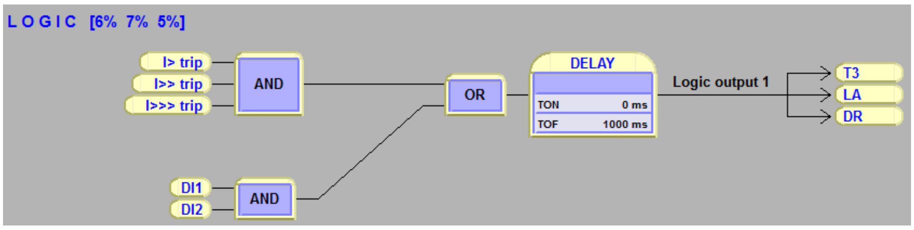


Figure 8.8: Logic can be found and modified in “logic” menu in VAMPSET setting tool

Percentages show used memory amount.

Inputs/Logical functions/Outputs- used. None of these is not allowed to exceed 100%. See guide below to learn basics of logic creation:

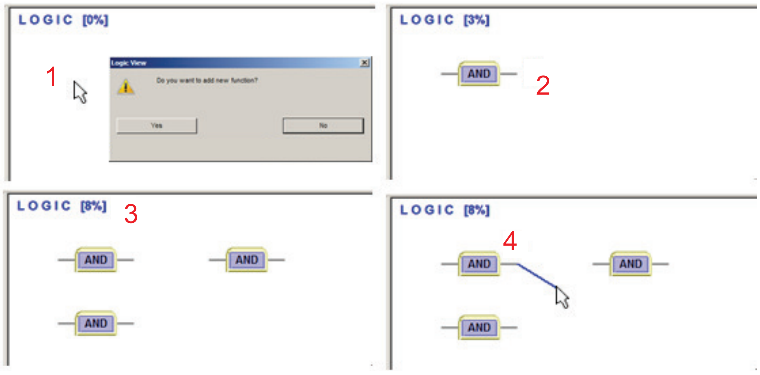


Figure 8.9: How to create logical nodes.

1. Press empty area to add a logic gate, confirm new function by pressing “Yes”.
2. Logic function is always "AND" -gate as a default.
3. While logic increases the capacity is increasing as well.
4. To joint logic functions, go on top of the output line of gate and hold down mouse left -> make the connection to other logic functions input.

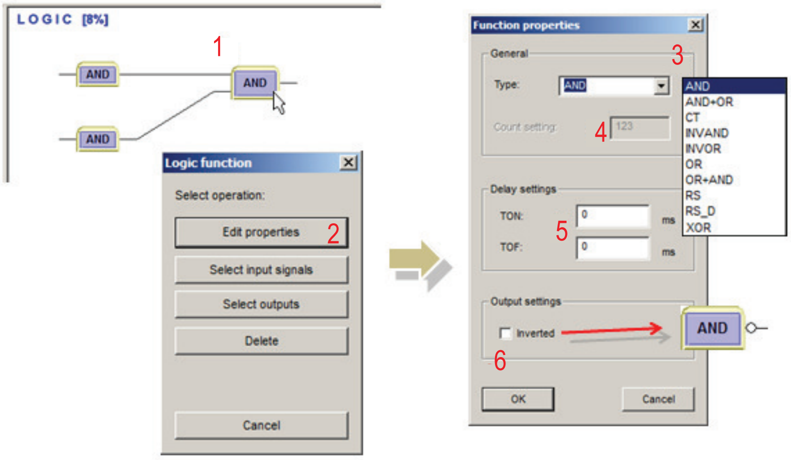


Figure 8.10: Logic creation

1. Left click on top of any logic function to activate the “Select operation” view.
2. Edit properties button opens the “Function properties” window.
3. Generally it is possible to choose the type of logic function between and/or/counter/swing -gate.
4. When counter is selected, count setting may be set here.
5. Separate delay setting for logic activation and dis-activation.
6. Possible to invert the output of logic. Inverted logic output is marked with circle.

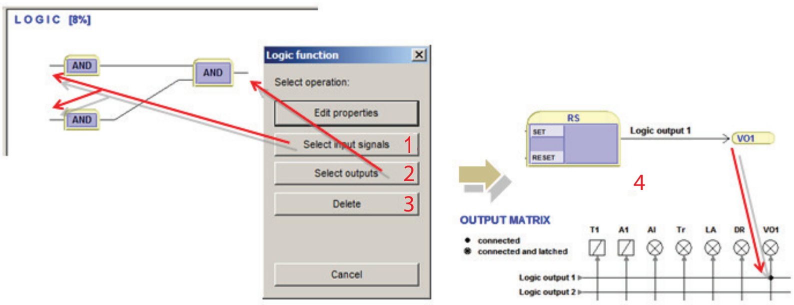


Figure 8.11: Logic creation

1. Select input signals can be done by pressing the following button or by clicking mouse left on top of the logic input line.
2. Select outputs can be done by pressing the following button or by clicking mouse left on top of the logic output line.
3. This deletes the logic function.
4. When logic is created and settings are written to the IED the unit requires a restart. After restarting the logic output is automatically assigned in output matrix as well.

NOTE: Whenever writing new logic to the IED the unit has to be restarted.

9 Communication and protocols

9.1 Communication ports

The relay has one communication port. See Figure 9.1.

There is also one optional communication module slot in the rear panel.

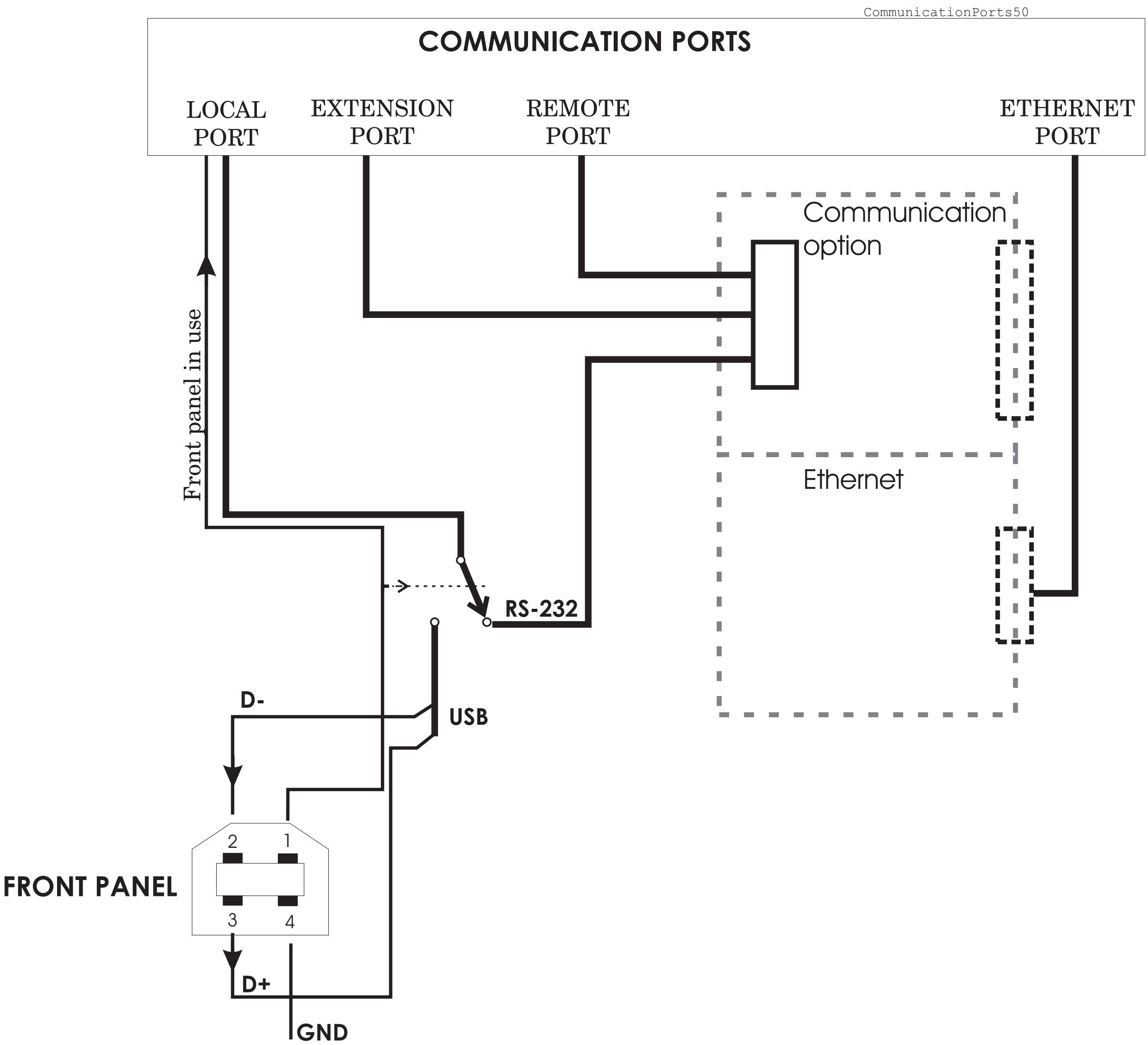


Figure 9.1: Communication ports and connectors. The DSR signal from the front panel port selects the active connector for the RS232 local port.

9.1.1 Local port (Front panel)

The relay has a USB-connector in the front panel

Protocol for the USB port

The front panel USB port is always using the command line protocol for VAMPSET regardless of the selected protocol for the rear panel local port.

9.1.2 Remote port

Table 9.1: Parameters

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for remote port	Set
	None		-	
	ANSI-85		Communication for line differential protection	

9.1.3 Extension port

Table 9.2: Parameters

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for extension port	Set
	None		-	
	ExternalIO		Modbus RTU master for external I/O-modules (VIO12-xx)	

9.1.4 Ethernet port

TCP port 1st INST and TCP port 2nd INST are ports for ethernet communication protocols. Ethernet communication protocols can be selected to these ports when such hardware option is installed. The parameters for these ports are set via local HMI or with VAMPSET in menus TCP port 1st INST and TCP port 2nd INST. Two different protocols can be used simultaneously on one physical interface (both protocols use the same IP address and MAC address but different IP port).

Protocol configuration menu contains address and other related information for the ethernet port. TCP port 1st and 2nd instance include selection for the protocol, IP port settings and message/error/timeout counters. More information about the protocol configuration menu on table below.

Table 9.3: Main configuration parameters (local display), inbuilt Ethernet port

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the extension port	Set
	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC-101		IEC-101	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 102	Set
IpAddr	n.n.n.n		Internet protocol address (set with VAMPSET)	Set
NetMsk	n.n.n.n		Net mask (set with VAMPSET)	Set
Gatew	default = 0.0.0.0		Gateway IP address (set with VAMPSET)	Set
NTPSvr	n.n.n.n		Network time protocol server (set with VAMPSET) 0.0.0.0 = no SNTP	Set
KeepAlive	nn		TCP keepalive interval	Set 1)
FTP server	on/off		Enable FTP server	Set
FTP speed	4 Kb/s (default)		Maximum transmission speed for FTP	Set
FTP password	? (user) config (configurator)		FTP password	Set
MAC address	001ADnnnnnnn		MAC address	
VS Port	nn 23 (default)		IP port for Vampset	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	
EthSffEn	on/off		Sniffer port enable	Set
SniffPort	Port2		Sniffer port	

Set = An editable parameter (password needed)

1) KeepAlive: The KeepAlive parameter sets in seconds the time between two keepalive packets are sent from the IED. The setting range for this parameter is between zero (0) and 20 seconds; with the exception that zero (0) means actually 120 seconds (2 minutes). A keep alive’s packet purpose is for the VAMP IED to send a probe packet to a connected client for checking the status of the TCP-connection when no other packet is being sent e.g. client does not poll data from the IED. If the keepalive packet is not acknowledged, the IED will close the TCP connection. Connection must be resumed on the client side.

Table 9.4: TCP PORT 1st INST

Parameter	Value	Unit	Description	Note
Protocol			Protocol selection for the extension port.	Set
	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 502	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

Table 9.5: CP PORT 2nd INST

Parameter	Value	Unit	Description	Note
Ethernet port protocol			Protocol selection for the extension port.	Set
(TCP PORT 2nd INST)	None		Command line interface for VAMPSET	
	ModbusTCPs		Modbus TCP slave	
	IEC 61850		IEC-61850 protocol	
	EtherNet/IP		Ethernet/IP protocol	
	DNP3		DNP/TCP	
Port	nnn		Ip port for protocol, default 502	Set
Msg#	nnn		Message counter	
Errors	nnn		Error counter	
Tout	nnn		Timeout counter	

Set = An editable parameter (password needed).

9.2 Communication protocols

The protocols enable the transfer of the following type of data:

- events
- status information
- measurements
- control commands.
- clock synchronizing

9.2.1 PC communication

PC communication is using a VAMP specified command line interface. The VAMPSET program can communicate using the local USB-port or using optional Ethernet interface.

For Ethernet configuration, see Chapter 9.1.4 Ethernet port.

9.2.2 Modbus TCP and Modbus RTU

These Modbus protocols are often used in power plants and in industrial applications. The difference between these two protocols is the media. Modbus TCP uses Ethernet and Modbus RTU uses asynchronous communication (RS-485, optic fibre, RS-232).

VAMPSET will show the list of all available data items for Modbus.

The Modbus communication is activated usually for remote port via a menu selection with parameter "Protocol". See Figure 9.1.

For Ethernet interface configuration, see Chapter 9.1.4 Ethernet port.

Table 9.6: Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 247		Modbus address for the device. Broadcast address 0 can be used for clock synchronizing. Modbus TCP uses also the TCP port settings.	Set
bit/s	1200 2400 4800 9600 19200	bps	Communication speed for Modbus RTU	Set
Parity	None Even Odd		Parity for Modbus RTU	Set

Set = An editable parameter (password needed)

9.2.3 DNP 3.0

The relay supports communication using DNP 3.0 protocol. The following DNP 3.0 data types are supported:

- binary input
- binary input change
- double-bit input
- binary output
- analog input
- counters

Additional information can be obtained from the “DNP 3.0 Device Profile Document” and “DNP 3.0 Parameters.pdf”. DNP 3.0 communication is activated via menu selection. RS-485 interface is often used but also RS-232 and fibre optic interfaces are possible.

Table 9.7: Parameters

Parameter	Value	Unit	Description	Set
bit/s	4800 9600 (default) 19200 38400	bps	Communication speed	Set
Parity	None (default) Even Odd		Parity	Set
SlvAddr	1 – 65519		An unique address for the device within the system	Set
MstrAddr	1 – 65519 255 = default		Address of master	Set
LLTout	0 – 65535	ms	Link layer confirmation timeout	Set
LLRetry	1 – 255 1 = default		Link layer retry count	Set
APLTout	0 – 65535 5000 = default	ms	Application layer confirmation timeout	Set
CnfMode	EvOnly (default); All		Application layer confirmation mode	Set
DBISup	No (default); Yes		Double-bit input support	Set
SyncMode	0 – 65535	s	Clock synchronization request interval. 0 = only at boot	Set

Set = An editable parameter (password needed)

9.2.4 External I/O (Modbus RTU master)

External Modbus I/O devices can be connected to the relay using this protocol. (See Chapter 11.8.1 Third-party external input / output modules module for more information).

9.2.5 IEC 61850

IEC 61850 protocol is available with the optional communication module. IEC 61850 protocol can be used to read / write static data from the relay to receive events and to receive / send GOOSE messages to other relays.

IEC 61850 server interface is capable of

- Configurable data model: selection of logical nodes corresponding to active application functions
- Configurable pre-defined data sets
- Supported dynamic data sets created by clients
- Supported reporting function with buffered and unbuffered Report Control Blocks
- Sending analogue values over GOOSE
- Supported control modes:
  - direct with normal security
  - direct with enhanced security
  - select before operation with normal security
  - select before operation with enhanced security
- Supported horizontal communication with GOOSE: configurable GOOSE publisher data sets, configurable filters for GOOSE subscriber inputs, GOOSE inputs available in the application logic matrix

Additional information can be obtained from the separate documents “IEC 61850 conformance statement.pdf”, “IEC 61850 Protocol data.pdf” and “Configuration of IEC 61850 interface.pdf”.

9.2.6 EtherNet/IP

The device supports communication using EtherNet/IP protocol which is a part of CIP (Common Industrial Protocol) family. EtherNet/IP protocol is available with the optional inbuilt Ethernet port. The protocol can be used to read / write data from the device using request / response communication or via cyclic messages transporting data assigned to assemblies (sets of data).

For more detailed information and parameter lists for EtherNet/IP, refer to a separate application note “Application Note EtherNet/IP.pdf”.

For the complete data model of EtherNet/IP, refer to the document “Application Note DeviceNet and EtherNetIP Data Model.pdf”.

9.2.7 FTP server

The FTP server is available on VAMP IEDs equipped with an inbuilt or optional Ethernet card.

The server enables downloading of the following files from an IED:

- Disturbance recordings.
- The MasterICD and MasterICDEd2 files.

The MasterICD and MasterICDEd2 files are VAMP-specific reference files that can be used for offline IEC61850 configuration.

The inbuilt FTP client in Microsoft Windows or any other compatible FTP client may be used to download files from the device.

Parameter	Value	Unit	Description	Note
Enable FTP server	Yes No		Enable or disable the FTP server.	Set
FTP password	Max 33 characters		Required to access the FTP server with an FTP client. Default is “config”. The user name is always “vamp”.	Set
FTP max speed	1 – 10	KB/s	The maximum speed at which the FTP server will transfer data.	Set

9.2.8 DeviceNet

The device supports communication using DeviceNet protocol which is a part of CIP (Common Industrial Protocol) family. DeviceNet protocol is available with the optional external VSE009 module. The protocol can be used to read / write data from the device using request / response communication or via cyclic messages transporting data assigned to assemblies (sets of data).

For more detailed information about DeviceNet, refer to a separate application note “Application Note DeviceNet.pdf”.

For the complete data model of DeviceNet, refer to the document “Application Note DeviceNet and EtherNetIP Data Model.pdf”.

10 Application

VAMP 59 can be used for protection of medium voltage networks with grounded or low-resistance grounded neutral point. The relay has the required functions to be applied as a backup relay in high voltage networks or to a transformer differential relay.

The relays provide circuit-breaker control functionality, additional primary switching devices (earthing switches and disconnector switches) can also be controlled from the relay HMI or the control or SCADA/automation system. Programmable logic functionality is also implemented in the relay for various applications e.g interlockings schemes. For details about the functionality in the relays, see Table 1.1.

10.1 Line protection and auto-reclosing

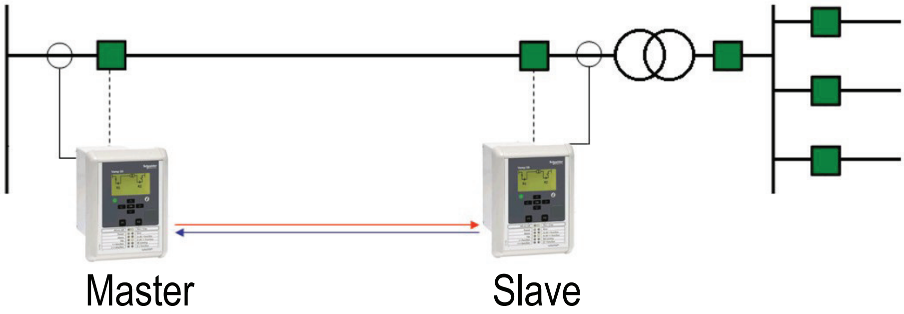


Figure 10.1: Line differential protection and auto-reclosing

1. Fault is disconnected by line differential protection. LdI starts auto-reclosing.
2. Only master does the reclosing, slave waits for permission to close breaker. I> checks if there is still fault. Line differential protection has to be blocked.
3. After successful reclosing slave is permitted to close the breaker. Slave receives POC-signal from master in 10 ms after successful reclosing. Line differential protection is no longer blocked.
4. Finally the station is energized.

10.2 Trip circuit supervision

Trip circuit supervision is used to ensure that the wiring from the protective device to a circuit-breaker is in order. This circuit is unused most of the time, but when a protection device detects a fault in the network, it is too late to notice that the circuit-breaker cannot be tripped because of a broken trip circuitry.

Also the closing circuit can be supervised, using the same principle.

10.2.1 Trip circuit supervision with one digital input

The benefits of this scheme is that only one digital inputs is needed and no extra wiring from the relay to the circuit breaker (CB) is needed. Also supervising a 24 Vdc trip circuit is possible.

The drawback is that an external resistor is needed to supervise the trip circuit on both CB positions. If supervising during the closed position only is enough, the resistor is not needed.

- The digital input is connected parallel with the trip contacts (Figure 10.2).
- The digital input is configured as Normal Closed (NC).
- The digital input delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The digital input is connected to a relay in the output matrix giving out any trip circuit alarm.
- The trip relay should be configured as non-latched. Otherwise, a superfluous trip circuit fault alarm will follow after the trip contact operates, and the relay remains closed because of latching.
- By utilizing an auxiliary contact of the CB for the external resistor, also the auxiliary contact in the trip circuit can be supervised.

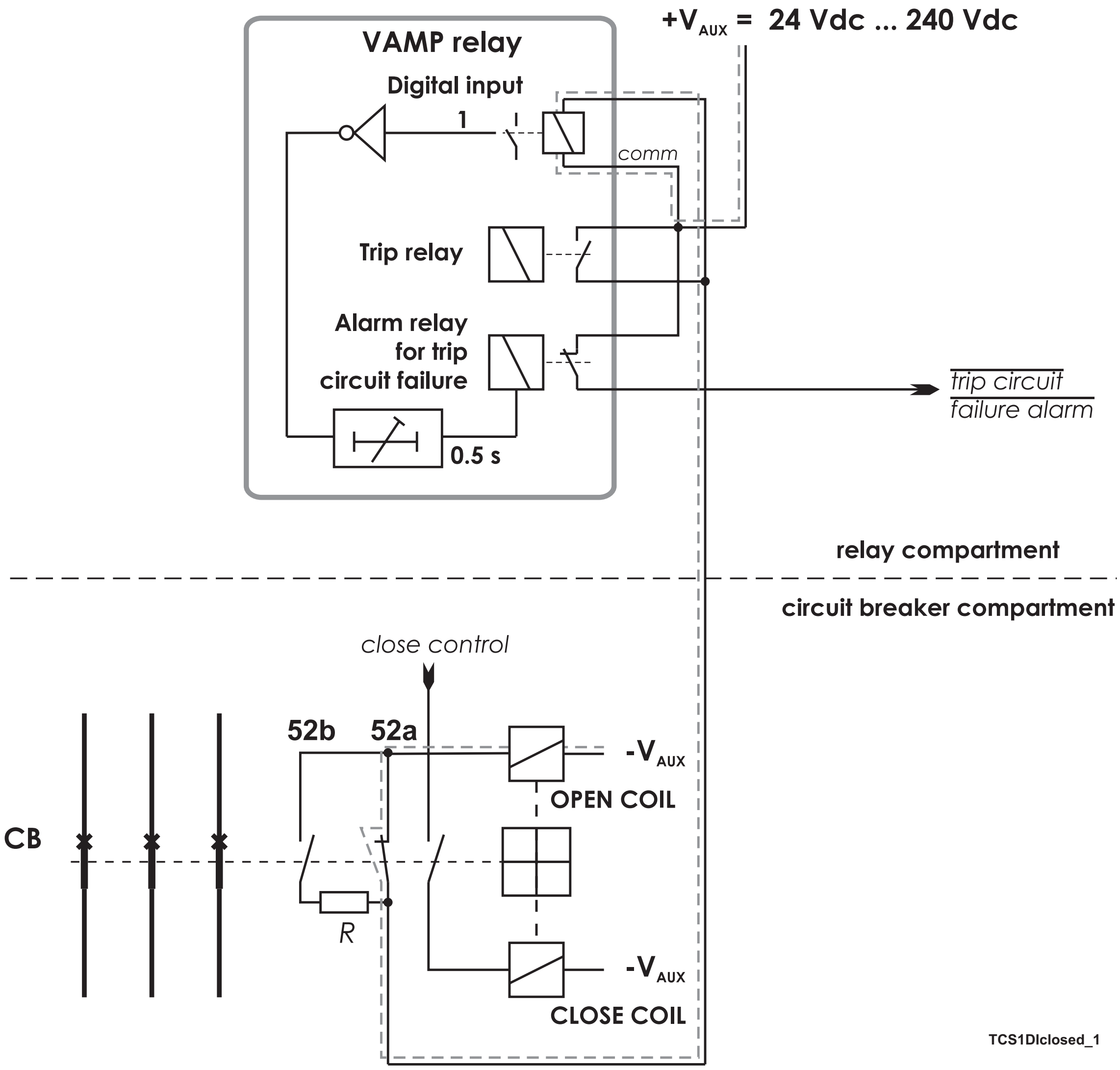


Figure 10.2: Trip circuit supervision using a single digital input and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete.

NOTE: The need for the external resistor R depends on the application and circuit breaker manufacturer's specifications.

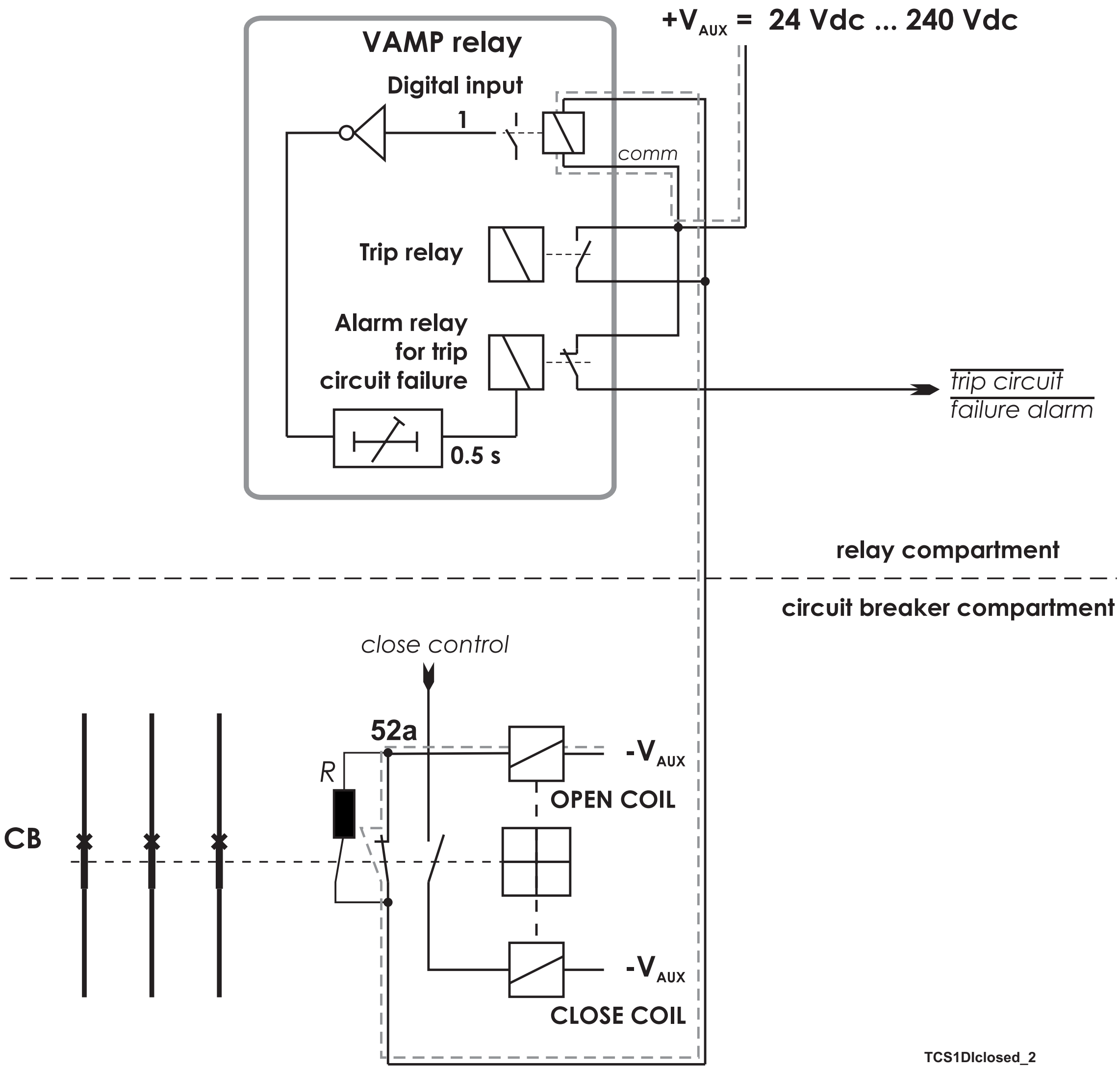


Figure 10.3: Alternative connection without using circuit breaker 52b auxiliary contacts. Trip circuit supervision using a single digital input and an external resistor R. The circuit-breaker is in the closed position. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete.

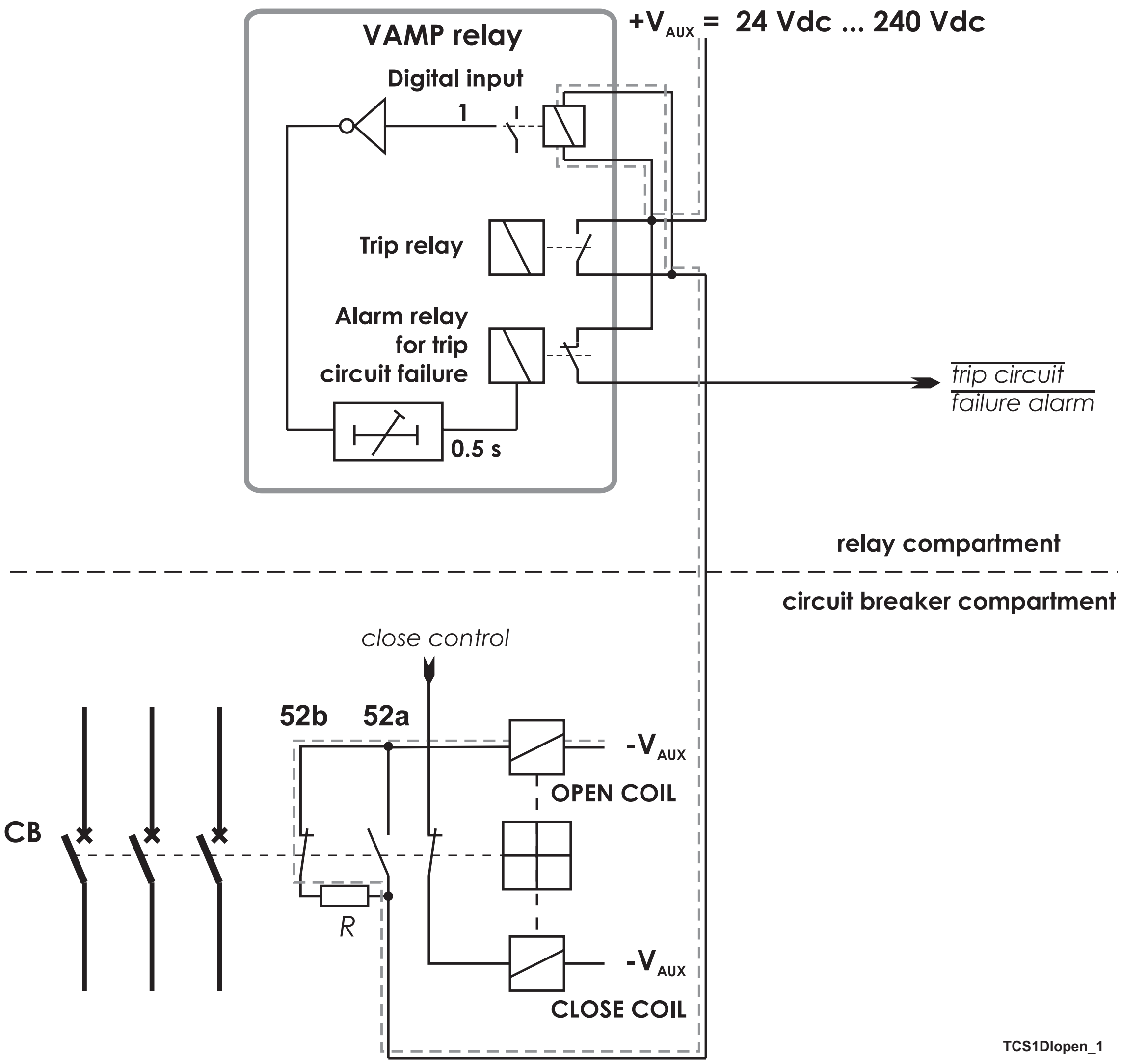


Figure 10.4: Trip circuit supervision using a single digital input, when the circuit breaker is in open position.

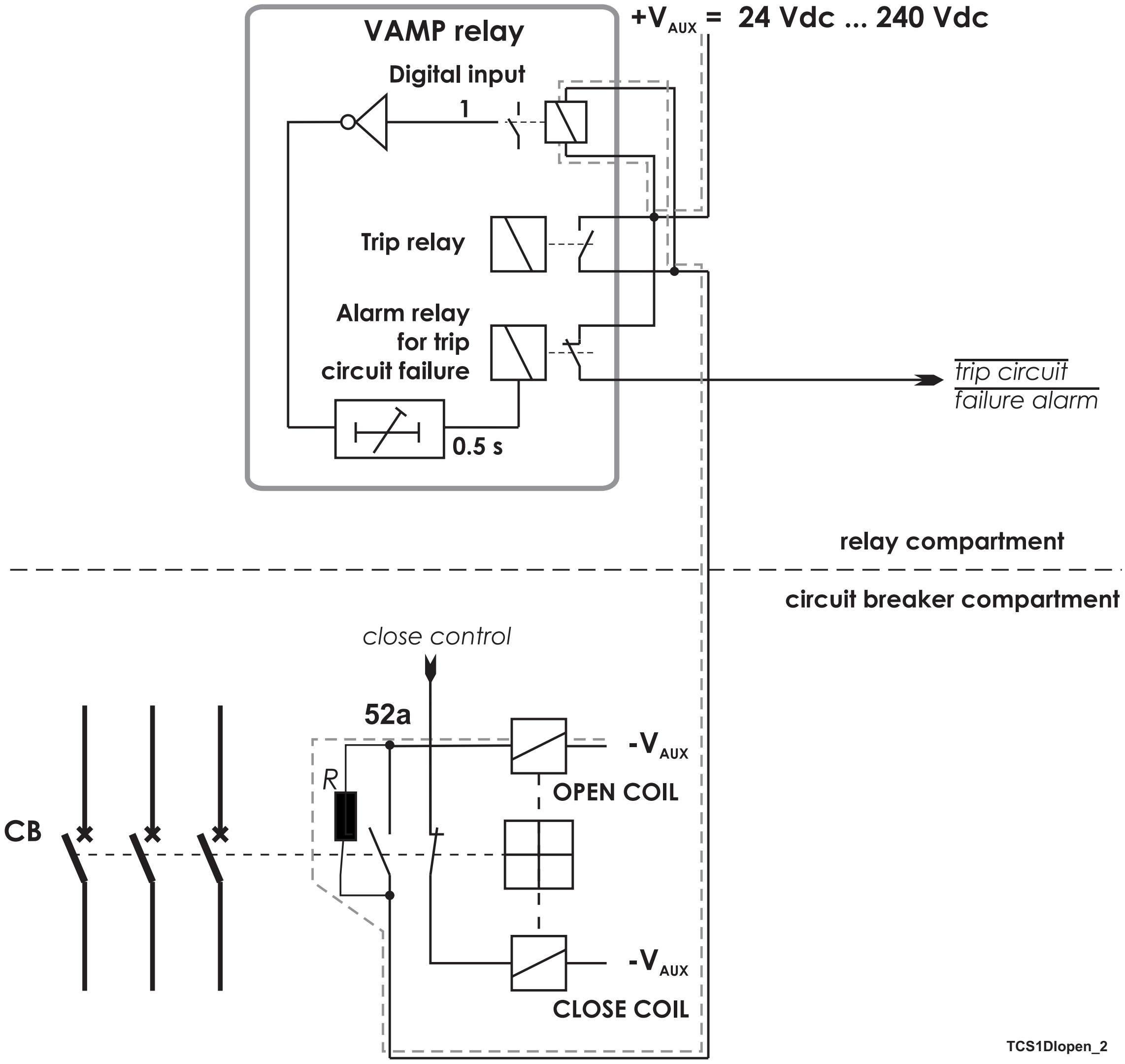
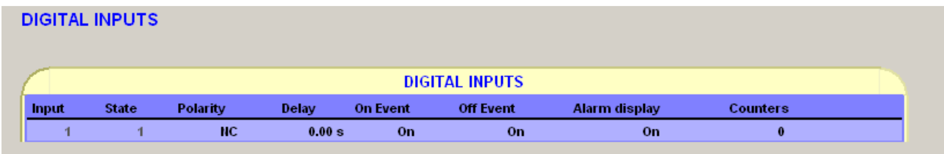


Figure 10.5: Alternative connection without using circuit breaker 52b auxiliary contacts. Trip circuit supervision using a single digital input, when the circuit breaker is in open position.



DIGITAL INPUTS

DIGITAL INPUTS

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	1	NC	0.00 s	On	On	On	0

Figure 10.6: An example of digital input DI1 configuration for trip circuit supervision with one digital input.

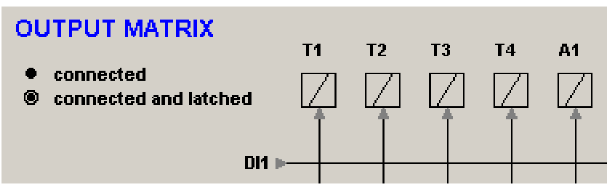


Figure 10.7: An example of output matrix configuration for trip circuit supervision with one digital input.

Example of dimensioning the external resistor R:

U_{AUX} =	110 Vdc - 20 % + 10%, Auxiliary voltage with tolerance
U_{DI} =	18 Vdc, Threshold voltage of the digital input
I_{DI} =	3 mA, Typical current needed to activate the digital input including a 1 mA safety margin.
P_{COIL} =	50 W, Rated power of the open coil of the circuit breaker. If this value is not known, 0 Ω can be used for the R_{COIL}.
U_{MIN} =	U_{AUX} - 20 % = 88 V
U_{MAX} =	U_{AUX} + 10 % = 121 V
R_{COIL} =	U^2_{AUX} / P_{COIL} = 242 Ω.

The external resistance value is calculated using Equation 10.1.

Equation 10.1:

$$R = \frac{U_{MIN} - U_{DI} - I_{DI} \cdot R_{Coil}}{I_{DI}}$$

R = (88 – 18 – 0.003 x 242)/0.003 = 23.1 kΩ

(In practice the coil resistance has no effect.)

By selecting the next smaller standard size we get **22 kΩ**.

The power rating for the external resistor is estimated using Equation 10.2 and Equation 10.3. The Equation 10.2 is for the CB open situation including a 100 % safety margin to limit the maximum temperature of the resistor.

Equation 10.2:

$$P = 2 \cdot I_{DI}^2 \cdot R$$

P = 2 x 0.003^2 x 22000 = 0.40 W

Select the next bigger standard size, for example **0.5 W**.

When the trip contacts are still closed and the CB is already open, the resistor has to withstand much higher power (Equation 10.3) for this short time.

Equation 10.3:

$$P = \frac{U_{MAX}^2}{R}$$

P = 121^2 / 22000 = 0.67 W

A 0.5 W resistor will be enough for this short time peak power, too. However, if the trip relay is closed for longer time than a few seconds, a 1 W resistor should be used.

10.2.2 Trip circuit supervision with two digital inputs

The benefits of this scheme is that no external resistor is needed.

The drawbacks are, that two digital inputs from two separate groups are needed and two extra wires from the relay to the CB compartment is needed. Additionally the minimum allowed auxiliary voltage is 48 Vdc, which is more than twice the threshold voltage of the dry digital input, because when the CB is in open position, the two digital inputs are in series.

- The first digital input is connected parallel with the auxiliary contact of the open coil of the circuit breaker.
- Another auxiliary contact is connected in series with the circuitry of the first digital input. This makes it possible to supervise also the auxiliary contact in the trip circuit.
- The second digital input is connected in parallel with the trip contacts.
- Both inputs are configured as normal closed (NC).
- The user’s programmable logic is used to combine the digital input signals with an AND port. The delay is configured longer than maximum fault time to inhibit any superfluous trip circuit fault alarm when the trip contact is closed.
- The output from the logic is connected to a relay in the output matrix giving out any trip circuit alarm.
- Both digital inputs must have their own common potential. Using the other digital inputs in the same group as the upper DI in the Figure 10.8 is not possible in most applications. Using the other digital inputs in the same group as the lower DI in the Figure 10.8 is limited, because the whole group will be tied to the auxiliary voltage V_{AUX}.

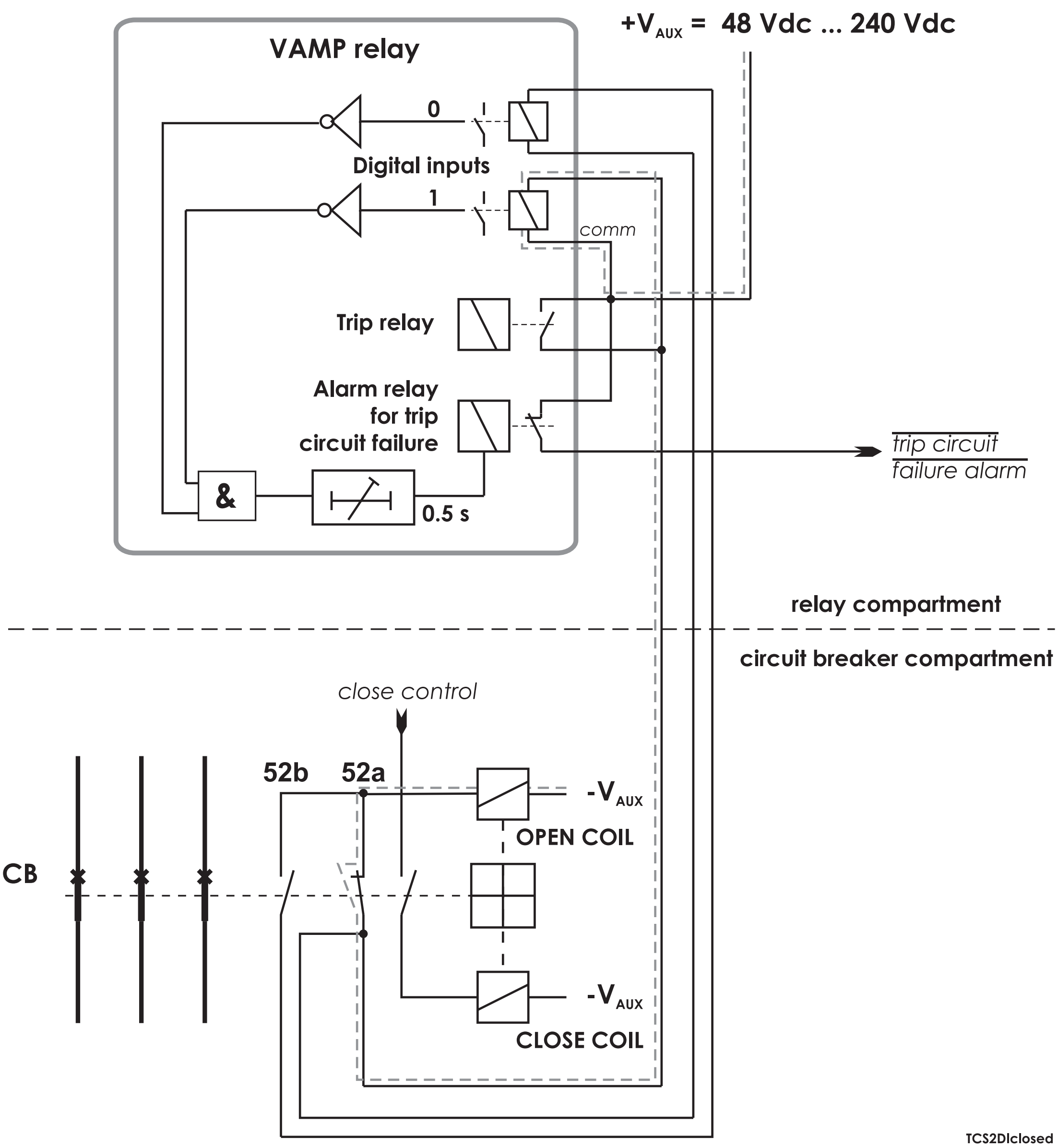


Figure 10.8: Trip circuit supervision with two digital inputs. The CB is closed. The supervised circuitry in this CB position is double-lined. The digital input is in active state when the trip circuit is complete.

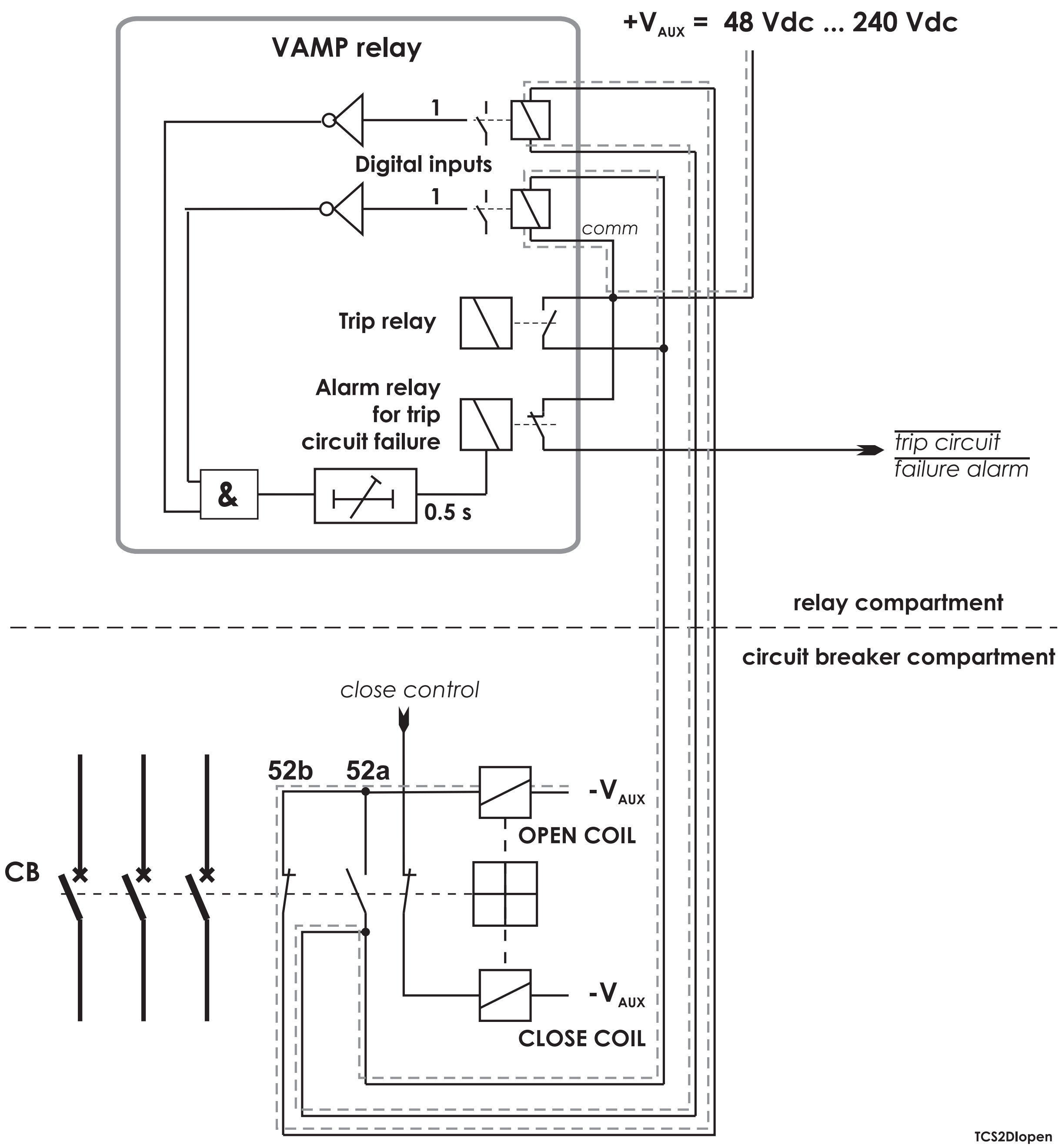
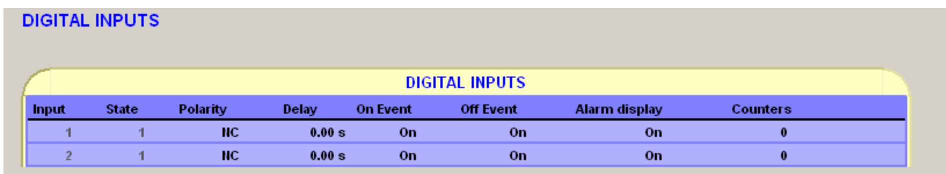


Figure 10.9: Trip circuit supervision with two digital inputs. The CB is in the open position. The two digital inputs are now in series.


DIGITAL INPUTS

DIGITAL INPUTS

Input	State	Polarity	Delay	On Event	Off Event	Alarm display	Counters
1	1	NC	0.00 s	On	On	On	0
2	1	NC	0.00 s	On	On	On	0

Figure 10.10: An example of digital input configuration for trip circuit supervision with two dry digital inputs DI1 and DI2.

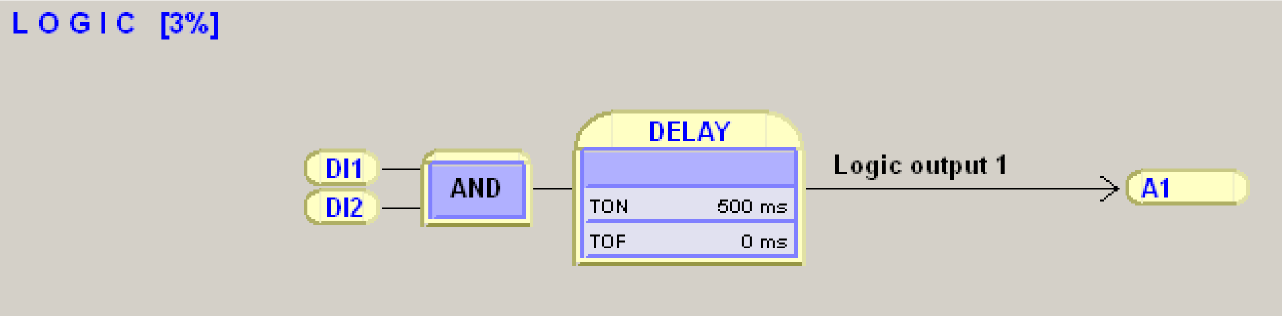


Figure 10.11: An example of logic configuration for trip circuit supervision with two dry digital inputs DI1 and DI2.

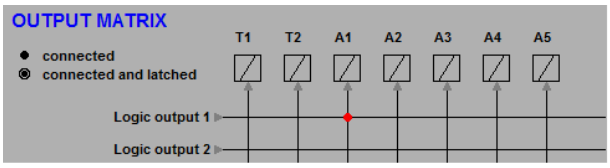


Figure 10.12: An example of output matrix configuration for trip circuit supervision with two digital inputs.

11 Connections

11.1 Rear panel

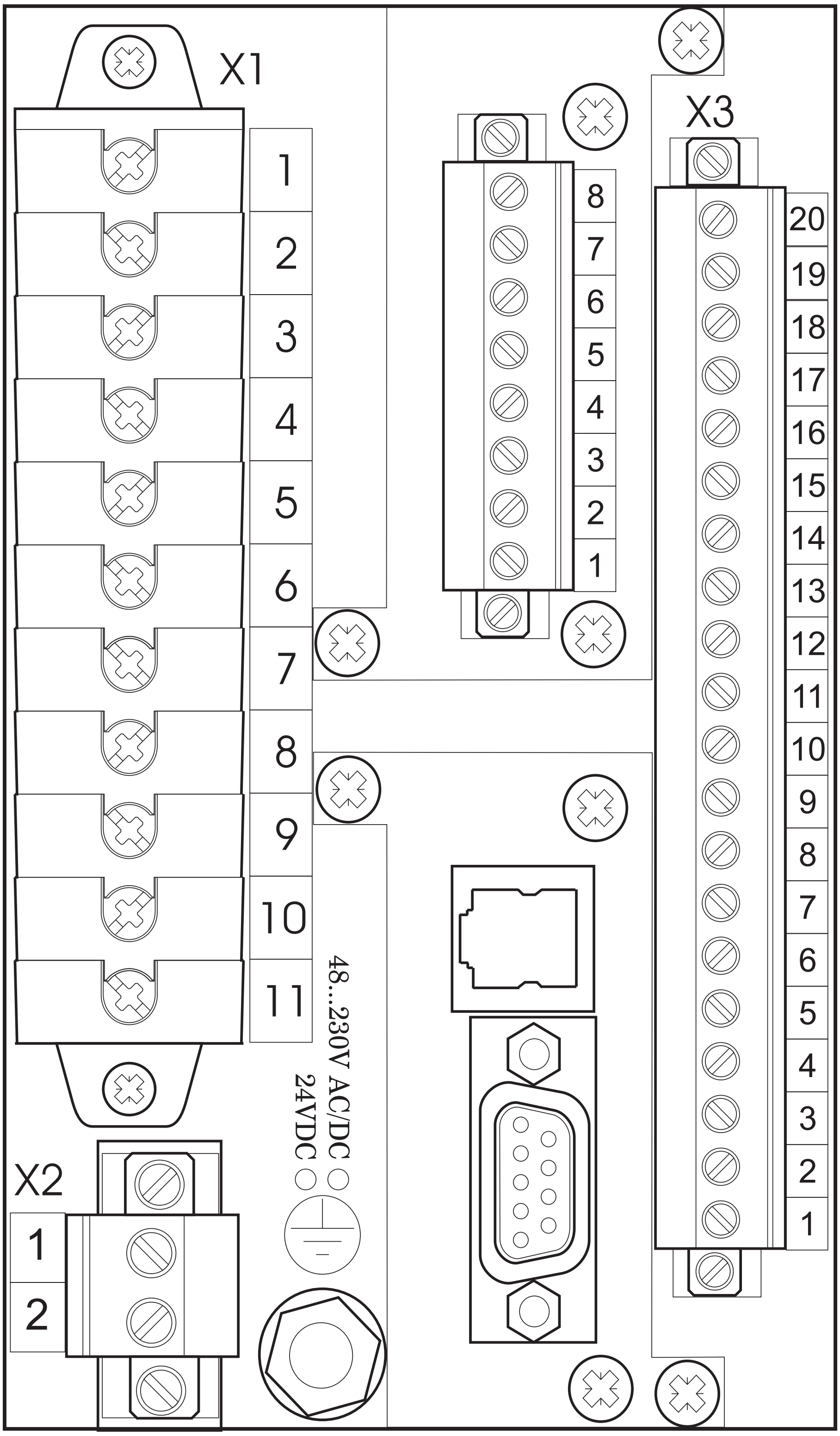
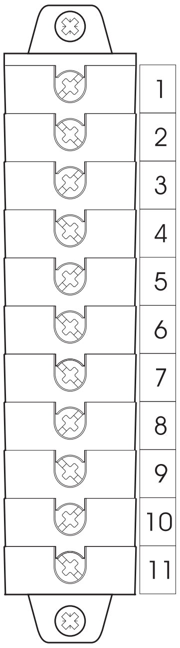


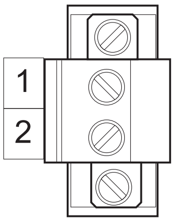
Figure 11.1: Connections on the rear panel

Terminal X1



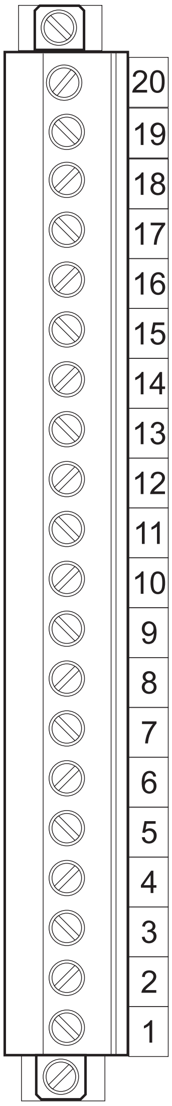
No	Symbol	Description
1	IL1(S1)	Phase current L1 (S1)
2	IL1(S2)	Phase current L1 (S2)
3	IL2(S1)	Phase current L2 (S1)
4	IL2(S2)	Phase current L2 (S2)
5	IL3(S1)	Phase current L3 (S1)
6	IL3(S2)	Phase current L3 (S2)
7	Io1	Residual current Io1 common for 1 A and 5 A (S1)
8	Io1/5A	Residual current Io1 5A (S2)
9	Io1/1A	Residual current Io1 1A (S2)
10	Uo	Zero sequence voltage Uo (Da)
11	Uo	Zero sequence voltage Uo (Da)

Terminal X2



No	Symbol	Description
1	U_{AUX}	Auxiliary voltage
2	U_{AUX}	Auxiliary voltage

Terminal X3



No	Symbol	Description
20	SF NO	Internal fault relay, common connector
19	SF NC	Internal fault relay, normal open connector
18	SF COM	Internal fault relay, normal closed connector
17	T1	Trip relay 1
16	T1	Trip relay 1
15	T2	Trip relay 2
14	T2	Trip relay 2
13	T3	Trip relay 3
12	T3	Trip relay 3
11	T4	Trip relay 4
10	T4	Trip relay 4
9	A1 NC	Alarm relay 1, common connector
8	A1 NO	Alarm relay 1, normal open connector
7	A1 COM	Alarm relay 1, normal closed connector
6	DI2 +	Digital inputs
5	DI2 -	Digital inputs
4	DI1 +	Digital inputs
3	DI1 -	Digital inputs
2	mA out -	Analogue output
1	mA out +	Analogue output

11.2 Auxiliary voltage

The external auxiliary voltage U_{AUX} (40 – 265 V ac or V dc, or optionally 18 – 36V dc) for the relay is connected to the pins X2: 1 – 2.

NOTE: When optional 18 – 36 Vdc power module is used the polarity is as follows: X2:1 positive (+), X2:2 negative (-).

11.3 Output relays

The relay is equipped with 5 configurable output relays, and a separate output relay for the self-supervision system.

- Trip relays T1 – T4 (terminals X3: 10-17)
- Alarm relay A1 (terminals X3: 7-9)
- Self-supervision system output relay IF (terminals X3: 18-20)

11.4 Serial communication connection

The device can be equipped with optional communication module. The physical location of the module is the lower option card slot at the back of the relay. The modules can be installed in the field (when power is first turned off).

There are three “logical communication ports” available in the relay: REMOTE, LOCAL and EXTENSION. Depending on the module type one or more of these ports are physically available at the external connectors.

11.4.1 Front panel USB connector

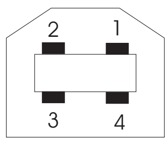


Figure 11.2: Pin numbering of the front panel USB type B connector

Pin	Signal name
1	VBUS
2	D-
3	D+
4	GND
Shell	Shield

11.4.2 Pin assignments of the optional communication interface cards

The communication card types and their pin assignments are introduced in the following table.

Type	Order code, Name	Communication ports	Signal levels	Connectors	Pin usage
VCM 232+00	LA RS-232 interface	REMOTE	RS-232	D-connector	2 = TX_REM 3 = RX_REM 7 = GND 9 = +12V
VCM 232+IR	LB RS-232 interface with timesyn-cronisation input	CLOCK SYNC (IRIG-B)	TTL	2-pole screw con-nector	1= Data 2= GND
VCM 232+FI	LC RS-232 interface with RTD fiber op-tic interface	EXTENSION RTD protocol must be selected for the port	Light	Snap-in connector	
VCM 232+I62	LE RS-232 interface with IEC 61850 in-terface	Ethernet	Ethernet 10Mbps	RJ-45	1=Transmit+ 2=Transmit- 3=Receive+ 4=Reserved 5=Reserved 6=Receive- 7=Reserved 8=Reserved
VCM 232+L6	LG RS-232 interface with IEC 61850 Ethernet fibre inter-face	Ethernet	Light 100Mbps	LC-connector	TX=Lower LC-con-nector RX=Upper LC-con-nector

11.5 Input/output card B = 4 x DI + 1 x DI/DO

The digital input/output option “B = 4 x DI + 1 x DI/DO" enables four more digital inputs and one optional digital input / output contact. This card enables use of digital inputs DI3 – DI7. In case DI7 is not used as digital input then it can be used as additional output T5, but not simultaneously.

NOTE: Pay special attention when using DI7 (terminals numbers X6:1 – X6:2) as digital input use. Never configure, operate or control T5 output if DI7 is used as an imput. Should the control of T5 happen the output contact will short-circuit DI7 and will lead to equipment damage and loss of data.

For this block information, please see Figure 11.5.

When this option card is installed to slot X6, the CARD INFO view indicates value “4DI + 1DO” for parameter “I/O card” in HMI and VAMPSET. In case arc sensor card is chosen for slot X6 then this I/O card cannot be used.

Digital inputs of the device can operate in three different voltage areas. It is also possible to select whether ac or dc –voltage is used. Digital input threshold of the device is selected in the ordering code when the relay(s) are being ordered.

When 110 or 220 V ac voltage is used to activate the digital Inputs, the AC mode should be selected as shown in the screenshot below:

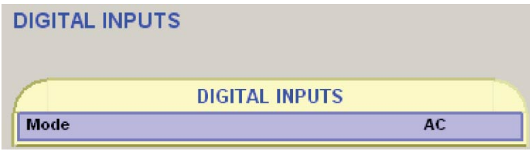


Figure 11.3: AC mode selection in VAMPSET

11.6 Arc protection card C = Arc (2 x Arc sensor + BIO)

NOTE: When this option card is installed, the parameter "I/O" has value "VOM Arc+BI". Please check the Chapter 14 Order information.

The optional arc protection card includes two arc sensor channels. The arc sensors are connected to terminals X6: 5 – 6 and 7 – 8.

The arc information can be transmitted and/or received through digital input and output channels. This is a 48 V dc signal.

The arc option card is inserted in the upper option card slot in the back of the unit.

For this block information, please see Figure 11.6.

The arc information can be transmitted and/or received through digital input and output channels BIO. The output signal is 48 V dc when active. The input signal has to be 18 – 48 V dc to be activated.

The GND must be connected together between the GND of the connected devices.

The binary output of the arc option card may be activated by one or both of the connected arc sensors, or by the binary input. The connection between the inputs and the output is selectable via the output matrix of the device. The binary output can be connected to an arc binary input of another VAMP protection relay or arc protection system.

11.7 Arc protection card D = Advanced arc (3 x Arc sensor + BIO)

NOTE: When this option card is installed, the parameter "I/O" has value "3S+1BI+1BO". Please check the Chapter 14 Order information.

The optional arc protection card includes two arc sensor channels. The arc sensors are connected to terminals X6: 6 – 7, 8 – 9 and 10 – 11.

The arc information can be transmitted and/or received through digital input and output channels. This is a 48 V dc signal.

The arc option card is inserted in the upper option card slot in the back of the unit.

For this block information, please see Figure 11.7.

The arc information can be transmitted and/or received through digital input and output channels BIO. The output signal is 48 V dc when active. The input signal has to be 18 – 48 V dc to be activated.

The GND must be connected together between the GND of the connected devices.

The binary output of the arc option card may be activated by one or both of the connected arc sensors, or by the binary input. The connection between the inputs and the output is selectable via the output matrix of the device. The binary output can be connected to an arc binary input of another VAMP protection relay or arc protection system.

11.8 External option modules

11.8.1 Third-party external input / output modules

The device supports also external input / output modules used to extend the number of digital/analog inputs and outputs.

The following types of devices are supported:

- Analog input modules (RTD)
- Analog output modules (mA-output)
- Binary input/output modules

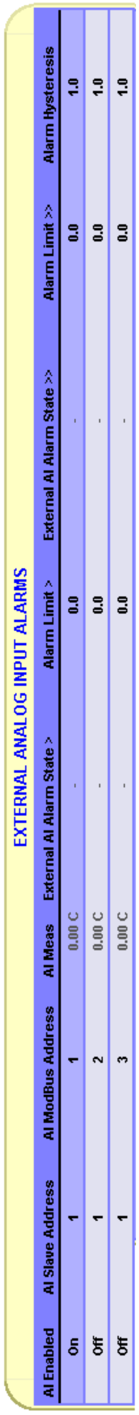
EXTENSION port is primarily designed for I/O modules. The relay must have a communication option card with EXTENSION port. Depending of the option card I/O devices may require an adapter to be able to connect to the port (i.e. VSE004).

NOTE: If External I/O protocol is not selected to any communication port, VAMPSET doesn’t display the menus required for configuring the I/O devices. After changing EXTENSION port protocol to External I/O, restart the relay and read all settings with VAMPSET.

External analog inputs configuration (VAMPSET only)

Range	Description			
	Communication read errors			
X: -32000 – 32000 Y: -1000 – 1000	Scaling	**Y2**	Scaled value	Point 2
		X2	Modbus value	
		Y1	Scaled value	Point 1
		X1	Modbus value	
-32000 – 32000		**Offset**	Subtracted from Modbus value, before running XY scaling	
InputR or HoldingR	Modbus register type			
1 – 9999	Modbus register for the measurement			
1 – 247	Modbus address of the I/O device			
C, F, K, mA, Ohm or V/A	Unit selection			
	Active value			
On / Off	Enabling for measurement			

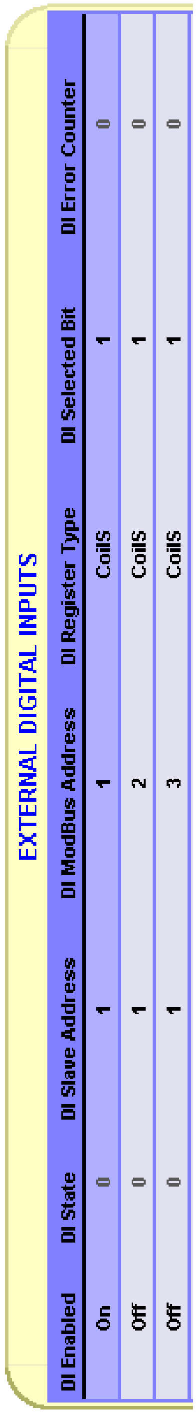
Alarms for external analog inputs



Range	Description	
0 – 10000	Hysteresis for alarm limits	
-21x107 – +21x107	**Alarm >>**	Limit setting
- / Alarm		Active state
-21x107 – +21x107	**Alarm >**	Limit setting
- / Alarm		Active state
	Active value	
1 – 9999	Modbus register for the measurement	
1 – 247	Modbus address of the I/O device	
On / Off	Enabling for measurement	

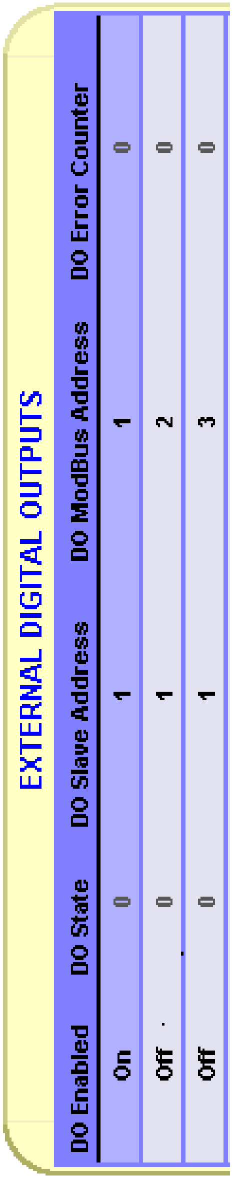
Analog input alarms have also matrix signals, “Ext. Aix Alarm1” and “Ext. Aix Alarm2”.

External digital inputs configuration (VAMPSET only)

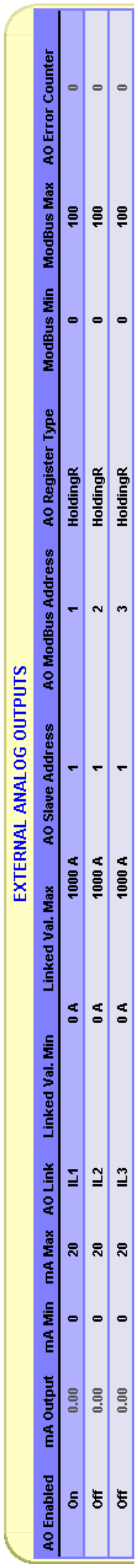


Range	Description
	Communication read errors
1 – 16	Bit number of Modbus register value
CoilS, InputS, InputR or HoldingR	Modbus register type
1 – 9999	Modbus register for the measurement
1 – 247	Modbus address of the I/O device
0 / 1	Active state
On / Off	Enabling for measurement

External digital outputs configuration (VAMPSET only)

	Range	Description
		Communication errors
	1 – 9999	Modbus register for the measurement
	1 – 247	Modbus address of the I/O device
	0 / 1	Output state
		Enabling for measurement

External analog outputs configuration (VAMPSET only)



EXTERNAL ANALOG OUTPUTS

AO Enabled	mA Output	mA Min	mA Max	AO Link	Linked Val. Min	Linked Val. Max	AO Slave Address	AO ModBus Address	AO Register Type	ModBus Min	ModBus Max	AO Error Counter
On	0.00	0	20	IL1	0 A	1000 A	1	1	HoldingR	0	100	0
Off	0.00	0	20	IL2	0 A	1000 A	1	2	HoldingR	0	100	0
Off	0.00	0	20	IL3	0 A	1000 A	1	3	HoldingR	0	100	0

Range	Description
	Communication errors
-32768 – +32767 (0 – 65535)	Modbus value corresponding Linked Val. Max
	Modbus value corresponding Linked Val. Min
InputR or HoldingR	Modbus register type
1 – 9999	Modbus register for the output
1 – 247	Modbus address of the I/O device
0 – 42x108, -21x108 – +21x108	Maximum limit for lined value, corresponding to “Modbus Max”
	Minimum limit for lined value, corresponding to “Modbus Min”
	Link selection
-21x107 – +21x107	Minimum & maximum output values
	Active value
On / Off	Enabling for measurement

11.9 Block optional diagram

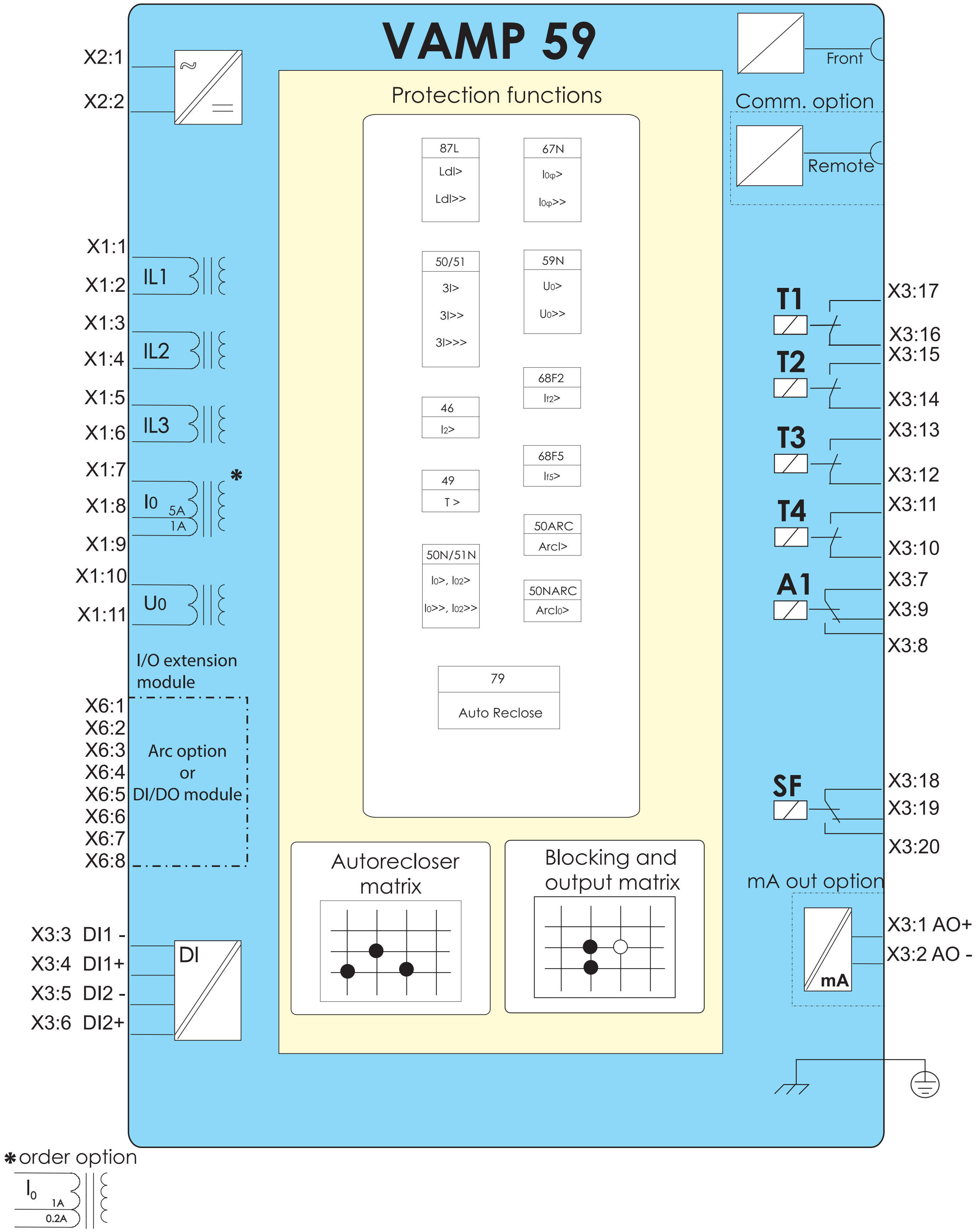


Figure 11.4: Block diagram of overcurrent and earthfault protection relay VAMP 59.

11.10 Block diagrams of optional modules

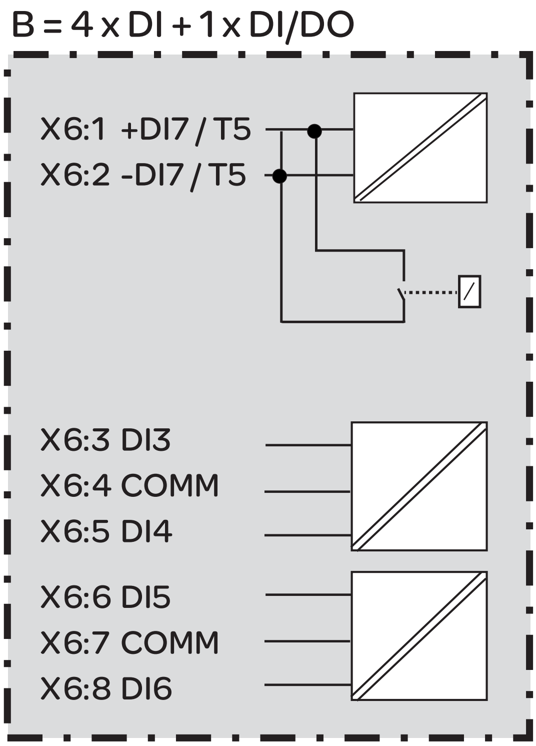


Figure 11.5: Block diagram of optional module “B = Digital I/O; 4 x DI + 1 x DI/DO”

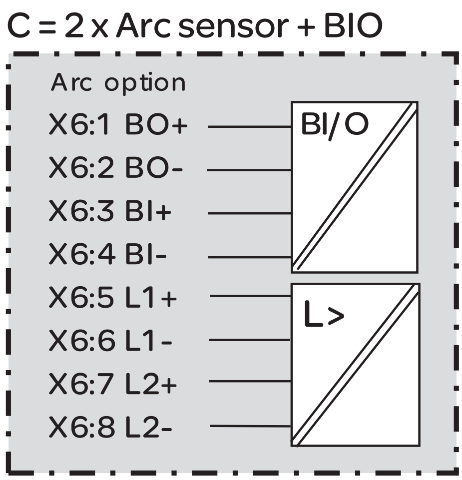


Figure 11.6: Block diagram of optional arc protection card C = Arc (2 x Arc sensor + BIO)

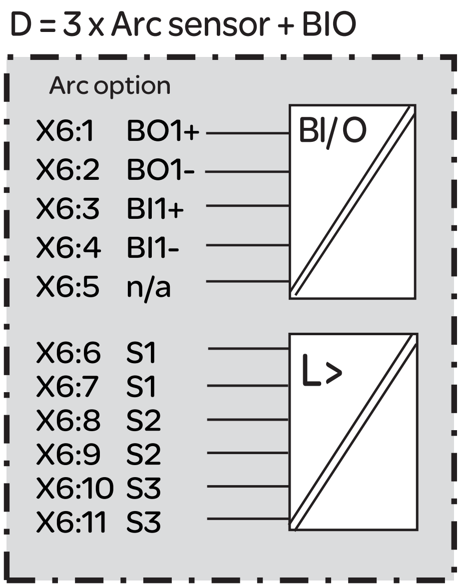


Figure 11.7: Block diagram of advanced optional arc protection card D = Advanced Arc (3 x Arc sensor + BIO)

11.11 Connection examples

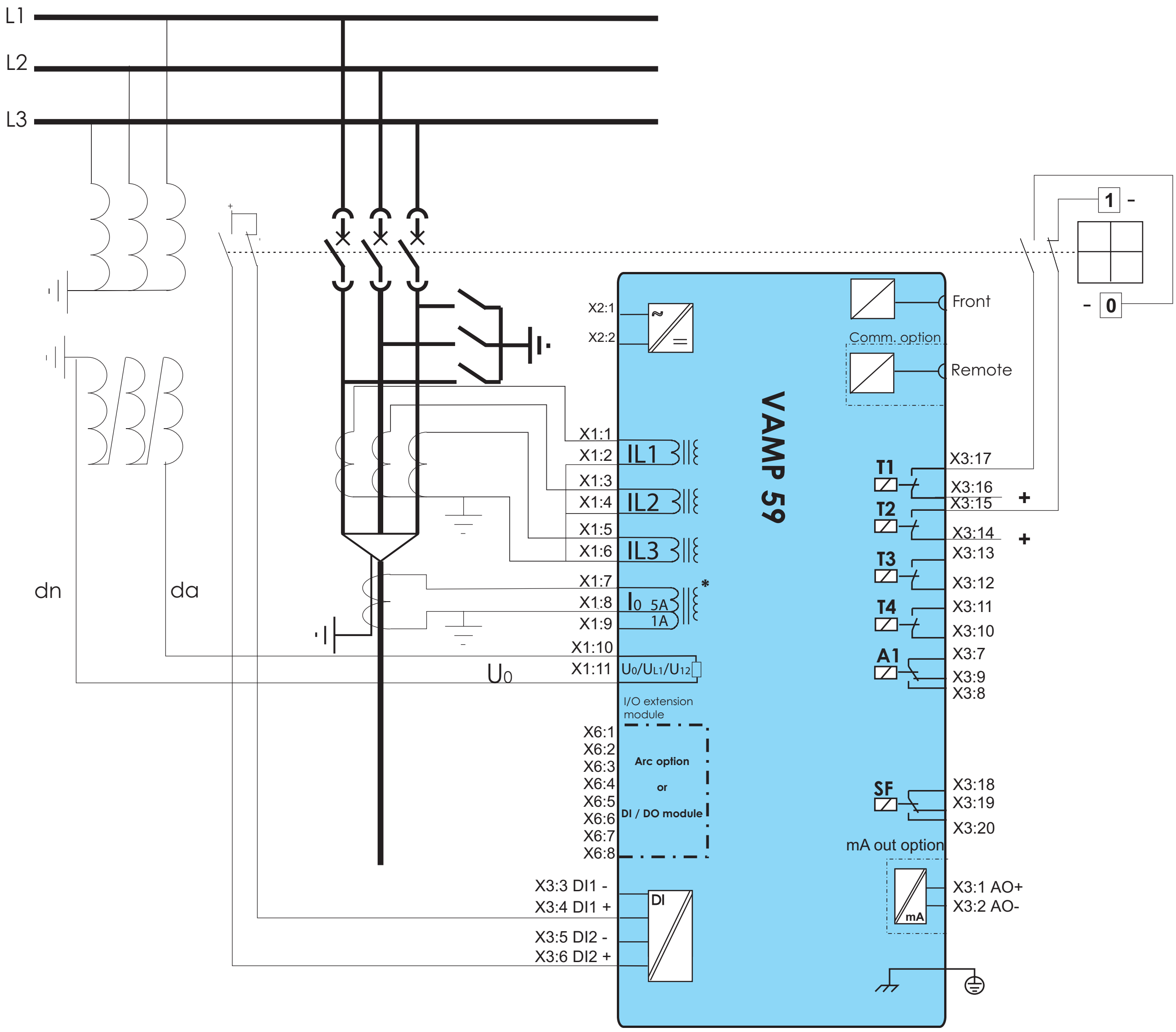


Figure 11.8: Block diagram of overcurrent and earthfault protection relay VAMP 59.

12 Technical data

12.1 Connections

Table 12.1: Measuring circuits

Phase current inputs	
Rated phase current	5 A (configurable for CT secondaries 1 – 10 A)
- Current measuring range	0.05 – 250 A
- Thermal withstand	20 A (continuously)
	100 A (for 10 s)
	500 A (for 1 s)
- Burden	0.075 VA
- Impedance	0.003 Ohm
I_0 input (5 A)	
Rated residual current	5 A (configurable for CT secondaries 0.1 – 10 A)
- Current measuring range	0.015 – 50 A
- Thermal withstand	20 A (continuously)
	100 A (for 10 s)
	500 A (for 1 s)
- Burden	0.075 VA
- Impedance	0.003 Ohm
I_0 input (1 A)	
Rated residual current	1 A (configurable for CT secondaries 0.1 – 10.0 A)
- Current measuring range	0.003 – 10 A
- Thermal withstand	4 A (continuously)
	20 A (for 10 s)
	100 A (for 1 s)
- Burden	0.02 VA
- Impedance	0.02 Ohm
I_0 input (0.2 A)	
Rated residual current	0.2 A (configurable for CT secondaries 0.1 – 10.0 A)
- Current measuring range	0.0006 – 2 A
- Thermal withstand	0.8 A (continuously)
	4 A (for 10 s)
	20 A (for 1 s)
- Burden	0.02 VA
- Impedance	0.02 Ohm

Frequency	
Rated frequency f_N	45 – 65 Hz (protection operates accurately)
Measuring range	16 – 95 Hz
	< 44Hz / > 66Hz (other protection is not steady except frequency protection)

Table 12.2: Auxiliary voltage

	Type A (standard)	Type B (option)
Rated voltage U_{AUX}	40 – 265 V ac/dc	18 – 36 V dc **Note! Polarity** X2:1= positive (+) X2:2= negative (-)
Start-up peak (DC) 24 V (Type B) 110 V (Type A) 220 V (Type A)	 25 A with time constant of 1000 µs 15 A with time constant of 500 µs 25 A with time constant of 750 µs	
Power consumption Max. permitted interruption time	< 15 W (normal conditions) < 25 W (output relays activated) < 50 ms (110 V dc)	
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm² (13 – 14 AWG)	

Table 12.3: Digital inputs internal operating voltage

Number of inputs	2
Voltage withstand	265 V ac/dc
External operating voltage, threshold	1: 24 – 230 V ac/dc (max. 265 V ac/dc) 2: 110 – 230 V ac/dc (max. 265 V ac/dc) 3: 220 – 230 V ac/dc (max. 265 V ac/dc)
Typical switching threshold	1: 12 V dc 2: 75 V dc 3: 155 V dc
Current drain	approx. 3 mA
Activation time dc/ac	< 11 ms / < 15 ms
Reset time dc/ac	< 11 ms / < 15 ms
Terminal block: - MSTB2.5 – 5.08	Maximum wire dimension: 2.5 mm² (13 – 14 AWG)

NOTE: set dc/ac mode according to the used voltage in VAMPSET.

Table 12.4: Trip contact, Tx

Number of contacts	4 making contacts (relays T1, T2, T3, T4)
Rated voltage	250 V ac/dc
Continuous carry	5 A
Make and carry, 0.5 s Make and carry, 3s	30 A 15 A
Breaking capacity, DC (L/R=40ms)	
at 48 V dc:	1.15 A
at 110 V dc:	0.5 A
at 220 V dc:	0.25 A
Contact material	AgNi 90/10
Terminal block: - MSTB2.5 - 5.08	Wire dimension: Maximum 2.5 mm^2 (13 – 14 AWG) Minimum 1.5 mm^2 (15 – 16 AWG)

Table 12.5: Signal contacts

Number of contacts:	2 change-over contacts (relays A1 and SF)
Rated voltage	250 V ac/dc
Continuous carry	5 A
Breaking capacity, DC (L/R=40ms)	
at 48 V dc:	1 A
at 110 V dc:	0.3 A
at 220 V dc:	0.15 A
Contact material	AgNi 0.15 gold plated
Terminal block - MSTB2.5 - 5.08	Wire dimension Maximum 2.5 mm^2 (13 – 14 AWG) Minimum 1.5 mm^2 (15 – 16 AWG)

Table 12.6: Local serial communication port

Number of ports	1 on front
Electrical connection	USB
Data transfer rate	2 400 – 187 500 kb/s

Table 12.7: Remote control connection (option)

Number of ports	1 option slot on rear panel
Electrical connection	RS 232 Glass fibre connection Ethernet 10 Base-T
Protocols	IEC 60870-5-101 IEC 60870-5-101 TCP DNP 3.0 DNP 3.0 TCP IEC 61850 Ethernet IP ANSI 85 (RS 232)

Table 12.8: Analogue output connection (option)

Number of analogue mA output channels	1
Maximum output current	1 – 20 mA, step 1 mA
Minimum output current	0 – 19 mA, step 1 mA
Exception output current	0 – 20.50 mA, step 25 μA
Resolution	10 bit
Current step	< 25 μA
Inaccuracy	±80 μA
Response time - normal mode - fast mode	 < 400 ms < 50 ms
Burden	< 600 Ω

Table 12.9: Ethernet fiber interface

Type	Multimode
Connector	LC for single FO Ethernet ST for double FO Ethernet
Physical layer	100 Base-Fx
Maximum cable distance	2 km
Optical wavelength	1300 nm
Cable core / cladding size	50/125 or 62.5/125 μm

12.2 Test and environmental conditions

Table 12.10: Disturbance tests

Test	Standard & Test class / level	Test value
Emission	EN 61000-6-4 / IEC 60255-26	
- Conducted	EN 55011, Class A / IEC 60255-25	0.01 – 30 MHz
- Emitted	EN 55011, Class A / IEC 60255-25 / CISPR 11	30 – 1000 MHz
Immunity	EN 61000-6-2 / IEC 60255-26	
- 1Mhz damped oscillatory wave	IEC 60255-22-1	±2.5kVp CM, ±1.0kVp DM
- Static discharge (ESD)	EN 61000-4-2 Level 4 / IEC 60255-22-2 Class 4	±8 kV contact, ±15 kV air
- Emitted HF field	EN 61000-4-3 Level 3 / IEC 60255-22-3	80 - 2700 MHz, 10 V/m
- Fast transients (EFT)	EN 61000-4-4 Level 4 / 3 / IEC 60255-22-4 Class A	4 kV / Signal ports 2.0 kV , 5/50 ns, 5 kHz
- Surge	EN 61000-4-5 Level 3 / IEC 60255-22-5	2 kV, 1.2/50 µs, CM 1 kV, 1.2/50 µs, DM
- Conducted HF field	EN 61000-4-6 Level 3 / IEC 60255-22-6	0.15 - 80 MHz, 10 Vemf
- Power-frequency magnetic field	EN 61000-4-8	300A/m (continuous), 1000A/m 1-3s
- Pulse magnetic field	EN 61000-4-9 Level 5	1000A/m, 1.2/50 µs
- Voltage dips	EN 61000-4-29 / IEC 60255-11	30%/1s, 60%/0.1s, 100%/0.01s
- Voltage short interruptions	EN 61000-4-11	30%/10ms, 100%/10ms, 60%/100ms, 95%/5000ms
- Voltage alternative component	EN 61000-4-17 / IEC 60255-11	12% of operating voltage (DC) / 10min

Table 12.11: Electrical safety tests

Test	Standard & Test class / level	Test value
- Impulse voltage withstand	EN 60255-5, Class III	5 kV, 1.2/50 ms, 0.5 J 1 kV, 1.2/50 ms, 0.5 J Communication
- Dielectric test	EN 60255-5, Class III	2 kV, 50 Hz 0.5 kV, 50 Hz Communication
- Insulation resistance	EN 60255-5	
- Protective bonding resistance	EN 60255-27	
- Power supply burden	IEC 60255-1	

Table 12.12: Mechanical tests

Test	Standard & Test class / level	Test value
Device in operation		
- Vibrations	IEC 60255-21-1, Class II / IEC 60068-2-6, Fc	1Gn, 10Hz – 150 HZ
- Shocks	IEC 60255-21-2, Class II / IEC 60068-2-27, Ea	10Gn/11ms
Device de-energized		
- Vibrations	IEC 60255-21-1, Class II / IEC 60068-2-6, Fc	2Gn, 10Hz – 150 HZ
- Shocks	IEC 60255-21-2, Class II / IEC 60068-2-27, Ea	30Gn/11ms
- Bump	IEC 60255-21-2, Class II / IEC 60068-2-27, Ea	20Gn/16ms

Table 12.13: Environmental tests

Test	Standard & Test class / level	Test value
Device in operation		
- Dry heat	EN / IEC 60068-2-2, Bd	65°C (149°F)
- Cold	EN / IEC 60068-2-1, Ad	-40°C (-40°F)
- Damp heat, cyclic	EN / IEC 60068-2-30, Db	• From 25°C (77°F) to 55°C (131°F) • From 93% RH to 98% RH • Testing duration: 6 days
- Damp heat, static	EN / IEC 60068-2-78, Cab	• 40°C (104°F) • 93% RH • Testing duration: 10 days
Flowing mixed gas corrosion test, method 2	IEC 60068-2-60, Ke	25°C (77°F), 75% RH, 10 ppb H_2S, 200 ppb NO_2, 10 ppb CL_2
Flowing mixed gas corrosion test, method 4	IEC 60068-2-60, Ke	25°C (77°F), 75% RH, 10 ppb H_2S, 200 ppb NO_2, 10 ppb CL_2, 200 ppb SO_2
Device in storage		
- Dry heat	EN / IEC 60068-2-2, Bb	75°C (167°F)
- Cold	EN / IEC 60068-2-1, Ab	-40°C (-40°F)

Table 12.14: Environmental conditions

Ambient temperature, in-service	-40 – 65°C (-40 – 149°F)
Ambient temperature, storage	-40 – 70°C (-40 – 158°F)
Relative air humidity	< 95%, no condensation allowed
Maximum operating altitude	2000 m (6561.68 ft)

Table 12.15: Casing

Degree of protection (IEC 60529)	IP54 front panel, IP 20 rear panel
Dimensions (w x h x d):	130 x 170 x 210 mm / 5.12 x 6.69 x 8.27 in
Material	1 mm (0.039 in) steel plate
Weight	2.0 kg (4.415 lb)
Colour code	RAL 7032 (Casing) / RAL 7035 (Back plate)

Table 12.16: Package

Dimensions (W x H x D)	230 x 215 x 175 mm / 9.06 x 8.46 x 6.89 in
Weight (Terminal, Package and Manual)	3.0 kg (6.623 lb)

12.3 Protection functions

*) EI = Extremely Inverse, NI = Normal Inverse, VI = Very Inverse, LTI = Long Time Inverse, MI= Moderately Inverse

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

12.3.1 Differential protection

Table 12.17: Line differential protection LdI> (87L)

$I_{Pick\text{-}Up}$	20 – 50 %
Start of slope 1	0.5 – 1.0 x I_N
Slope 1	0 – 100 %
Start of slope 2	1.0 – 3.0 x I_N
Slope 2	50 – 200 %
Second harmonic blocking Fifth harmonic blocking	5 – 30 % I_N (step 1%) 20 – 50 % I_N (step 1%)
Reset time Reset ratio:	< 95 ms 0.95
Inaccuracy:	
- 2nd harmonic blocking	±1% - unit
- 5th harmonic blocking	±1% - unit
- Starting	±5% of set value or 0.05 x IN when currents are > 200 mA
- Operating time (3.5 x I_{SET})	typically 35 ms

NOTE: The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the nominal current is 5 A, the 100 Hz component needs to exceed 100 mA.

Table 12.18: Differential overcurrent stage LdI>> (87L)

Setting range	1.2 – 20.0 x I_N (step 0.1)
Second harmonic blocking Fifth harmonic blocking	5 – 30 % I_N (step 1%) 20 – 50 % I_N (step 1%)
Inaccuracy: - 2nd harmonic blocking - 5th harmonic blocking	 ±1% - unit ±1% - unit
- Starting	±5% of the set value
- Operating time (3.5 x I_{SET})	typically 35 ms

Table 12.19: Transformer settings (scaling menu)

Connection group	None (no transformer) Yy0, Yy6, Yd1, Yd5, Yd7, Yd11, Dy1, Dy5, Dy7, Dy11, Dd0 and Dd6
Transformer side	HV (relay located on high voltage side) LV (relay located on low voltage side)
Transformer grounding: - I_0 compensation - I'_0 compensation	 enabled or disabled depending whether starpoint is grounded or not

12.3.2 Non-directional current protection

Table 12.20: Overcurrent stage I> (50/51)

Pick-up value	0.10 – 5.00 x I_N (step 0.01)
Definite time function: - Operating time	DT** 0.04 – 300.00 s (step 0.01 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI…, depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio:	0.97
Transient over-reach, any τ	< 10 %
Inaccuracy:	
- Starting	±3% of the set value or 5 mA secondary
- Operating time at definite time function	±1% or ±25 ms
- Operating time at IDMT function	±5% or at least ±25 ms**

Table 12.21: Overcurrent stage I>> (50/51)

Pick-up value	0.10 – 20.00 x I_N (step 0.01)
Definite time function: Operating time	DT** 0.04 – 1800.00 s (step 0.01 s)
Start time	Typically 30 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio:	0.97
Transient over-reach, any τ	< 10 %
Inaccuracy: - Starting - Operation time	 ±3% of the set value or 5 mA secondary ±1% or ±25 ms

Table 12.22: Overcurrent stages I>>> (50/51)

Pick-up value	0.10 – 40.00 x I_N (step 0.01)
Definite time function: Operating time	DT** 0.03 – 300.00 s (step 0.01 s)
Instant operation time: I_M / I_{SET} ratio > 1.5 I_M / I_{SET} ratio 1.03 – 1.5	 <30 ms < 50 ms
Start time	Typically 20 ms
Reset time	<95 ms
Retardation time	< 50 ms
Reset ratio:	0.97
Inaccuracy:	
- Starting	±3% of the set value or 5 mA secondary
- Operation time DT (I_M/I_{SET} ratio > 1.5)	±1% or ±15 ms
- Operation time DT (I_M/I_{SET} ratio 1.03 – 1.5)	±1% or ±25 ms

Table 12.23: Thermal overload stage T> (49)

Maximum continuous current:	0.1 – 2.40 x I_N (step 0.01)
Alarm setting range:	60 – 99 % (step 1%)
Time constant Tau:	2 – 180 min (step 1)
Cooling time coefficient:	1.0 – 10.0 x Tau (step 0.1)
Max. overload at +40°C	70 – 120 %I_{MODE} (step 1)
Max. overload at +70°C	50 – 100 %I_{MODE} (step 1)
Ambient temperature	-55 – 125°C (step 1°)
Resetting ratio (Start & trip)	0.95
Accuracy: - Operating time	 ±5% or ±1 s

Table 12.24: Current unbalance stage $I_2/I_1>$ (46)

Settings: - Setting range I_2 / I_1>	 2 – 70% (step 1%)
Definite time function: - Operating time	 1.0 – 600.0 s (step 0.1 s)
Start time	Typically 300 ms
Reset time	< 450 ms
Reset ratio:	0.95
Inaccuracy: - Starting - Operate time	 ±1% - unit ±5% or ±200 ms

Table 12.25: Earth fault stage $I_0>$ (50N/51N)

Input signal	I_0 (input X1:7 – 8 or input X1:7 – 9) I_{0Calc} (= I_{L1} + I_{L2} + I_{L3})
Pick-up value	0.005 – 8.00 pu (when I_0) (step 0.001) 0.05 – 20.0 pu (when I_{0Calc})
Definite time function: - Operating time	DT** 0.04** – 300.00 s (step 0.01 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI..., depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time	Typically 30 ms
Reset time	<95 ms
Reset ratio:	0.95
Inaccuracy:	
- Starting	±2% of the set value or ±0.3% of the rated value
- Starting (Peak mode)	±5% of the set value or ±2% of the rated value (Sine wave <65 Hz)
- Operating time at definite time function	±1% or ±25 ms
- Operating time at IDMT function	±5% or at least ±25 ms**

Table 12.26: Earth fault stages I_0>>, I_0>>>, I_0>>>> (50N/51N)

Input signal	I_0 (input X1:7 – 8 or input X1:7 – 9) I_{0Calc} (= $I_{L1} + I_{L2} + I_{L3}$)
Pick-up value	0.01 – 8.00 pu (When I_0) (step 0.01) 0.05 – 20.0 pu (When I_{0Calc}) (step 0.01)
Definite time function: - Operating time	 0.04** – 300.00 s (step 0.01 s)
Start time	Typically 30 ms
Reset time	<95 ms
Reset ratio:	0.95
Inaccuracy:	
- Starting	±2% of the set value or ±0.3% of the rated value
- Starting (Peak mode)	±5% of the set value or ±2% of the rated value (Sine wave <65 Hz)
- Operate time	±1% or ±25 ms

12.3.3 Directional current protection

Table 12.27: Directional earth fault stages $I_{0\varphi}$>, $I_{0\varphi}$>> (67N)

Pick-up value	0.005 – 20.00 x I_{0N} (up to 8.00 for inputs other than I_{0Calc})
Start voltage	1 – 50 %U_{0N} (step 1%)
Input signal	I_0 (input X1:7 – 8 or X1:7 – 9) I_{0Calc} (= I_{L1} + I_{L2} + I_{L3})
Mode	Non-directional/Sector/ResCap
Base angle setting range	-180° – 179°
Operation angle	±88°
Definite time function: - Operating time	 0.10** – 300.00 s (step 0.02 s)
IDMT function:	
- Delay curve family	(DT), IEC, IEEE, RI Prg
- Curve type	EI, VI, NI, LTI, MI…, depends on the family*
- Time multiplier k	0.05 – 20.0, except 0.50 – 20.0 for RI, IEEE and IEEE2
Start time	Typically 60 ms
Reset time	<95 ms
Reset ratio:	0.95
Reset ratio (angle)	2°
Inaccuracy:	
- Starting U_0 & I_0 (rated value In= 1 – 5A)	±3% of the set value or ±0.3% of the rated value
- Starting U_0 & I_0 (Peak Mode when, rated value I_{0n}= 1 – 10A)	±5% of the set value or ±2% of the rated value (Sine wave <65 Hz)
- Starting U_0 & I_0 (I_{0Calc})	±3% of the set value or ±0.5% of the rated value
- Angle	±2° when U> 1V and I_0> 5% of I_{0N} or > 50 mA else ±20°
- Operate time at definite time function	±1% or ±30 ms
- Operate time at IDMT function	±5% or at least ±30 ms**

12.3.4 Circuit-breaker failure protection CBFP (50BF)

Table 12.28: Circuit-breaker failure protection CBFP (50BF)

Relay to be supervised	T1, T2, T3 and T4
Definite time function: - Operating time	 0.1** – 10.0 s (step 0.1 s)
Inaccuracy - Operating time	 ±100 ms

12.3.5 Magnetising inrush 68F2

Table 12.29: Magnetising inrush 68F2

Settings:	
- Pick-up value	10 – 100 % (step 1%)
- Operating time	0.03 – 300.00 s (step 0.01 s)
Inaccuracy:	
- Starting	±1% - unit

NOTE: The amplitude of second harmonic content has to be at least 2% of the nominal of CT. If the moninal current is 5 A, the 100 Hz component needs to exceed 100 mA.

12.3.6 Over exicitation 68F5

Table 12.30: Over exicitation 68F5

Settings:	
- Setting range over exicitation	10 – 100 % (step 1%)
- Operating time	0.03 – 300.00 s (step 0.01 s)
Inaccuracy:	
- Starting	±2%- unit

NOTE: The amplitude of fifth harmonic content has to be at least 2% of the nominal of CT. If the moninal current is 5 A, the 250 Hz component needs to exceed 100 mA.

12.3.7 Digital input / output card (option)

Table 12.31: Digital input / output card (option)

Number of digital inputs	4 (5)
External operating voltage	Voltage selectable in order code (same as DI nominal voltage for the relay): 1: 24 dc/ac (max 265 V)* 2: 110 dc/ac (max 265 V)* 3: 220 dc/ac (max 265 V)*
Current drain, when active	Approx. 3 mA
Number of digital outputs	(1)
Voltage withstand Continuous carry Make and carry 0.5 s Make and carry 3 s	265 V dc/ac 5 A 30 A 15 A
Breaking capacity. DC (L/R = 40 ms) at 48 V dc: at 110 V dc: at 220 V dc:	 1.0 A 0.44 A 0.22 A
Terminal block Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm2 (13 – 14 awg)

* set dc/ac mode according to the used voltage in VAMPSET.

NOTE: Approximately 2 mA of current is going trough the T5 (X6:1 & X6:2) circuit even when used as a digital output. This has to be noticed when T5 is used with certain type of applications (if 2 mA is enough to control for example a breaker).

When DI/DO-option cards are ordered separately the threshold has to be modified manually on field according the description in the manual (see Chapter 11.5 Input/output card B = 4 x DI + 1 x DI/DO).

12.3.8 Arc fault protection (option)

1. 2S+BIO

The operation of the arc protection depends on the setting value of the ArcI> and ArcI$_0$> current limits.

The arc current limits cannot be set, unless the relay is provided with the optional arc protection card.

Table 12.32: Arc protection stage ArcI> (50ARC), ArcI$_0$> (50NARC)

Pick-up value	0.5 – 10.0 x I_N
Arc sensor connection: - Operating time (Light only) - Operating time (4 x I_{SET} + light) - Operating time (BIN) - Operating time (Delayed Arc L>) - BO operating time	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI 13 ms 17ms 10 ms 0.01 – 0.15 s < 3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	< 85 ms
Reset ratio:	0.90
Inaccuracy: - Starting - Operating time - Delayed ARC light	 10% of the set value ±5 ms ±10 ms

2. 3S+BIO

The operation of the arc protection depends on the setting value of the I>int and I$_0$>int current limits.

The arc current limits cannot be set, unless the relay is provided with the optional arc protection card.

Table 12.33: Advanced arc protection stage

Pick-up value	0.5 – 10.0 x I_N for I> 0.1 – 5.0 x I_N for I_0>
Arc sensor connection: - Operating time	S1, S2, S3, BI, GOOSE 7 ms
Inaccuracy: - Under nominal current - Over nominal current	 2.5% of nominal 2.5% of measurement

12.4 Supporting functions

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Table 12.34: Disturbance recorder (DR)

Mode of recording	Saturated / Overflow
Sample rate:	
- Waveform recording	32/cycle, 16/cycle, 8/cycle
- Trend curve recording	10, 20, 200 ms 1, 5, 10, 15, 30 s 1 min
Recording time (one record)	0.1 s – 12 000 min (According recorder setting)
Pre-trigger rate	0 – 100%
Number of selected channels	0 – 12

The recording time and the number of records depend on the time setting and the number of selected channels.

Table 12.35: Inrush current detection

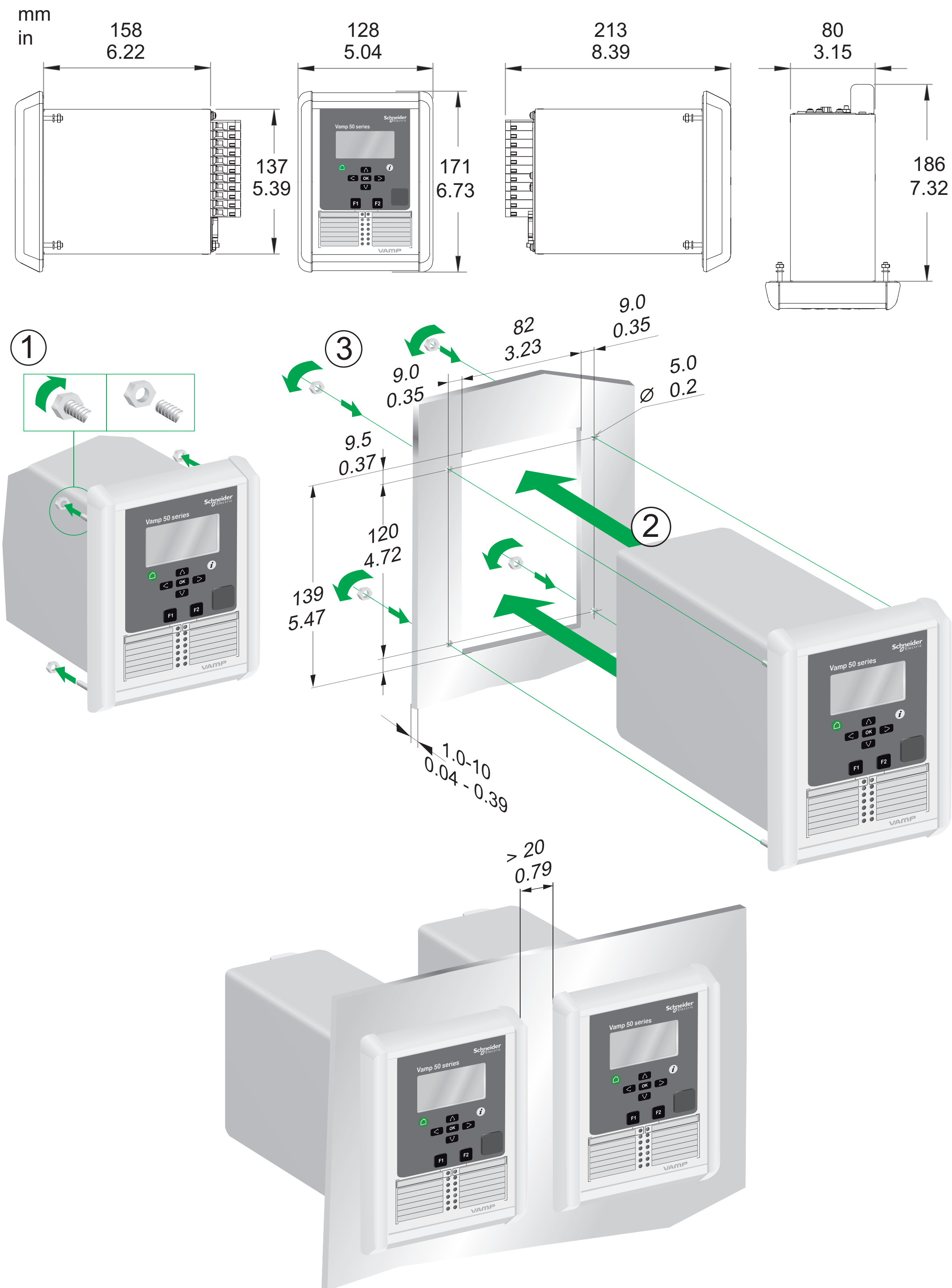
Cold load settings: - Idle current - Pickup current - Maximum time	 0.01 – 0.50 x I_N 0.30 – 10.00 x I_N 0.01** – 300.00 s (step 0.01 s)
Inrush settings: - Pickup for 2nd harmonic	 0 – 99 %

Table 12.36: Current transformer supervision

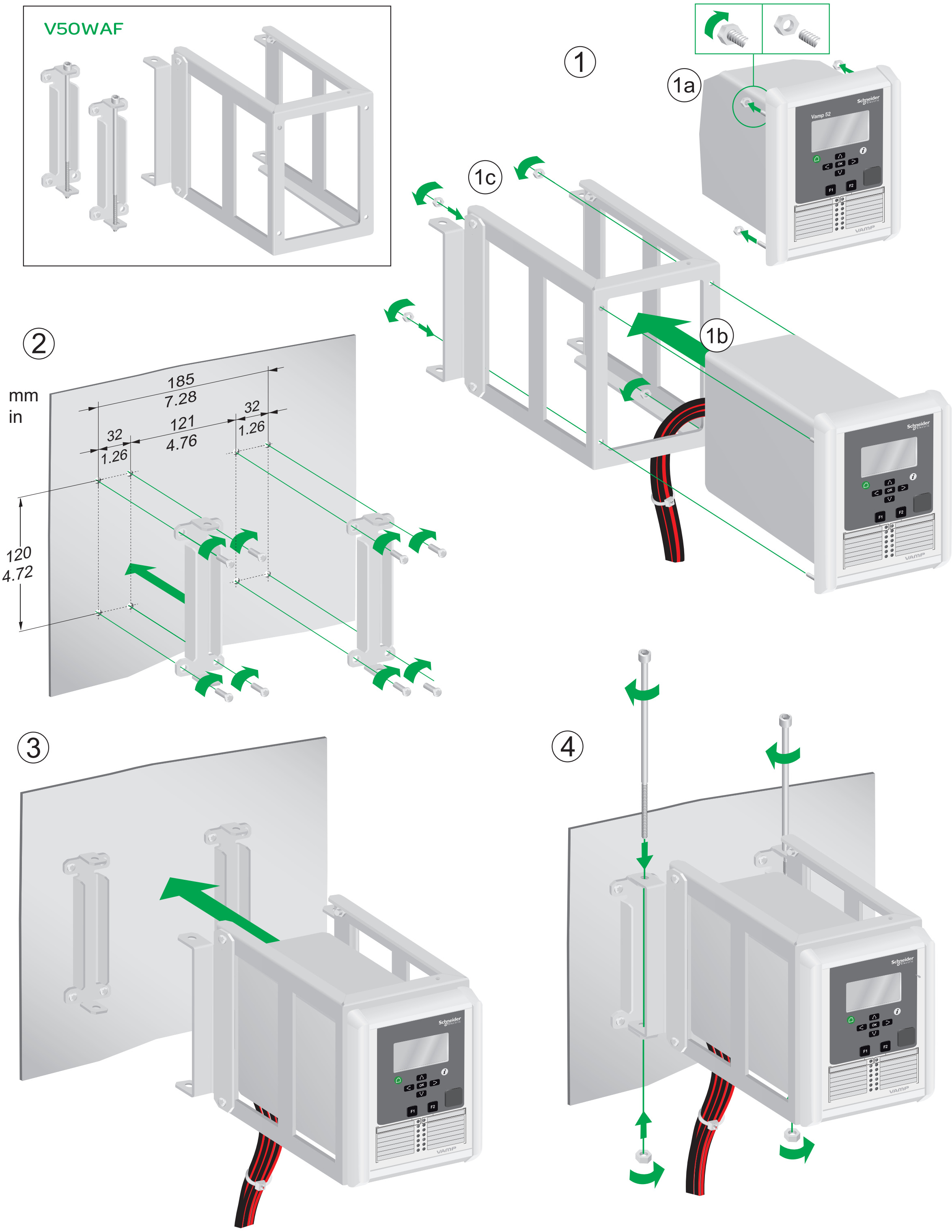
I_{MAX}> setting I_{MIN}< setting	0.00 – 10.00 x I_N (step 0.01) 0.00 – 10.00 x I_N (step 0.01)
Definite time function: - Operating time	DT 0.04 – 600.00 s (step 0.02 s)
Reset time Reset ratio I_{MAX}> Reset ratio I_{MIN}<	< 60 ms 0.97 1.03
Inaccuracy: - Activation - Operating time at definite time function	 ±3% of the set value ±1% or ±30 ms

13 Mounting

PANEL MOUNTING VAMP 50 SERIES



VAMP 50 SERIES (DEFAULT SIZE) WALL MOUNTING FRAME TYPE V50WAF



14 Order information

When ordering, please state:

- Type designation:
- Quantity:
- Options (see respective ordering code):

V59 - □□□□□□□□ - Line Differential Protection Relay

Relay type
= Default

Phase current inputs [A]
3 = 1A / 5A

Earth-fault current input [A]
A = 1A / 5A
B = 0.2A /1A

Nominal Supply Voltage [V]
A = Power A 48 - 230 V (40.. 265Vac/dc)
B = Power B 24 V (18.. 36Vdc)

mA output option
A = None
B = mA output

DI nominal voltage
1 = 24 VDC / 110 VAC
2 = 110 VDC / 220VAC
3 = 220 VDC

Optional I/O extension modules
A = None (***
B = 4xDI + 1xDI/DO
C = Arc (2 x Arc sensor + BIO)
D = Advanced arc (3 x Arc sensor + BIO)

Optional communication module 1
A = None
L = RS-232 remote port inteface and support for module 2
M = RS-232 remote port interface with IRIG B and extension port and support for module 2

Optional communication module 2
A = None
B = IRIG-B time syncronisation input (*
C = RTD interface (Glass fibre) (*
E = RJ-45 10Mbps ethernet interface inc. IEC 61850 (*
G = LC 100Mbps ethernet fibre interface inc. IEC 61850 (*

Note:
(* Option available only with communication module 1: L and M

Note: (* Option available only with communication module 1: L and M

Accessories

Order code	Description	Note
VSE001GG	Fibre optic Interface Module (glass - glass)	Max. distance 1 km
3P032	WESTERMO ODW-720-F1	(Base module)
3P033	WESTERMO SLC20 (1310 nm)	Max. distance 20 km
3P034	WESTERMO SLC40 (1310 nm)	Max. distance 40 km
3P035	WESTERMO SLC80 (1550 nm)	Max. distance 80 km
3P036	WESTERMO SLC120 (1550 nm)	Max. distance 120km
VX063	RS232 converter cable for WESTERMO ODW-720-F1	Cable length 3m
3P014	MOXA TCF-90	Max. distance 40 km
VX048	RS232 converter cable for MOXA TCF-90	Cable length 3m
3P022	MOXA TCF-142-S-ST	Max. distance 40 km
VX062	RS232 converter cable for MOXA TCF-142-S-ST	Cable length 3m
VX052-3	USB programming cable (VAMPSET)	Cable length 3m
VX044	Interface cable to VIO 12 (RTD module)	Cable length 2 m
VIO 12 AA	RTD Module, 12pcs RTD inputs, Optical Tx Communication (24-230 Vac/dc)	
VIO 12 AC	RTD/mA Module, 12pcs RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (24 Vdc)	
VIO 12 AD	RTD/mA Module, 12pcs RTD inputs, PTC, mA inputs/outputs, RS232, RS485 and Optical Tx/Rx Communication (48-230 Vac/dc)	
VA 1 DA-6	Arc sensor	Cable length 6 m
VA 1 DA-20	Arc sensor	Cable length 20 m
V50WAF	V50 wall assembly frame	

15 Firmware revision

10.xx	Maximum rated power increased to 400000 kVA from 200000 kVA Support for two instances of TCP protocols on Ethernet port Virtual output events added Ethernet/IP: mapping extensions (ExtDOs, ExtAOs and ExtAIs alarms) “get/set” added to communication ports’ protocol lists VTZsecondary VTysecondary added to scaling menu Phasor diagrams added for synchrocheck First version for VAMP 59
10.97	Autoreclose: • when two CB's are used and both closed, AR is blocked • start counter is not increased after manual CB close 2nd harmonic blocking stage added 5th harmonic blocking stage added Intermediate transformer parameters added to HMI LdI>> hysteresis changed from 5% to 3%
10.106	GOOSE supervision signals added Automatic LED latch release added Disturbance recorder full event added
10.108	Use of recorder memory in percents added Various additions to IEC 61850
10.116	IP and other TCP parameters are able to change without reboot Logic output numbering is not changed when changes are made in the logic **NOTE! Vampset version 2.2.97 required**
10.118	Enable sending of analog data in GOOSE message Day light saving (DST) rules added for system clock HMI changes: • Order of the first displays changed, 1.measurement, 2. mimic, 3. title • timeout does not apply if the first 3 displays are active
10.122	Stages renamed: • I_{f2}> = MAGNETISING INRUSH 68F2 • I_{f5}> = OVER EXCITATION 68F5 • P< = DIRECTIONAL POWER 32 • P<< = DIRECTIONAL POWER 32

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