VAMP 40

Feeder and motor protection relay

Operation and configuration instructions

Technical description

Table of Contents

1. General

This first part (Operation and configuration) of the publication contains general descriptions of the functions, of the generator protection relay as well as operation instructions. It also includes instructions for parameterization and configuration of the relay and instructions for changing settings.

The second part (Technical description) of the publication includes detailed protection function descriptions as well as application examples and technical data sheets.

The Mounting and Commissioning Instructions are published in a separate publication with the code VMMC.EN0xx.

1.1. 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.

List of protection functions

IEEE/ANSI code	IEC symbol	Function name	Note
50/51	3I>, 3I>>, 3I>>>	Overcurrent protection	
46R	$I_2/I_1>$	Broken conductor protection	
46	$I_2>$	Current unbalance protection	Only available when application option is in **motor protection mode.**
47	$I_2>>$	Phase reversal / incorrect phase sequence protection	
48	$I_{st}>$	Stall protection	
66	N>	Frequent start protection	
49	T>	Thermal overload protection	
37	I<	Undercurrent protection	
50N/51N	$I_0>$, $I_0>>$, $I_0>>>$, $I_0>>>>$	Earth fault protection	
67NT	I_{0T}	Intermittent transient earth fault protection	
		Capacitor bank unbalance protection	
59C	$U_0>$	Capacitor overvoltage protection	
67N	$I_{0\varphi}>$, $I_{0\varphi}>>$	Directional earth fault protection	Only available when measurement option is **Uo**
59N	$U_0>$, $U_0>>$	Residual voltage protection	
59	U>, U>>, U>>>	Single-phase overvoltage protection	Only available when measurement option is **1LL (line-to-line voltage) or 1LN (phase-to-neutral voltage).**
27	U<, U<<, U<<<	Single-phase undervoltage protection	
32	P<, P<<	Reverse and underpower protection	
50BF	CBFP	Circuit-breaker failure protection	
99	Prg1...8	Programmable stages	
50ARC/ 50NARC	ArcI>, $ArcI_{01}>$, $ArcI_{02}>$	Optional arc fault protection (with an external module)	

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 60870-5-101, IEC 60870-5-103, IEC 61850, SPA bus, and DNP 3.0.

1.2. 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 serial port on the front panel or on the rear panel of the relay (both cannot be used simultaneously)
- Via remote control over the remote control port on the relay rear panel.

1.3. Operating Safety

The terminals on the rear panel of the relay may carry dangerous voltages, even if the auxiliary voltage is switched off. A live current transformer secondary circuit must not be opened. **Disconnecting a live circuit may cause dangerous voltages!** Any operational measures must be carried out according to national and local handling directives and instructions.

Carefully read through all operation instructions before any operational measures are carried out.

2. Local panel user interface

2.1. Relay front panel

The figure below shows, as an example, the front panel of the feeder and motor protection relay VAMP 40 and the location of the user interface elements used for local control.

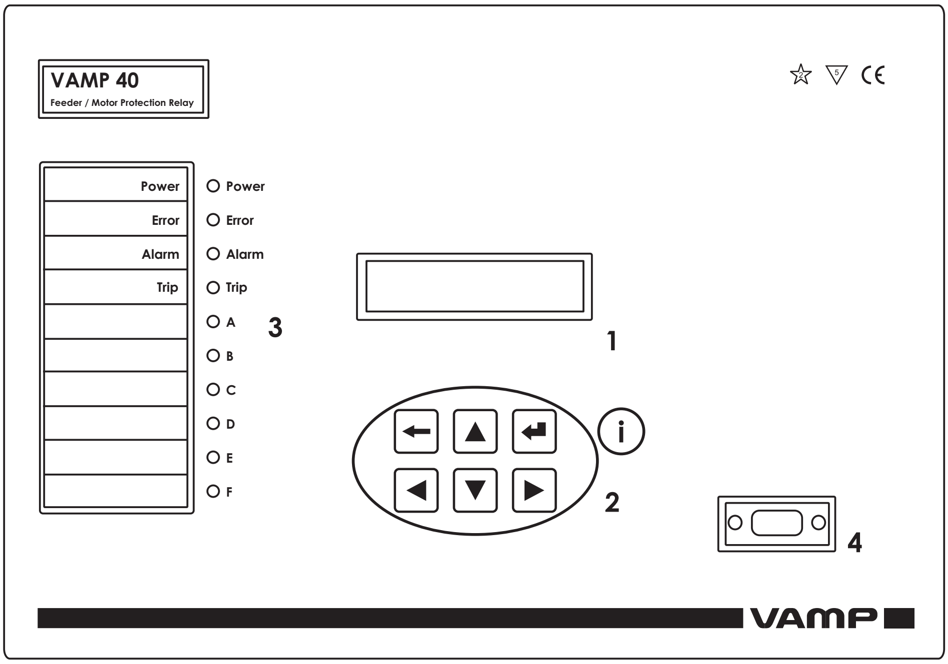


Figure 2.1-1. Relay front panel

1. Two-row LCD display
2. Keypad
3. LED indicators
4. RS 232 serial communication port for PC

2.1.1. Display

The relay is provided with a backlit two-row LCD display. The display shows 16 characters in each row. Its purpose is to show the configuration and parameterization values of the relay (Figure 2.1.1-1). If the text exceeds 16 characters the display changes to scrolling mode, to show the entire text.

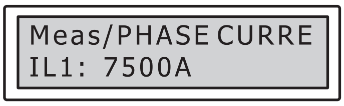


Figure 2.1.1-1 Example of the display menu.

In the title screen the user can choose to show 4 measurement values of the relay. These will substitute the relay type on the displays lower row.

Backlight control

Display backlight can be switched on with a digital input, virtual input or virtual output. DEVICE INFO/**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. Menu navigation and pointers

1. Use the arrow keys UP and DOWN to move up and down in the menus . The active main menu option is shown under the relay type definition.
2. When moving into a main menu, by pressing the RIGHT key, the active main and submenu will appear in the upper row. The options in the submenu items are abbreviations, e.g. Evnt = events. To view the explanation for a certain abbreviation press the INFO key.
3. Further, each display holds the measured values and units of one or more quantities or parameters, e.g. ILmax 300A.

2.1.3. Keypad

You can navigate in the menu and set the required parameter values using the keypad. The keypad is composed of four arrow keys, one cancel key, one enter key and one info key.

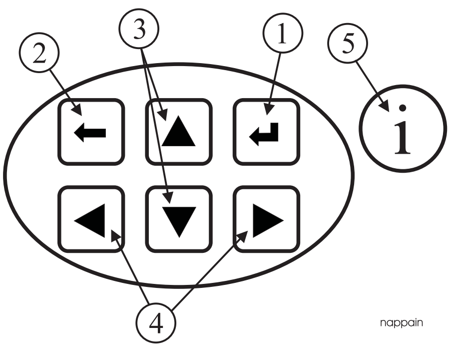


Figure 2.1.3-1 Keys on the keypad

1. Enter and confirmation key (ENTER)
2. Cancel key (CANCEL)
3. Up/Down [Increase/Decrease] arrow keys (UP/DOWN)
4. Keys for selecting submenus [selecting a digit in a numerical value] (LEFT/RIGHT)
5. Additional information key (INFO)

NOTE! The term, which is used for the buttons in this manual, is inside the brackets.

2.1.4. Operation indicators

The relay is provided with ten LED indicators:

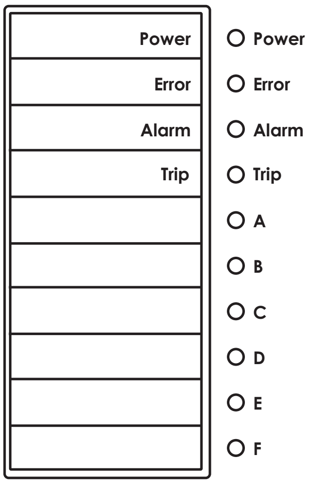


Figure 2.1.4-1. Operation indicators of the relay

LED indicator	Meaning	Measure/ Remarks
Power LED lit	The auxiliary power has been switched on	Normal operation state
Error LED lit	An internal fault has been detected	The relay attempts to reboot [REBOOT]. If the error LED remains lit, call for maintenance.
Alarm LED lit	One or several signals of the output relay matrix have been assigned to output Al and the output has been activated by one of the signals. (For more information about output relay configuration, please see chapter 2.4.5 on page 23).	The LED is switched off when the signal that caused output Al to activate, e.g. the START signal, is reset. The resetting depends on the type of configuration, connected or latched.
Trip LED lit	One or several signals of the output relay matrix have been assigned to output Tr, and the output has been activated by one of the signals. (For more information about output relay configuration, please see chapter 2.4.5 on page 23).	The LED is switched off when the signal that caused output Tr to activate, e.g. the TRIP signal, is reset. The resetting depends on the type of configuration, connected or latched.
A- F LED lit	Application-related status indicators.	Configurable

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 the CANCEL key. Then reset the latched indicators and output relays by pushing the ENTER key.
- Acknowledge each event in the alarm list one by one by pushing the ENTER key equivalent times. Then, in the initial display, reset the latched indicators and output relays by pushing the ENTER key.

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

2.1.5. 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**.

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 one of the local communication ports. Some parameters are factory-set.

2.2.1. Navigating in menus

All the menu functions are based on the main menu/submenu structure. Figure 2.2.1-1shows the basic structure of the menu on the local display. The actual menu structure depends on the configuration, for example, motor mode/ feeder mode, voltage measurement mode, etc.

Some submenus may contain more than two rows. Press arrows down and up to glance through these certain submenus.

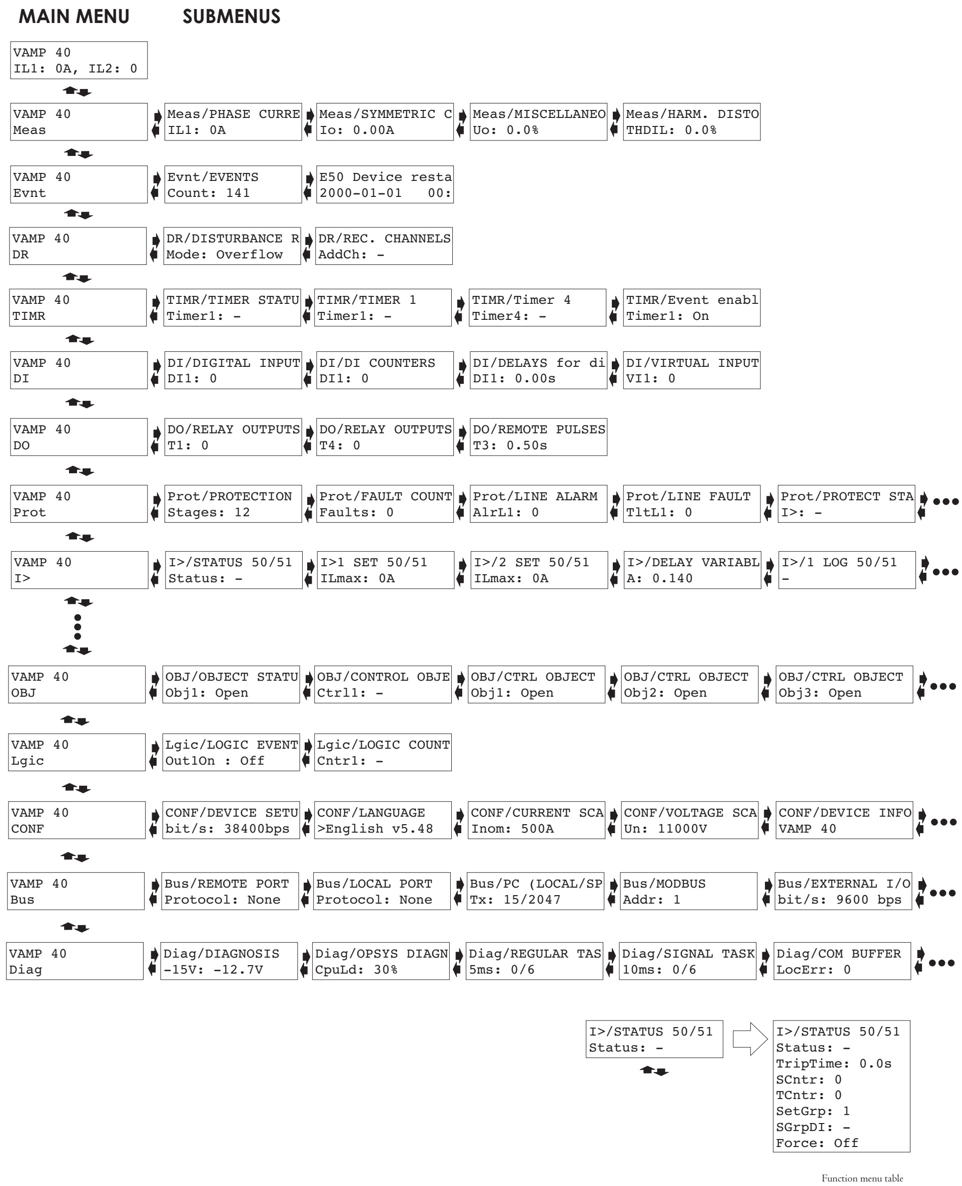


Figure 2.2.1-1 Principles of the menu structure and navigation in the menus

1. Use the arrow keys UP and DOWN to move up and down in the main menu.
2. To move to a submenu, repeatedly push the RIGHT key until the required submenu is shown. Correspondingly, push the LEFT key to return to the main menu.
3. Push the CANCEL key to move back to the main menu at once and to cancel a selection.
4. Hold the CANCEL key pushed for appr. 4 sec. to display the title screen.
5. Push the INFO key and then the ENTER key to give the password.
6. Push the CANCEL key to revert to the normal display.
7. Push the INFO key to obtain additional information about any menu item.

Main menu

The general menu structure is shown in Figure 2.2.1-1. 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 (* Not in U_0 mode)

Main menu	Number of menus	Description	ANSI code	Note
P*	6	Power measurements		
E*	4	Energy measurements		
I	3	Current measurements		
U*	16	Voltage measurements		
Evnt	2	Events		
DR	3	Disturbance recorder		2
Runh	1	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	4	Digital inputs including virtual inputs		
DO	3	Digital outputs (relays) and output matrix		
ExtAI		External analogue inputs		3
ExDI		External digital inputs		3
ExDO		External digital outputs		3
Prot	18	Protection counters, combined overcurrent status, protection status, protection enabling, cold load and inrush detectionIf2> and block matrix		
I>	12	1st overcurrent stage	50/51	4
I>>	11	2nd overcurrent stage	50/51	4
I>>>	11	3rd overcurrent stage	50/51	4
I<	11	Undercurrent stage	37	4
I2/I1>	11	Broken conductor prot. stage	46R	4
I2>	10	Unbalance stage	46	4
I2>>	10	Phase reversal / incorrect phase sequence stage	47	4
Ist>	10	Stall protection stage	48	4
N>	11	Frequent start	66	4
T>	3	Thermal overload stage	49	4
Uc>	4	Capacitor o/v stage	59C	4
Io>	12	1st earth fault stage	50N/51N	4
Io>>	11	2nd earth fault stage	50N/51N	4
Io>>>	11	3rd earth fault stage	50N/51N	4
Io>>>>	11	4th earth fault stage	50N/51N	4

Main menu	Number of menus	Description	ANSI code	Note
Ioφ>	14	1st directional earth fault stage	67N	4
Ioφ>>	14	2nd directional earth fault stage	67N	4
Ioint>	4	Transient intermittent E/F	67NI	4
U>	12	1st overvoltage stage	59	4
U>>	11	2nd overvoltage stage	59	4
U>>>	11	3rd overvoltage stage	59	4
U<	12	1st undervoltage stage	27	4
U<<	11	2nd undervoltage stage	27	4
U<<<	11	3rd undervoltage stage	27	4
Uo>	11	1st residual overvoltage stage	59N	4
Uo>>	11	2nd residual overvoltage stage	59N	4
P<	11	1st reverse and underpower stage	32	4
P<<	11	2nd reverse and underpower stage	32	4
Prg1	11	1st programmable stage		4
Prg2	11	2nd programmable stage		4
Prg3	11	3rd programmable stage		4
Prg4	11	4th programmable stage		4
Prg5	11	5th programmable stage		4
Prg6	11	6th programmable stage		4
Prg7	11	7th programmable stage		4
Prg8	11	8th programmable stage		4
CBFP	10	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 = I01	50NARC	4
ArcIo2>	10	Optional arc protection stage for earth faults. Current input = I02	50NARC	4
OBJ	10	Object definitions		5
AR	4	Auto-reclose	79	
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
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.

2.2.2. Example of menu structure I>

I>/STATUS 50/51

Status	Trip	State of protection function (-, Start, Trip)
TripTime	0.0s	Estimated time to trip
SCntr	8	Start counter
TCntr	7	Trip counter
SetGrp	1	Active set group (1, 2)
SGrpDI	DI1	Set group DI control (DI1, DI2, VI1 – VI4, LedAl, LedTr, LedA – LedC, LedDR, VO1-VO6)
Force	Off	Forced operation of state (ON, OFF)

I>/1 SET 50/51 (several SET menus possible)

ILmax	100A	Actual value, the value on which the protection is based
Status	-	State of protection function (-, Start, Trip)
I> I>	110A 1.10xIn	Set value of protection function [A] Set value of protection function [pu]
Curve	IEC	Delay curve family (IEC, IEEE, IEEE2, RI, Prg1-Prg3, DT)
Type	DT	Selection of delay time curve (DT, NI, VI, EI, LTI, Parameters)
k>	0.50	Inverse time coefficient
t>	0.30s	Operation delay
Dly20x	1.13s	Inverse delay (20x)
Dly4x	2.48s	Inverse delay (4x)
Dly2x	5.01s	Inverse delay (2x)
Dly1x	35.90s	Inverse delay (1x)

I>/DELAY VARIABLES 50/51

A	-	Constant A
B	-	Constant B
C	-	Constant C
D	-	Constant D
E	-	Constant E

I>/1 LOG 50/51 (several LOG menus possible)

	2002-08-22 20:34:11	Event time stamp
Type	1	Fault type
Flt	1.20xIn	Fault current
Load	0.5xIn	Pre-fault current
EDly	100%	Elapsed delay
SetGrp	1	

2.2.3. Setting groups

Most of the protection functions of the relay have two 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 2.2.3-1 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 2.2.3-2).

```
I>/I> STATUS
SGrpDI: 1
```

Figure 2.2.3-1 Example of protection submenu with setting group parameters 1

```
I>/I> STATUS
SetGrp: 2
```

Figure 2.2.3-2 Example of protection submenu with setting group parameters 2

The changing of the setting parameters can be done easily. When the desired submenu has been found (with the arrow keys) it will show the values of the active setting group. Set1 is setting group one and Set2 is setting group two.

2.2.4. 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.

2.2.5. 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

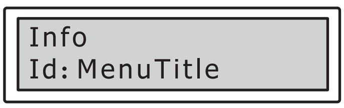
Use:	Possible to control objects and to change e.g. the settings of the protection stages
Opening:	Default password is 1
Setting state:	Push ENTER
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

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 ENTER
Closing:	The level is automatically closed after 10 minutes idle time. Giving the password 9999 can also close the level.

Opening access

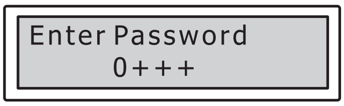
1. Push the INFO key, on the front panel. This will open the info screen.



info

Figure 2.2.5-1 Example of INFO screen

2. Push the ENTER key to enter password.



PwdScreen

Figure 2.2.5-2 Entering the password

3. 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 the RIGHT key and then setting the desired digit value using the UP key.
4. Push the ENTER key.

Password handling

The passwords can only be changed using VAMPSET software connected to the local RS-232 port on 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 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 vampsupport@vamp.fi 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 VAMP Ltd.)

Now the passwords are restored to the default values (See chapter 2.2.5).

2.3. Operating measures

2.3.1. Measured data

The measured values can be read from the Meas* menu and its submenus or from the menus P**, E**, I** and U** and there submenus. Furthermore, any measurement value in the following table can be displayed on the start screen as a scrolling text. Four measurements can be shown.

Value		Menu/Submenu	Description
P	**	P/POWER	Active power [kW]
Q	**	P/POWER	Reactive power [kvar]
S	**	P/POWER	Apparent power [kVA]
φ	**	P/POWER	Active power angle [°]
P.F.	**	P/POWER	Power factor [ ]
F	****	P/POWER	Frequency [Hz]
Time	**	P/POWER DEMAND	Demand time
Pda	**	P/POWER DEMAND	Active power [kW]****
Qda	**	P/POWER DEMAND	Reactive power [kvar]****
Sda	**	P/POWER DEMAND	Apparent power [kVA]****
Pfda	**	P/POWER DEMAND	Power factor [ ]****
fda	**	P/POWER DEMAND	Frequency [Hz]****
PL1	**	P/POWER/PHASE 1	Active power of phase 1 [kW]
QL1	**	P/POWER/PHASE 1	Reactive power of phase 1 [kvar]
SL1	**	P/POWER/PHASE 2	Apparent power of phase 1 [kVA]
PF_L1	**	P/POWER/PHASE 2	Power factor of phase 1 [ ]
cosφ	**	P/COS & TAN	Cosine phi [ ]
tanφ	**	P/COS & TAN	Tangent phi [ ]
cosL1	**	P/COS & TAN	Cosine phi of phase L1 [ ]
Iseq	**	P/PHASE SEQUENCIES	Actual current phase sequency [OK; Reverse; ??]
Ioφ	**	P/PHASE SEQUENCIES	Io/Uo angle [°]
Io2φ	**	P/PHASE SEQUENCIES	Io2/Uo angle [°]
fAdop	**	P/PHASE SEQUENCIES	Adopted frequency [Hz]
PDir	**	P/PHASE SEQUENCIES	Power direction
E+	**	E/ENERGY	Exported energy [MWh]
Eq+	**	E/ENERGY	Exported reactive energy [Mvar]
E-	**	E/ENERGY	Imported energy [MWh]
Eq-	**	E/ENERGY	Imported reactive energy [Mvar]
E+.nn	**	E/DECIMAL COUNT	Decimals of exported energy [ ]
Eq.nn	**	E/DECIMAL COUNT	Decimals of reactive energy [ ]
E-.nn	**	E/DECIMAL COUNT	Decimals of imported energy [ ]
Ewrap	**	E/DECIMAL COUNT	Energy control
E+	**	E/E-PULSE SIZES	Pulse size of exported energy [kWh]
Eq+	**	E/E-PULSE SIZES	Pulse size of exported reactive energy [kvar]
E-	**	E/E-PULSE SIZES	Pulse size of imported energy [kWh]
Eq-	**	E/E-PULSE SIZES	Pulse duration of imported reactive energy [ms]
E+	**	E/E-PULSE DURATION	Pulse duration of exported energy [ms]
Eq+	**	E/E-PULSE DURATION	Pulse duration of exported reactive energy [ms]

Value	Menu/Submenu	Description
E- **	E/E-PULSE DURATION	Pulse duration of imported energy [ms]
Eq- **	E/E-PULSE DURATION	Pulse duration of imported reactive energy [ms]
E+ **	E/Epulse TEST	Test the exported energy pulse [ ]
Eq+ **	E/Epulse TEST	Test the exported reactive energy [ ]
E- **	E/Epulse TEST	Test the imported energy [ ]
Eq- **	E/Epulse TEST	Test the imported reactive energy [ ]
IL1 ***	I/PHASE CURRENTS	Phase current IL1 [A]
IL2 ***	I/PHASE CURRENTS	Phase current IL2 [A]
IL3 ***	I/PHASE CURRENTS	Phase current IL3 [A]
IL1da ***	I/PHASE CURRENTS	15 min average for IL1 [A]
IL2da ***	I/PHASE CURRENTS	15 min average for IL2 [A]
IL3da ***	I/PHASE CURRENTS	15 min average for IL3 [A]
Io ***	I/SYMMETRIC CURRENTS	Primary value of zerosequence/ residual current Io [A]
Io2 ***	I/SYMMETRIC CURRENTS	Primary value of zero-sequence/residual current Io2 [A]
IoC ***	I/SYMMETRIC CURRENTS	Calculated Io [A]
I1 ***	I/SYMMETRIC CURRENTS	Positive sequence current [A]
I2 ***	I/SYMMETRIC CURRENTS	Negative sequence current [A]
I2/I1 ***	I/SYMMETRIC CURRENTS	Negative sequence current related to positive sequence current (for unbalance protection) [%]
THDIL ***	I/HARM. DISTORTION	Total harmonic distortion of the mean value of phase currents [%]
THDIL1 ***	I/HARM. DISTORTION	Total harmonic distortion of phase current IL1 [%]
THDIL2 ***	I/HARM. DISTORTION	Total harmonic distortion of phase current IL2 [%]
THDIL3 ***	I/HARM. DISTORTION	Total harmonic distortion of phase current IL3 [%]
Uline **	U/LINE VOLTAGES	Average value for the three line voltages [V]
U12 **	U/LINE VOLTAGES	Phase-to-phase voltage U12 [V]
U23 **	U/LINE VOLTAGES	Phase-to-phase voltage U23 [V]
U31 **	U/LINE VOLTAGES	Phase-to-phase voltage U31 [V]
UL **	U/PHASE VOLTAGES	Average for the three phase voltages [V]
UL1 **	U/PHASE VOLTAGES	Phase-to-neutral voltage UL1 [V]
UL2 **	U/PHASE VOLTAGES	Phase-to-neutral voltage UL2 [V]
UL3 **	U/PHASE VOLTAGES	Phase-to-neutral voltage UL3 [V]
Uo ****	U/SYMMETRIC VOLTAGES	Residual voltage Uo [%]

Value	Menu/Submenu	Description
THDUa **	U/HARM. DISTORTION	Total harmonic distortion of the voltage input a [%]
Count **	U/VOLT. INTERRUPTS	Voltage interrupts counter [ ]
Prev **	U/VOLT. INTERRUPTS	Previous interruption [ ]
Total **	U/VOLT. INTERRUPTS	Total duration of voltage interruptions [days, hours]
Prev **	U/VOLT. INTERRUPTS	Duration of previous interruption [s]
Status **	U/VOLT. INTERRUPTS	Voltage status [LOW; NORMAL]
IL1har	HARMONICS of IL1	Harmonics of phase current IL1 [%]
IL2har	HARMONICS of IL2	Harmonics of phase current IL2 [%]
IL3har	HARMONICS of IL3	Harmonics of phase current IL3 [%]

*) Available when voltage measurement option is U_0.

**) Available when voltage measurement option is 1Line (line-to-line voltage) or 1Phase (phase-to-neutral voltage).

***) In measurement option U_0 this value is found under main menu 'Meas' instead of 'I'.

****) In measurement option U_0 this value is found at Meas/Miscellaneous

2.3.2. Reading event register

The event register is able to store 200 latest events and can be read from the Evnt main menu:

1. Push the RIGHT key twice.
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. The upper row displays the event code, i.e. E3, after which the event description is shown. The second row displays the date and time of the event.

```
E3 DI2 on
2005-10-21  17:3
```

Figure 2.3-1. Example of an event register

3. Scroll through the event list with the UP and DOWN keys.
4. Exit the event list by pushing the LEFT key.

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 (Figure 2.3-2).

```
Evnt/EVENTS
Order: New-Old
```

EventScreen2

Figure 2.3-2. Figure of how to change order of event list

2.3.3. 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. Move to the setting state of the desired function, for example DO (see chapter 2.4, on page 20).
2. Select the Force function.

```
DO/RELAY OUTPUTS
Force: On
```

Figure 2.3-3. Selecting Force function

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

Operating level: CONFIGURATOR

- Choose and configure the digital inputs in the DI submenu.
- Configure the digital outputs in the DO submenu.
- Select the needed protection functions in the Prot submenu.
- Set the ”Device Setup”, the scaling (for example Inom, Isec, etc.) and the date and time in the CONF submenu.
- Change the parameters of the protection functions in the function-related submenus, for example I>.
- Choose and configure the communication buses in the Bus submenu.
- Configure interlockings for objects and protection functions with the VAMPSET software.

Some of the parameters can only be changed via the RS-232 serial port using the VAMPSET software. Such parameters, (for example passwords, blockings) are normally set only during commissioning.

Some of the parameters require the restarting of the relay. This restarting is done automatically when necessary. If an attempt to change such a parameter is made, the relay will inform about the auto-reset feature by showing the following text: “Changing will cause autboot!” (see Figure 2-1).

Figure 2-1. Example of auto-reset display

Press CANCEL to return to the setting view. If a parameter must be changed, press the ENTER key again. The parameter can now be set. If no key is pressed, the auto-reset will be executed within few seconds. In the lower right corner of the display an indicator will appear to inform of the impending boot.

2.4.1. Parameter setting

1. Move to the desired screen of the menu (for example CONF/CURRENT SCALING) by pushing the RIGHT key.
2. Enter the password associated with the configuration level by pushing the INFO key and then using the arrow keys and the ENTER key (default value = 0002). For more information about the operating levels, please refer to 2.2.5.
3. If needed, scroll through the parameters using the UP and DOWN keys.
4. Select the desired parameter (for example Inom) with the ENTER key.
5. The "Edit value" text appears in the upper row of the display.
6. Use the UP and DOWN keys to change a parameter value. If the value contains more than one digit, use the LEFT and RIGHT keys to shift from digit to digit, and the UP and DOWN keys to change the digits.
7. Push the ENTER key to accept a new value. If you want to leave the parameter value unchanged, exit the edit state by pushing the CANCEL key.

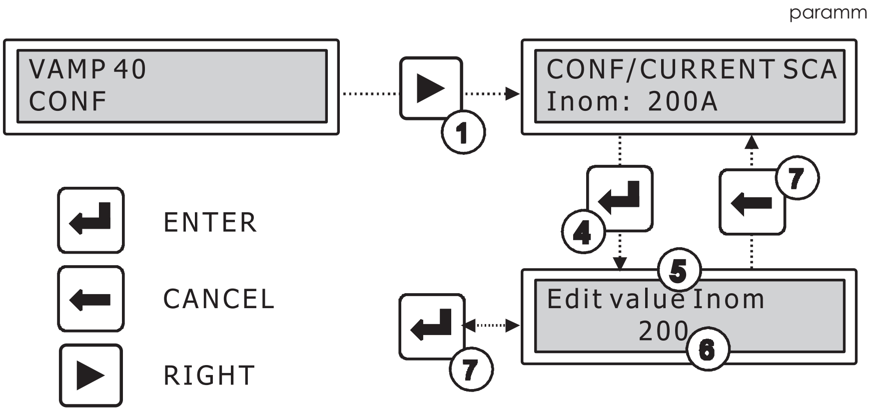


Figure 2.4-1. Changing parameters

2.4.2. Setting range limits

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

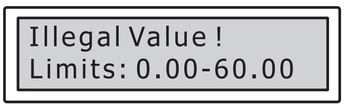


Figure 2.4-2. Example of a fault message

Push the CANCEL key to return to the setting mode.

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 RECORDER

- Recording mode (Mode)
- Sample rate (SR)
- Recording time (Time)
- Pre trig time (PreTrig)
- Manual trigger (ManTrig)
- Count of ready records (ReadyRec)

REC. CHANNELS

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

Available links:

- DO, DI
- Uline, Uphase *
- IL
- I2/In, I2/I1, I2, I1, IoCalc
- CosFii *
- PF, S, Q, P *
- f
- Uo**
- UL1 *
- U12 *
- Io2, Io
- IL3, IL2, IL1
- Tanfii *
- Prms, Qrms, Srms
- THDIL1, THDIL2, THDIL3
- THDUa *

*) Only when measurement option is either 1Line (line-to-line voltage) or 1Phase (phase-to-neutral voltage)

**) Only when measurement option is U0

2.4.4. Configuring digital inputs DI

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

- The status of digital inputs (DIGITAL INPUTS 1,2)
- Operation counters (DI COUNTERS)
- Operation delay (DELAYs for DigIn)
- The polarity of the input signal (INPUT POLARITY). Either normally open (NO) or normally closed (NC) circuit.
- 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 relay
    - Forced control (0 or 1) of the IF 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 and F (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. Protection menu Prot

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

- Reset all the counters (PROTECTION SET/ClAll)
- Read the status of all the protection functions (PROTECT STATUS 1-x)
- Enable and disable protection functions (ENABLED STAGES 1-x)
- 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.

2.4.7. 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 ports X4 and the front panel. The front panel is always using this setting. If SPABUS is selected for the rear panel local port X4, the bit rate is according SPABUS settings.
- Access level [Acc]

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. The rated value is selected at the back panel connector X6.
- Rated value of I_{01} CT primary current (Ionom)
- Rated value of I_{01} CT secondary current (Iosec)
- Rated I_{01} input of the relay [Ioinp] is 5 A or 1 A. This is specified in the order code of the device.
- Rated value of I_{02} CT primary current (Io2nom)
- Rated value of I_{02} CT secondary current (Io2sec)
- Rated I_{02} input of the relay [Io2inp] is 1 A or 0.2 A. The rated value is selected at the back panel connector X6.

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 VT primary voltage (Uprim)
- Rated VT secondary voltage (Usec)
- Rated U0 VT secondary voltage (Uosec)
- Voltage measuring mode (Umode)

MOTOR SETTING

- Rated current of the motor (Imot).

DEVICE INFO

- Relay type (Type VAMP 40)
- 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).

2.4.8. Protocol menu Bus

There are three communication ports in the rear panel. In addition there is a connector in the front panel overruling the local port in the rear panel.

REMOTE PORT X4

- Communication protocol for remote port X4 [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.

LOCAL PORT (front panel and X4)

This port is disabled, if a cable is connected to the front panel connector.

- Communication protocol for the local port X4 [Protocol]. For VAMPSET use "None" or "SPABUS".
- 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. For VAMPSET and protocol "None" the setting is done in menu CONF/DEVICE SETUP.

MODBUS

- Modbus addres 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 the technical description part of the manual.

SPA BUS

Several instances of this protocol are possible.

- SPABUS addres for this device [Addr]. This address has to be unique within the system.
- Bit rate [bit/s]. Default is "9600".
- Event numbering style [Emode]. Default is "Channel".

For details see the technical description part of the manual.

IEC 60870-5-103

Only one instance of this protocol is possible.

- Address for this device [Addr]. This address has to be unique within the system.
- Bit rate [bit/s]. Default is "9600".
- Minimum measurement response interval [MeasInt].
- ASDU6 response time mode [SyncRe].

For details see the technical description part of the manual.

IEC 103 DISTURBANCE RECORDINGS

For details see the technical description part of the manual.

PROFIBUS

Only one instance of this protocol is possible.

- [Mode]
- Bit rate [bit/s]. Use 2400 bps. This parameter is the bit rate between the main CPU and the Profibus ASIC. The actual Profibus bit rate is automatically set by the Profibus master and can be up to 12 Mbit/s.
- Event numbering style [Emode].
- Size of the Profibus Tx buffer [InBuf].
- Size of the Profibus Rx buffer [OutBuf].
  When configuring the Profibus master system, the length of these buffers are needed. The size of the both buffers is set indirectly when configuring the data items for Profibus.
- Address for this slave device [Addr]. This address has to be unique within the system.
- Profibus converter type [Conv]. If the shown type is a dash "-", either Profibus protocol has not been selected or the device has not restarted after protocol change or there is a communication problem between the main CPU and the Profibus ASIC.

For details see the technical description part of the manual.

DNP3

Only one instance of this protocol is possible.

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

For further details see the technical description part of the manual.

IEC 60870-5-101

- Bit rate [bit/s]. Default is “9600”.
- [Parity].
- Link layer address for this device [LLAddr].
- ASDU address [ALAddr].

For further details see the technical description part of the manual.

TCP/IP

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

- IP address [IpAddr].
- Net mask [NetMsk].
- Gateway [Gatew].
- Name server [NameSw].
- Network time protocol (NTP) server [NTPSvr].
- Protocol port for IP [Port]. Default is 502.

2.4.9. 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 (VMV.EN0xx).

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.

Two RS 232 serial ports are available for connecting a local PC with VAMPSET to the relay; one on the front panel and one on the rear panel of the relay. These two serial ports are connected in parallel. However, if the connection cables are connected to both ports, only the port on the front panel will be active. To connect a PC to a serial port, use a connection cable of type VX 003-3.

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

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 www.vamp.fi. For more information about the VAMPSET software, please refer to the user's manual with the code VMV.EN0xx. Also the VAMPSET user's manual is available at our web site.

Table of Contents

1. Introduction

This part of the user manual describes the protection functions, provides a few application examples and contains technical data.

The numerical VAMP device includes all the essential protection functions needed to protect feeders and motors in distribution networks of utilities, industry, power plants and offshore applications. Further, the device includes several programmable functions, such as arc (option), thermal, trip circuit supervision and circuit breaker protection and communication protocols for various protection and communication situations.

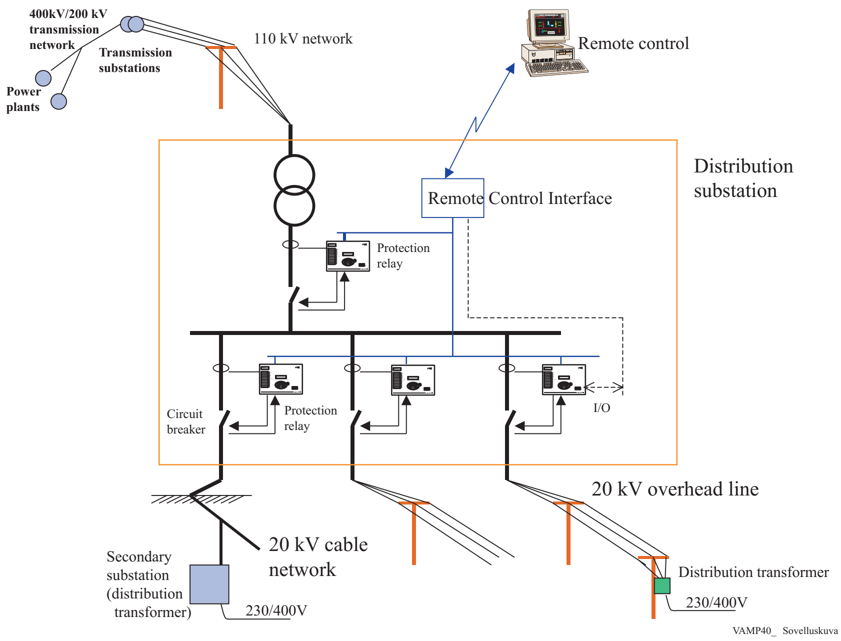


Figure 1.1-1. Application of the feeder and motor protection relay

1.1. Main features

- Fully digital signal handling with a powerful 16-bit microprocessor, and high measuring accuracy on all the setting ranges due to an accurate 16-bit A/D conversion technique.
- Wide setting ranges for the protection functions, e.g. the earth fault protection can reach a sensitivity of 0.5%.
- 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.
- Configurable display with 4 measurement values.
- Recording of events and fault values into an event register from which the data can be read via a keypad and a local 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 power plant automation system due to a versatile serial connection and several available communication protocols.
- Built-in, self-regulating ac/dc converter for wide range auxiliary power supply from any source within the range from 19 to 265 V dc or ac.
- Built-in disturbance recorder for evaluating all the analogue and digital signals.

1.2. 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 signal (voltage or current) and a sample rate according to the 2^n series, the FFT technique leads to a solution, which can be realized with just 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 IL1 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. For example, the function of the unbalanced load protection stage is based on the use of the negative phase sequence component of the current.

Figure 1.2-1 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 1.2-2 shows the heart of the numerical technology. That is the main block diagram for calculated functions.

Figure 1.2-3 shows a principle diagram of a single-phase overvoltage or overcurrent function.

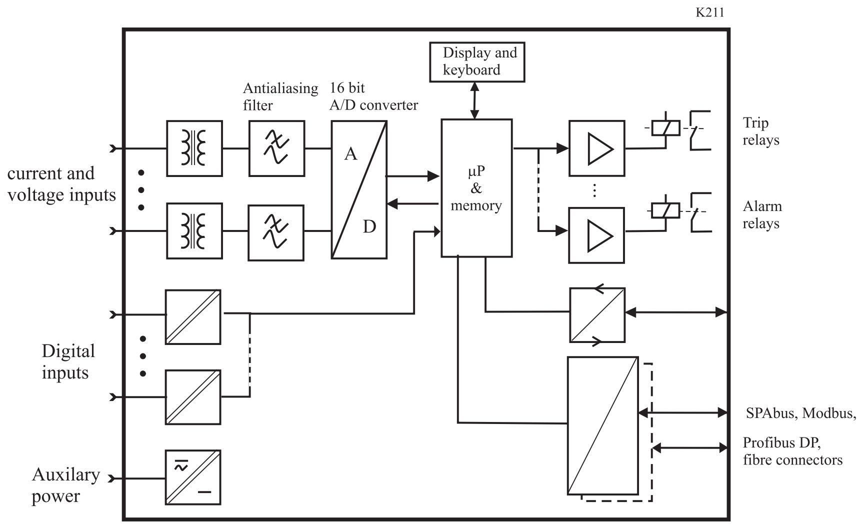


Figure 1.2-1 Principle block diagram of the VAMP hardware

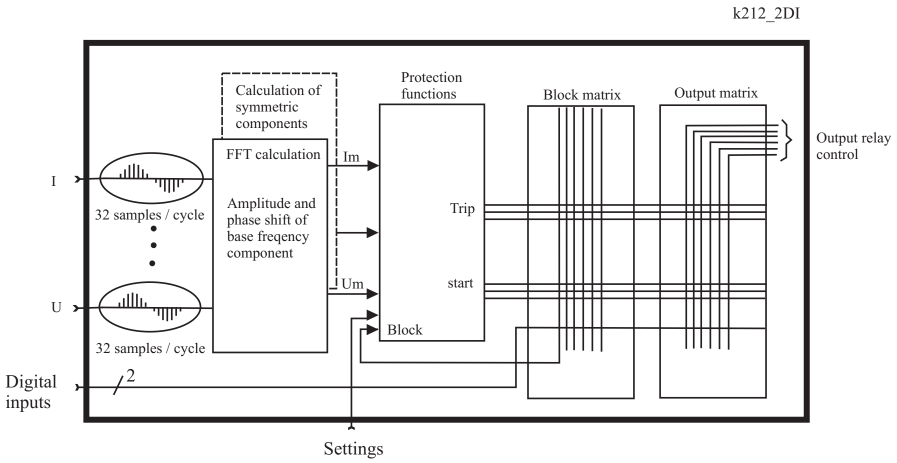


Figure 1.2-2 Block diagram of signal processing and protection software

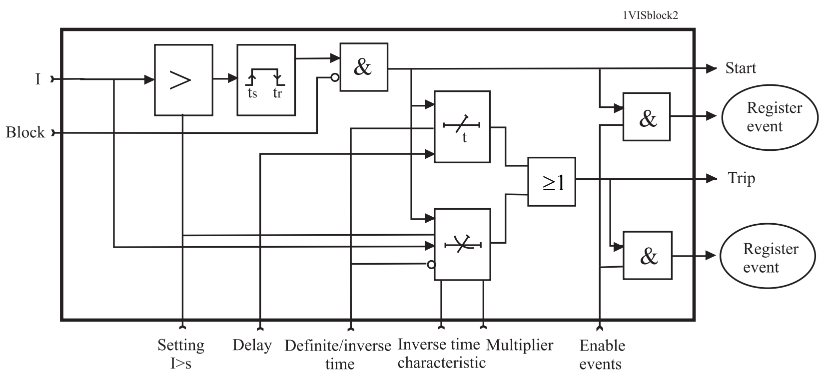


Figure 1.2-3 Block diagram of a basic protection function

2. Protection functions

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

2.1. 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 in the Operation and Configuration instruction.

2.2. List of protection functions

IEEE/ANSI code	IEC symbol	Function name	Note
50/51	3I>, 3I>>, 3I>>>	Overcurrent protection	
46R	I_2/I_1>	Broken line protection	
46	I_2>	Current unbalance protection	Only available when application option is in **motor protection mode. Please also see chapter 4.7 for more information**
47	I_2>>	Incorrect phase sequence protection	
48	I_{st}>	Stall protection	
66	N>	Frequent start protection	
49	T>	Thermal overload protection	
37	I<	Undercurrent protection	
50N/51N	I_0>, I_0>>, I_0>>>, I_0>>>>	Earth fault protection	
67NT	I_{0T}>	Intermittent transient earth fault protection	
		Capacitor bank unbalance protection	
59C	U_c>	Capacitor overvoltage protection	
67N	$I_{0\varphi}$>, $I_{0\varphi}$>>	Directional earth fault protection	Only available when measurement option is **U_0**
59N	U_0>, U_0>>	zero sequence voltage protection	
59	U>, U>>, U>>>	Single-phase overvoltage protection	Only available when measurement option is **1LL (line-to-line voltage) or 1LN (phase-to-neutral voltage). Please also see chapter 4.7 for more information**
27	U<, U<<, U<<<	Single-phase undervoltage protection	
32	P<, P<<	Reverse and underpower protection	
50BF	CBFP	Circuit-breaker failure protection	
99	Prg1...8	Programmable stages	
50ARC/ 50NARC	ArcI>, ArcI_{01}>, ArcI_{02}>	Optional arc fault protection (with an external module)	

2.3. General features of protection stages

Setting groups

Most stages have two setting groups. Changing between setting groups can be controlled manually or using any of the digital inputs, virtual inputs, virtual outputs or LED indicator signals. 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.

Forcing start or trip condition for testing

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

- Ok = '–' The stage is not detecting any fault.
- 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 **5.5**.

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.

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 5.4.

Blocking

Any protection function, except arc protection, can be blocked with internal and external signals using the block matrix (chapter 5.5). 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.

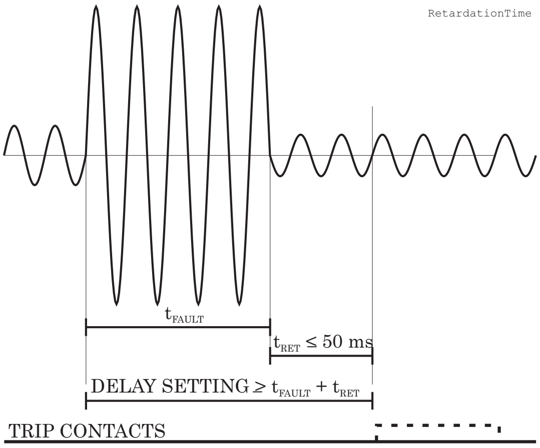


Figure 2.3-1. Definition for retardation time. If the delay setting would be slightly shorter, an unselective trip might occur (the dash line pulse).

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 2.3-1 shows an overcurrent 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 2.3-2 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. The reset time varies from fault to fault depending on the fault size. After a big fault the time is longer. The reset time also depends on the specific protection stage. The maximum reset time for each stage is specified in chapter 9.3. For most stages it is less than 95 ms.

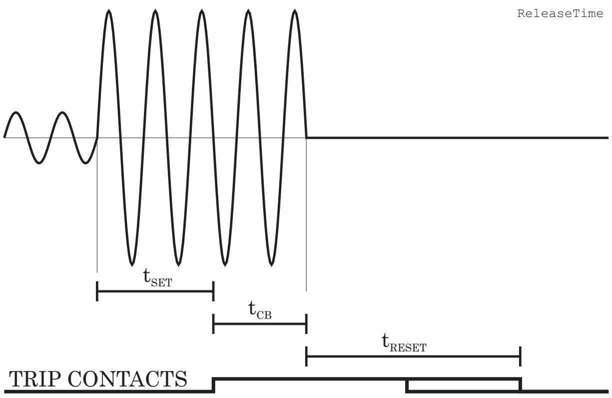


Figure 2.3-2. Reset time is the time it takes the trip or start relay contacts to open after the fault has been cleared.

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.

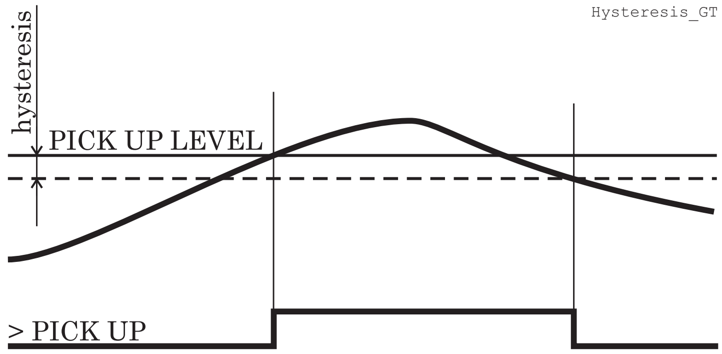


Figure 2.3-3. Behaviour of a greater than comparator. For example in overcurrent and overvoltage stages the hysteresis (dead band) acts according this figure.

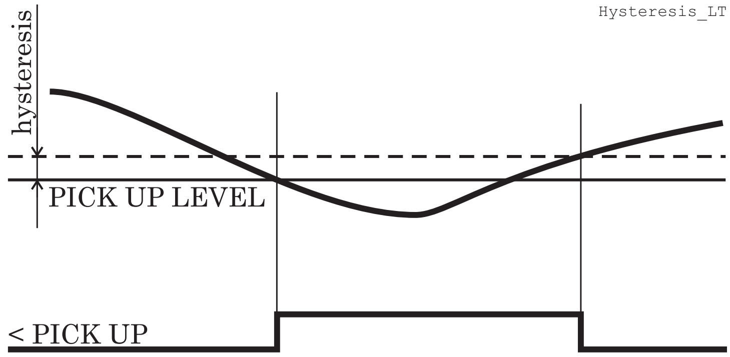


Figure 2.3-4. Behaviour of a less than comparator. For example in under-voltage and under frequency stages the hysteresis (dead band) acts according this figure.

2.4. Relay function dependencies

2.4.1. 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.

2.4.2. 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.

2.5. 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.

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 2.5-1 shows a functional block diagram of the I> overcurrent stage with definite time and inverse time operation time. Figure 2.5-1 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 2.25. 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 50xI_N. This limits the scope of inverse curves with high pick-up settings. See chapter 2.25 for more information.

Cold load and inrush current handling

See chapter 3.3.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually.

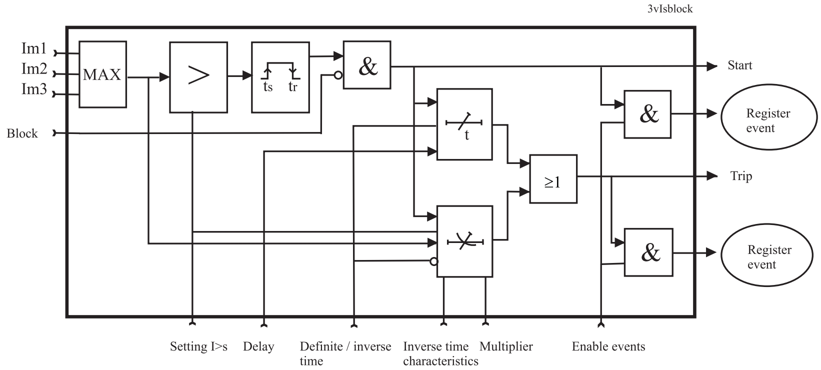


Figure 2.5-1 Block diagram of the three-phase overcurrent stage I>.

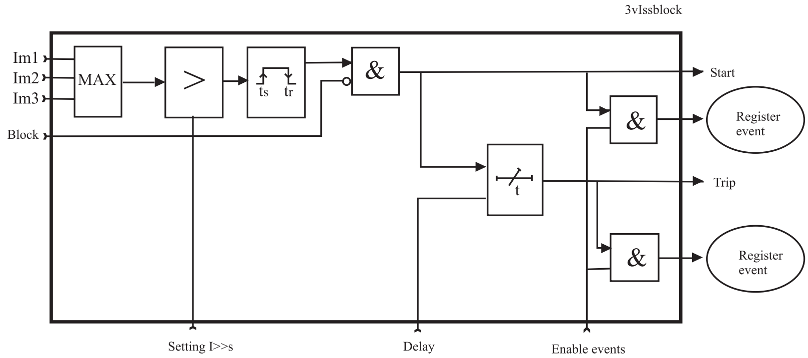


Figure 2.5-1 Block diagram of the three-phase overcurrent stage I>> and I>>>.

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	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set

Parameter	Value	Unit	Description	Note
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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	
I>		A	Pick-up value scaled to primary value	
I>		xImode	Pick-up setting	Set
Curve	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 2.25. Pre 1996	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 2.25.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Dly20x		s	Delay at 20xIset	
Dly4x		s	Delay at 4xIset	
Dly2x		s	Delay at 2xIset	
Dly1x		s	Delay at 1xIset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 2.25.	Set

For details of setting ranges see chapter 9.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

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 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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	
I>>, I>>>		A	Pick-up value scaled to primary value	
I>>, I>>>		xImode	Pick-up setting	Set
t>>, t>>>		s	Definite operation time	Set

For details of setting ranges see chapter 9.3 .

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 type, fault current, load current before the fault, elapsed delay and setting group.

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		xImode	Maximum fault current
Load		xImode	1 s average phase currents before the fault
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

2.6. Broken line protection $I_2/I_1>$ (46R)

The purpose of the broken line protection is to detect unbalanced load conditions, for example a broken wire 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 8.10. The unbalance protection has definite time operation characteristic.

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

$I1 = I_{L1} + aI_{L2} + a^2I_{L3}$
$I2 = I_{L1} + a^2I_{L2} + aI_{L3}$

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

Setting parameters of unbalanced load function:

I_2/I_1> (46R)

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

Measured and recorded values of unbalanced load function:

I_2/I_1> (46R)

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

2.7. Current unbalance stage I_2> (46)

Current unbalance in a motor causes double frequency currents in the rotor. This warms up the surface of the rotor and the available thermal capacity of the rotor is much less than the thermal capacity of the whole motor. Thus an rms current based overload protection (see chapter 2.18) is not capable to protect a motor against current unbalance.

The current unbalance protection is based on the negative sequence of the base frequency phase currents. Both definite time and inverse time characteristics are available.

Inverse delay

The inverse delay is based on the following equation.

Equation 2.7-1

$$T = \frac{K_1}{\left(\frac{I_2}{I_{MOT}}\right)^2 - K_2^2}$$, where

T	=	Operation time
K_1	=	Delay multiplier
I_2	=	Measured and calculated negative sequence phase current of fundamental frequency.
I_{MOT}	=	Nominal current of the motor
K_2	=	Pick-up setting $I_2>$ in pu. The maximum allowed degree of unbalance.

Example:

K_1	=	15 s
I_2	=	22.9 % = 0.229 xI_{MOT}
K_2	=	5 % = 0.05 xI_{MOT}

$$t = \frac{15}{\left(\frac{0.229}{1}\right)^2 - 0.05^2} = 300.4$$

The operation time in this example will be five minutes.

More stages (definite time delay only)

If more than one definite time delay stages are needed for current unbalance protection, the freely programmable stages can be used (chapter 2.25).

Setting groups

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

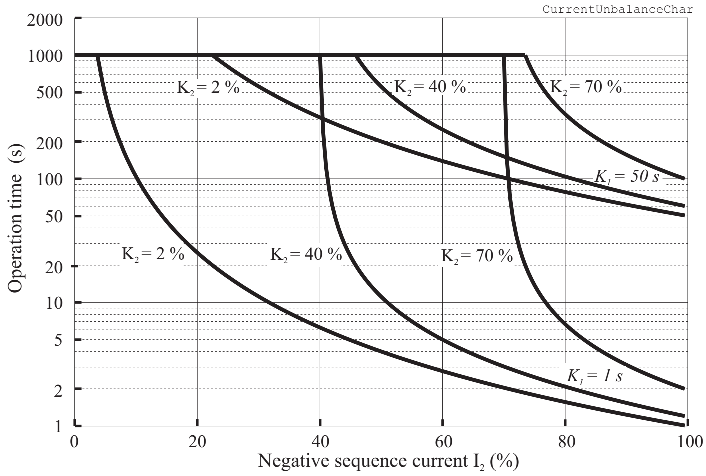


Figure 2.7-1. Inverse operation delay of current unbalance stage I₂>. The longest delay is limited to 1000 seconds (=16min 40s).

Parameters of the current unbalance stage I_2> (46)

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 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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
I2/Imot		%Imot	The supervised value.	
I2>		%Imot	Pick-up setting	Set
t>		s	Definite operation time (Type=DT)	Set
Type	DT INV		Definite time Inverse time (Equation 2.7-1)	Set
K1		s	Delay multiplier (Type =INV)	Set

For details of setting ranges see chapter 9.3.

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, unbalance current, elapsed delay and setting group.

Recorded values of the current unbalance stage (8 latest faults) I_2> (46)

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

2.8. Incorrect phase sequence protection I_2>> (47)

The phase sequence stage prevents the motor from running in the wrong direction, thus protecting the load.

When the ratio between negative and positive sequence current exceeds 80%, the phase sequence stage starts and trips after 100 ms.

Parameters of the incorrect phase sequence stage:

I_2>> (47)

	Parameter	Value/unit	Description
Measured value	I2/I1	%	Neg. phase seq. current/pos. phase seq. current
Recorded values	SCntr		Start counter (Start) reading
	TCntr		Trip counter (Trip) reading
	Flt	%	Max. value of fault current
	EDly	%	Elapsed time as compared to the set operate time, 100% = tripping

2.9. Stall protection I_{st}> (48)

The stall protection unit I_{st}> measures the fundamental frequency component of the phase currents.

Stage I_{st}> can be configured for definite time or inverse time operation characteristic.

The stall protection stage protects the motor against prolonged starts caused by e.g. a stalled rotor. While the current has been less than I_{STOP} for at least 500 ms and then within 200 milliseconds exceeds $I_{StartMin}$ the stall protection stage starts to count the operation time T according to Equation 2.9-1. The equation is also drawn in Figure 2.9-1. When current drops below 120 % x I_{mot} the stall protection stage releases. Stall protection is active only during the start of the motor.

Equation 2.9-1

$$T = \frac{I_{START}}{I_{MEAS}} T_{START} \text{ , where}$$

T	=	Operation time
I_{START}	=	Start current of the motor. Default 6.00xI_{mot}
I_{MEAS}	=	Measured current during start
T_{START}	=	Maximum allowed start time for the motor

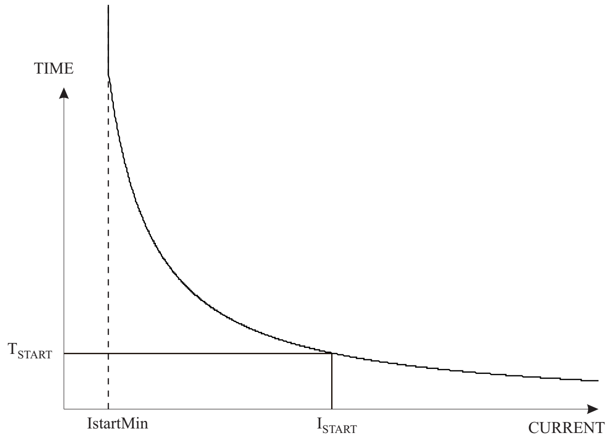


Figure 2.9-1 Operation time delay of the stall protection stage Ist>.

If the measured current is less than the specified start current I_{start} the operation time will be longer than the specified start time T_{start} and vice versa.

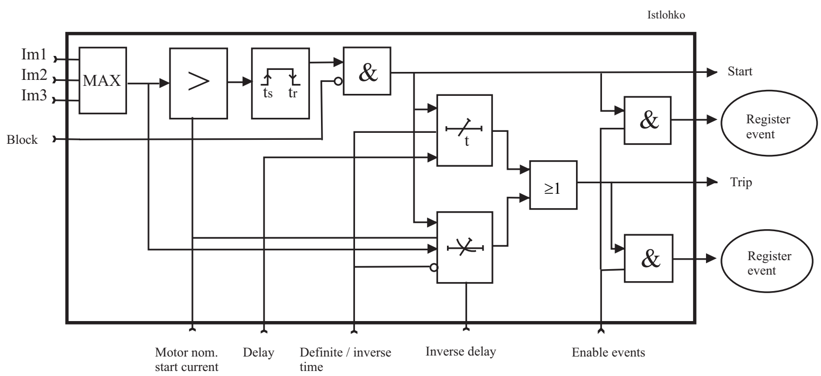


Figure 2.9-2 Block diagram of the stall protection stage Ist>.

Parameters of the stall protection stage:

I_{st}> (48)

	Parameter	Value/unit	Description
Setting values	ImotSt	xImot	Nominal motor starting current
	Ist>	%Imot	Motor start detection current. Must be less than initial motor starting current.
	Type	DT	Operation charact./ definite time
		Inv	Operation charact./ inverse time
	tDT>	s	Operation time [s]
	tInv>	s	Time multiplier at inverse time
Recorded values	SCntr		Start counter (Start) reading
	TCntr		Trip counter (Trip) reading
	Flt	xImot	Max. value of fault.
	EDly	%	Elapsed time as compared to the set operate time, 100% = tripping

2.10. Frequent start protection N> (66)

The simplest way to start an asynchronous motor is just to switch the stator windings to the supply voltages. However every such start will heat up the motor considerably because the initial currents are significantly above the rated current.

If the motor manufacturer has defined the maximum number of starts within on hour or/and the minimum time between two consecutive starts this stage is easy to apply to prevent too frequent starts.

When current has been less that I_{stop} and then exceeds $I_{StartMin}$ the situation is recognized as a start. A typical setting for $I_{StartMin}$ is 150 % x I_{MOT}. When the current is less than 10 % x I_{MOT}, the motor is regarded as stopped.

The stage will give a start signal when the second last start has been done. The trip signal is normally activated and released when there are no starts left. Figure 2.10-1 shows an application.

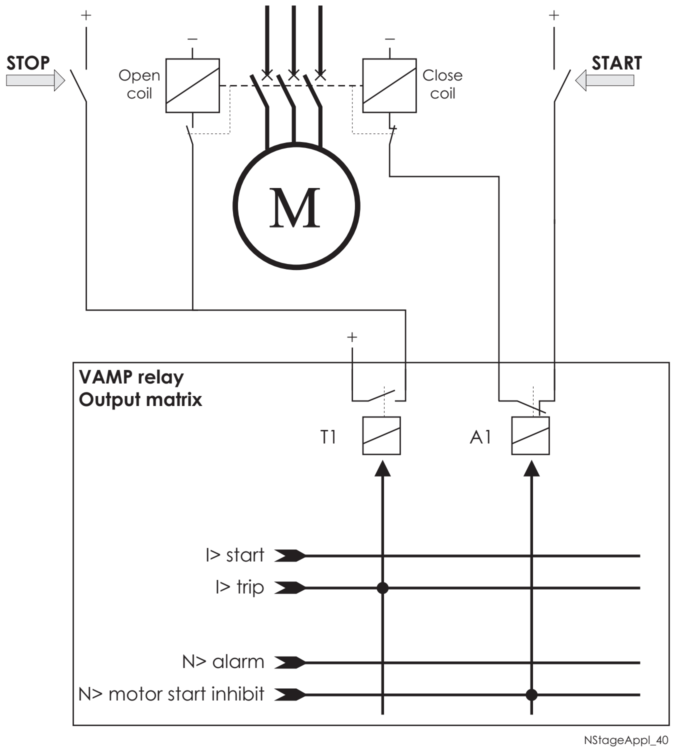


Figure 2.10-1 Application for preventing too frequent starting, using the N> stage. The relay A1 has been configured to be "normal closed". The start is just an alarm telling that there is only one start left at the moment.

Parameters of the frequent start protection:

N> (66)

	Parameter	**Value/unit**	**Description**
Measured value	Mot strs		Motor starts in last hour
	T	Min	Elapsed time from motor start
Setting values	Sts/h		Max. starts in one hour
	Interval	Min	Min. interval between two consecutive starts
Recorded values	SCntr		Start counter (Start) reading
	TCntr		Trip counter (Trip) reading
	Descr	1StartLeft	1 start left, activates the N> start signal
		MaxStarts	Max. start trip, activates the N> trip signal
		Interval	Min. interval between two consecutive starts has not yet been elapsed, activates the N> trip signal
	Tot Mot Strs		Number of total motor starts
	Mot Strs/h		Number of motor starts in last hour
	El. Time from mot Strt	Min	Elapsed time from the last motor start

2.11. Undercurrent protection I< (37)

The undercurrent unit measures the fundamental frequency component of the phase currents.

The stage I< can be configured for definite time characteristic.

The undercurrent stage is protecting rather the device driven by the motor e.g. a submersible pump, than the motor itself.

Parameters of the undercurrent stage:

I< (37)

	Parameter	Value/unit	Description
Measured value	ILmin	A	Min. value of phase currents IL1…IL3 in primary value
Setting values	I<	xImode	Setting value as per times Imot
	t<	S	Operation time [s]
Recorded values	SCntr		Start counter (Start) reading
	TCntr		Trip counter (Trip) reading
	Type	1-N, 2-N 3-N	Fault type/single-phase fault e.g.: 1-N = fault on phase L1
		1-2, 2-3 1-3	Fault type/two-phase fault e.g.: 2-3 = fault between L2 and L3
		1-2-3	Fault type/three-phase fault
	Flt	%	Min. value of fault current as per times Imot
	Load	%	1s mean value of pre-fault currents IL1—IL3
	EDly	%	Elapsed time as compared to the set operate time, 100% = tripping

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

The directional earth fault protection is used for earth faults in networks or motors 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. This $-U_0$ voltage is measured via energizing input U_0 (see chapter 4.7):

- 1LL / 1LN: directional earth fault protection is disabled du to no U_0 measured.
- 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 8.10-1) in order to get a correct polarization. Please note that actually the negative U_0, $-U_0$, is connected to the device.

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 2.12-2. The base angle is usually set to zero degrees.
  - Cap
    The stage is sensitive to the capacitive component of the selected I0 signal. This mode is used with **unearthed networks.** The trip area is a half plane as drawn in Figure 2.12-2. 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 2.12-3.

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_{01} for all networks other than rigidly earthed.
- Input I_{02} for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3} = 3I_0$.

Additionally the stage $I_0\varphi$> have two more input signal alternatives to measure current peaks to detect short restriking intermittent earth faults:

- I_{01Peak} to measure the peak value of input I_{01}.
- I_{02Peak} to measure the peak value of input I_{02}.

Intermittent earth fault detection

Short earth faults make the protection to start (to pick up), but will not cause trip. When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting. The mode should be Undir. The phase angle detection of I_0 in directional mode is insecure.

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. By using input signals I_{01Peak} or I_{02Peak} a single one-millisecond current peak is enough to start the stage and increase the delay counter by 20 ms. For example if the operating time is 120 ms, and the time between two peaks does not exceed the intermittent time setting, the sixth peak will cause a trip.

Two independent stages

There are two separately adjustable stages: $I\varphi$> and $I\varphi$>>. 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

2.25. 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 $10xI_{0N}$ and maximum measured phase current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 2.25 for more information.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually.

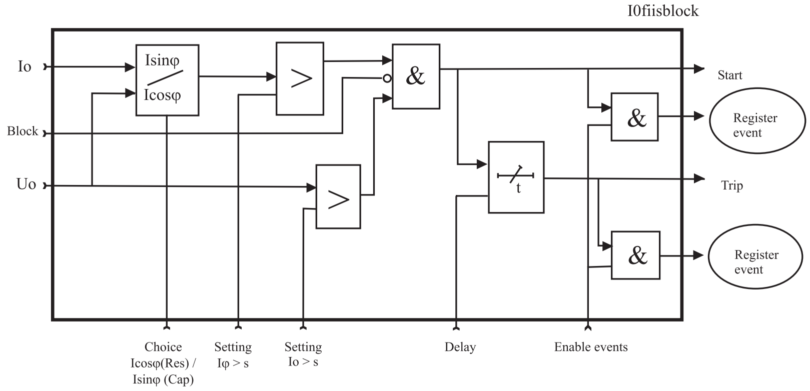


Figure 2.12-1. Block diagram of the directional earth fault stages $I_0\varphi$> and $I_0\varphi$>>

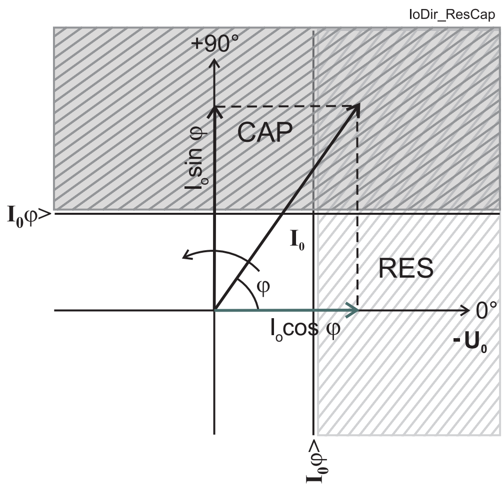


Figure 2.12-2. Operation characteristic of the directional earth fault protection in Res or Cap mode. Res mode can be used with compensated networks and Cap mode is used with ungrounded networks.

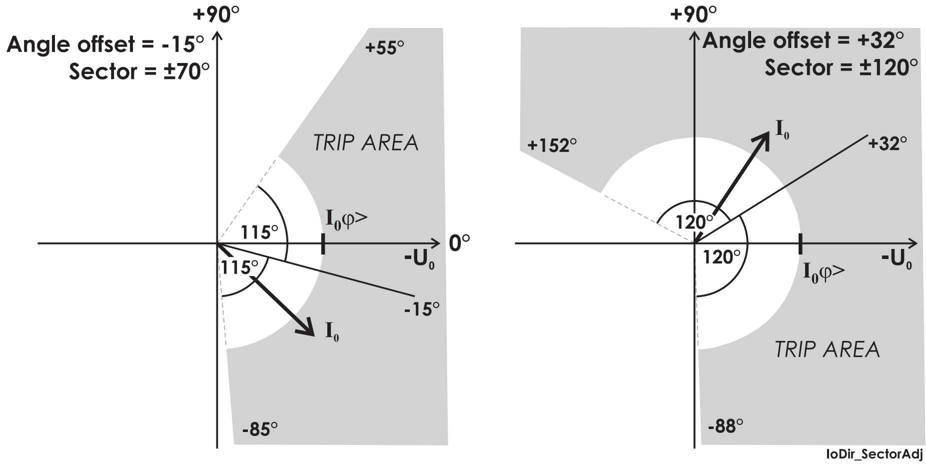


Figure 2.12-3. Two example of operation characteristics of the directional earth fault stages in sector mode. The drawn I_0 phasor in both figures is inside the trip area. The angle offset and half sector size are user's parameters.

Parameters of the directional earth fault stages $I_0φ>$, $I_0φ>>$ (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 or 2		Active setting group	Set

Parameter	Value	Unit	Description	Note
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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 Io2 IoCalc IoPeak Io2Peak		pu	The supervised value according the parameter "Input" below. ($I_0\varphi$> only) ($I_0\varphi$> 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	
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	 DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 2.25.	Set
Type	 DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 2.25.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set

Parameter	Value	Unit	Description	Note
Mode	ResCap Sector Undir		High impedance earthed nets Low impedance earthed nets Undirectional mode	Set
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 DI1, DI2 VI1..4		Res/Cap control in mode ResCap Fixed to Resistive characteristic Fixed to Capacitive characteristic Controlled by digital input Controlled by virtual input	Set
InUse	 - Res Cap		Selected submode in mode ResCap. Mode is not ResCap Submode = resistive Submode = capacitive	
Input	Io1 Io2 IoCalc Io1Peak Io2Peak		X6-7,8,9. See chapter 8. X6-10,11,12 IL1 + IL2 + IL3 X6-7,8,9 peak mode ($I_0\varphi$> only) X6-10,11,12 peak mode ($I_0\varphi$> only)	Set
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20xIoset	
Dly4x		s	Delay at 4xIoset	
Dly2x		s	Delay at 2xIoset	
Dly1x		s	Delay at 1xIoset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 2.25.	Set

For details of setting ranges see chapter 9.3.

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 earth faults: Time stamp, fault current, elapsed delay and setting group.

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
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		Active setting group during fault

2.13. 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.

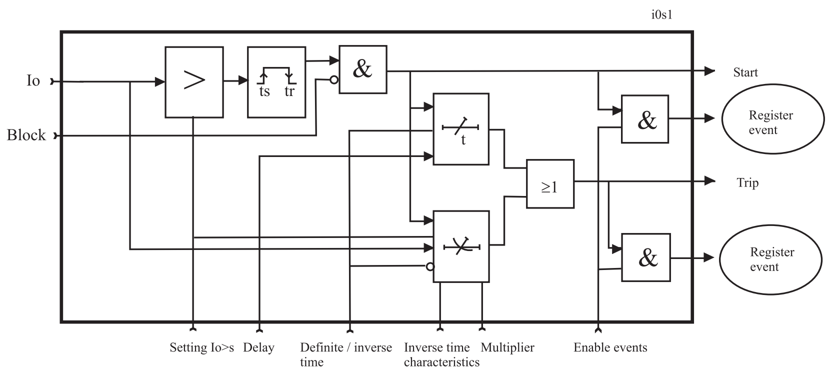


Figure 2.13-1. Block diagram of the earth fault stage $I_0>$

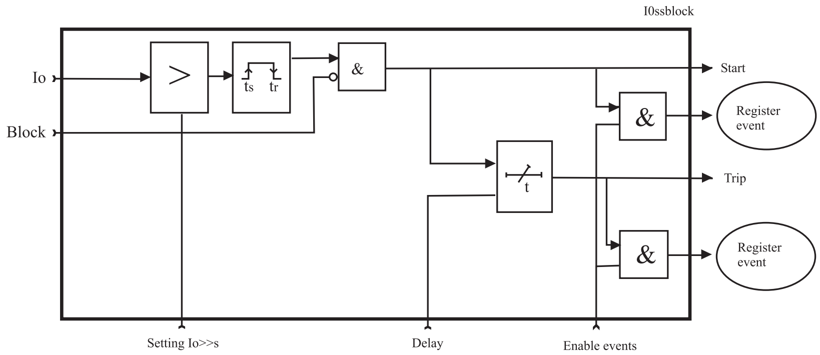


Figure 2.13-2. Block diagram of the earth fault stages I_0>>, I_0>>> and I_0>>>>

Figure 2.13-1 shows a functional block diagram of the I_0> earth overcurrent stage with definite time and inverse time operation time. Figure 2.13-2 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_{01} for all networks other than rigidly earthed.
- Input I_{02} for all networks other than rigidly earthed.
- Calculated signal I_{0Calc} for rigidly and low impedance earthed networks. $I_{0Calc} = I_{L1} + I_{L2} + I_{L3}$.

Additionally the stage I_0> have two more input signal alternatives to measure current peaks to detect a restriking intermittent earth fault:

- I_{01Peak} to measure the peak value of input I_{01}.
- I_{02Peak} to measure the peak value of input I_{02}.

Intermittent earth fault detection

Short earth faults make the protection to start (pick up), but will not cause trip. 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. By using input signals I_{01Peak} or I_{02Peak} a single one-millisecond current peak is enough to start the stage and increase the delay counter by 20 ms. For example if the operating time is 120 ms, and the time between two peaks does not exceed the intermittent time setting, the sixth peak will cause a 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 2.12) 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 2.25. 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 $10xI_{0N}$ and maximum measured phase current is $50xI_N$. This limits the scope of inverse curves with high pick-up settings. See chapter 2.25 for more information.

Setting groups

There are two settings groups available for each stage. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually.

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

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 or 2		Active setting group	Set

Parameter	Value	Unit	Description	Note
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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 Io2 IoCalc IoPeak Io2Peak		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	DT IEC IEEE IEEE2 RI PrgN		Delay curve family: Definite time Inverse time. See chapter 2.25.	Set
Type	DT NI VI EI LTI Parameters		Delay type. Definite time Inverse time. See chapter 2.25.	Set
t>		s	Definite operation time (for definite time only)	Set
k>			Inverse delay multiplier (for inverse time only)	Set
Input	Io1 Io2 IoCalc Io1Peak Io2Peak		X6-7,8,9. See chapter 8. X6-10,11,12 IL1 + IL2 + IL3 X6-7,8,9. peak mode X6-10,11,12 peak mode	Set
Intrmt		s	Intermittent time	Set
Dly20x		s	Delay at 20xIon	

Parameter	Value	Unit	Description	Note
Dly4x		s	Delay at 4xIoset	
Dly2x		s	Delay at 2xIoset	
Dly1x		s	Delay at 1xIoset	
A, B, C, D, E			User's constants for standard equations. Type=Parameters. See chapter 2.25.	Set

For details of setting ranges see chapter 9.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

Parameters of the undirectional earth fault stages I_0>>, I_0>>>, I_0>>>> (50N/51N)

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 or 2		Active setting group	Set
SgrpDI	 - Dix Vix LEDx Vox		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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 Io2 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	Io1 Io2 IoCalc		X6-7,8,9. See chapter 8. X6-10,11,12 IL1 + IL2 + IL3	 Set

For details of setting ranges see chapter 9.3.
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 earth faults: Time stamp, fault current, elapsed delay and setting group.

Recorded values of the undirectional earth fault stages (8 latest faults) I_0>, 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		Active setting group during fault

2.14. Intermittent transient earth fault protection I_{0T}> (67NT)

NOTE! This function is available only in voltage measurement modes[1], which include direct -U_0 measurement like for example U_0, but not for example in mode 1LL.

The directional intermittent transient earth fault protection is used to detect short intermittent transient faults in compensated cable networks. The transient faults are self extinguished at some zero crossing of the transient part of the fault current I_{Fault} and the fault duration is typically only 0.1 ms ... 1 ms. Such short intermittent faults can not be correctly recognized by normal directional earth fault function using only the fundamental frequency components of I_0 and U_0.

Although a single transient fault usually self extinguishes within less than one millisecond, in most cases a new fault happens when the phase-to-earth voltage of the faulty phase has recovered (Figure 2.14-1).

[1] The voltage measurement modes are described in a separate chapter.

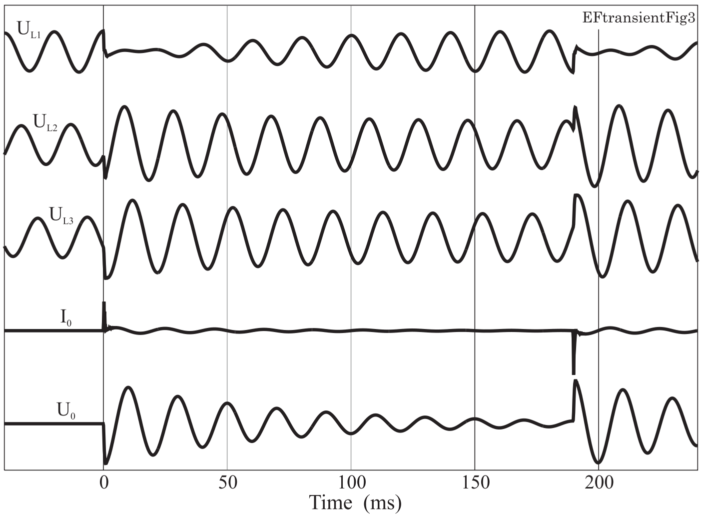


Figure 2.14-1 Typical phase to earth voltages, residual current of the faulty feeder and the zero sequence voltage U_0 during two transient earth faults in phase L1. In this case the network is compensated.

Direction algorithm

The function is sensitive to the instantaneous sampled values of the residual current and zero sequence voltage. The selected voltage measurement mode has to include a direct $-U_0$ measurement.

I_0 pick-up sensitivity

The sampling time interval of the relay is 625 μs at 50 Hz (32 samples/cycle). The I_0 current spikes can be quite short compared to this sampling interval. Fortunately the current spikes in cable networks are high and while the anti-alias filter of the relay is attenuates the amplitude, the filter also makes the pulses wider. Thus, when the current pulses are high enough, it is possible to detect pulses, which have duration of less than twenty per cent of the sampling interval. Although the measured amplitude can be only a fraction of the actual peak amplitude it doesn't disturb the direction detection, because the algorithm is more sensitive to the sign and timing of the I_0 transient than sensitive to the absolute amplitude of the transient. Thus a fixed value is used as a pick up level for the I_0.

Co-ordination with U_0> back up protection

Especially in a fully compensated situation, the zero sequence voltage back up protection stage U_0> for the bus may not release between consecutive faults and the U_0> might finally do an unselective trip if the intermittent transient stage I_{0T}> doesn't operate fast enough. The actual operation time of the I_{0T}> stage is very dependent on the behaviour of the fault and the intermittent time setting. To make the co-ordination between U_0> and I_{0T}> more simple, the start signal of the transient stage I_{0T}> in an outgoing feeder can be used to block the U_0> backup protection.

Co-ordination with the normal directional earth fault protection based on fundamental frequency signals

The intermittent transient earth fault protection stage I_{0T}> should always be used together with the normal directional earth fault protection stages Iφ>, Iφ>>. The transient stage I_{0T}> may in worst case detect the start of a steady earth fault in wrong direction, but will not trip because the peak value of a steady state sine wave I_0 signal must also exceed the corresponding base frequency component's peak value in order to make the I_{0T}> to trip.

The operation time and U_0 setting of the transient stage I_{0T}> should be higher than the settings of any Iφ> stage to avoid any unnecessary and possible incorrect start signals from the I_{0T}> stage.

Auto reclosing

The start signal of any Iφ> stage initiating auto reclosing (AR) can be used to block the I_{0T}> stage to avoid the I_{0T}> stage with a long intermittent setting to interfere with the AR cycle in the middle of discrimination time.

Usually the I_{0T}> stage itself is not used to initiate any AR. For transient faults the AR will not help, because the fault phenomena itself already includes repeating self extinguishing.

Intermittent time

Single transient faults make the protection to pick up, but will not cause trip if the stage has time to release between to successive faults. When starting happens often enough, such intermittent faults can be cleared using the intermittent time setting.

When a new fault happens within the set intermittent time, the operation delay counter is not cleared between adjacent faults and finally the stage will trip. A single transient fault is enough to start the stage and increase the delay counter by 20 ms. For example if the operating time is 140 ms, and the time between two peaks does not exceed the intermittent time setting, then the seventh peak will cause a trip (Figure 2.14-3).

Operation time setting and the actual operation time

When the algorithm detects the direction of the fault outwards from the bus, the stage picks up and the operation delay counter is incremented with 20 ms and a start signal is issued. If the time between successive faults is less than 40 ms, a trip signal is issued when the operation time is full.

When the time between successive faults is more than 40 ms, the stage will release between the faults and the delay counting is restarted from zero for every single fault and no trip will be issued. For such cases the intermittent setting can be used. Figure 2.14-2 shows an example of how the intermittent setting works. The upper start and trip signals are a case with zero intermittent setting. The lower signals are another case with intermittent setting 0.12 s. The operation time setting is 0.14 s in both cases corresponding to seven 20 ms time slots with faults.

The time between the second and the third fault exceeds the release time + intermittent time. Thus the operation delay counter is cleared in both cases: with zero intermittent time and with 0.12 s intermittent time.

The fourth and the next faults do occur after release time but within release time + intermittent time. Thus the operation delay counter is advanced at every fault in the case the intermittent time setting is more than 100 ms (the lower status lines in the figure) and finally a trip signal is issued at t=0.87 s.

When faults do occur more than 20 ms apart each other, every single fault will increment the operation delay counter by 20 ms. In this example the actual operation time starting from the third fault will be 617 ms although, the setting was 140 ms. In case the intermittent setting would have been 0.2 s or more, the two first faults had been included and a trip would have issued at t=0.64 s.

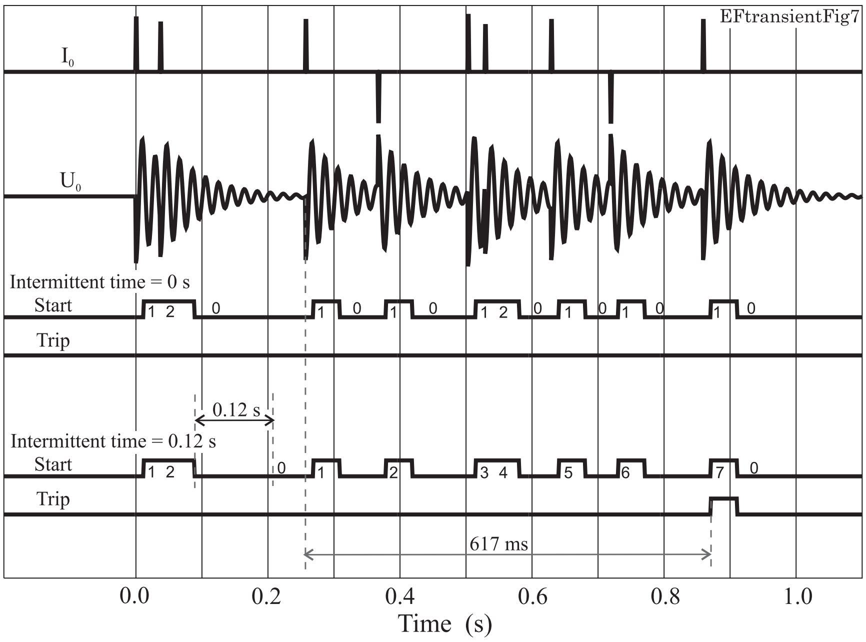


Figure 2.14-2. Effect of the intermittent time parameter. The operation delay setting is 0.14 s = 7x20 ms. The upper start and trip status lines are for a case with the intermittent time set to zero. No trip will happen. The lower start and trip status lines show another case with intermittent time setting 0.12 s. In this case a trip signal will be issued at t=0.87 s.

Setting groups

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

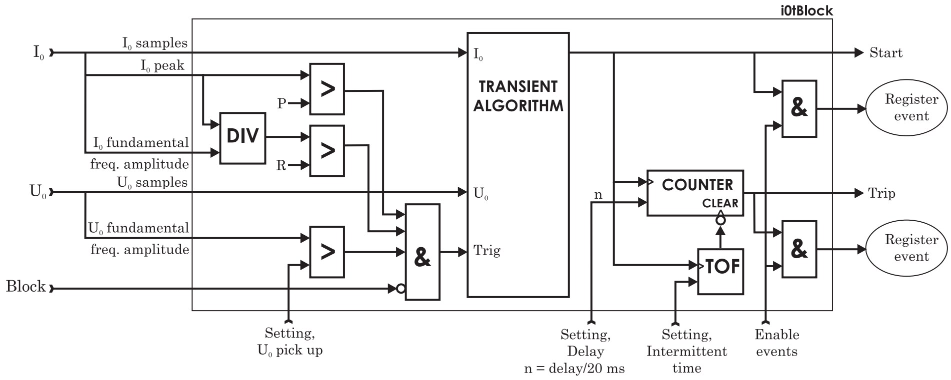


Figure 2.14-3. Block diagram of the directional intermittent transient earth fault stage I_{0T}>.

Parameters of the directional intermittent transient earth fault stage I_{0T}> (67NT)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	- DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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 after a five minute timeout.	Set
Io1 Io2		pu	The detected I_0 value according the parameter "Input" below.	
Uo		%	The measured U_0 value. U_{0N} = 100 %	
Uo>		%	U_0 pick up level. U_{0N} = 100 %	Set
t>		s	Operation time. Actually the number of cycles including faults x 20 ms. When the time between faults exceeds 20 ms, the actual operation time will be longer.	Set
Io input	Io1Peak Io2Peak		I_{01} Connectors X1-7&8 I_{02} Connectors X1-9&10	Set
Intrmt		s	Intermittent time. When the next fault occurs within this time, the delay counting continues from the previous value.	Set

For details of setting ranges see chapter 9.3 .

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 detected faults: Time stamp, U_0 voltage, elapsed delay and setting group.

Recorded values of the directional intermittent transient earth fault stage (8 latest faults) I_{0T}> (67NT)

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 detected earth fault current
EDly		%	Elapsed time of the operating time setting. 100% = trip
Uo		%	Max. U_0 voltage during the fault
SetGrp	1 2		Active setting group during fault

2.15. Capacitor bank unbalance protection

The device enables versatile capacitor, filter and reactor bank protection, with its five current measurement inputs. The fifth input is typically useful for unbalance current measurement of a double-wye connected unearthed bank. Furthermore, the unbalance protection is highly sensitive to internal faults of a bank because of the sophisticated natural unbalance compensation. However, the location method gives the protection a new dimension and enables easy maintenance monitoring for a bank.

This protection scheme is specially used in double wye connected capacitor banks. The unbalance current is measured with a dedicated current transformer (could be like 5A/5A) between two starpoints of the bank. The unbalance current is not affected by system unbalance. However, due to manufacturing tolerances, some amount of natural unbalance current exists between the starpoints. This natural unbalance current affects the settings, thus, the setting has to be increased.

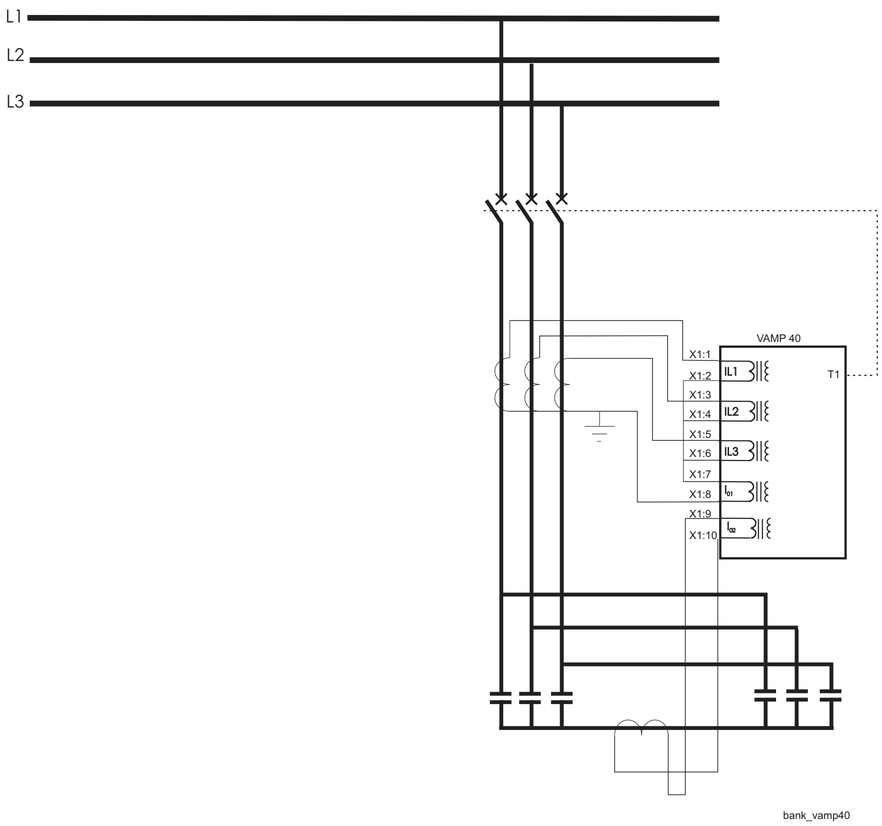


Figure 2.15-1 Typical capacitor bank protection application with VAMP 40.

Compensation method

The sophisticated method for unbalance protection is to compensate the natural unbalance current. The compensation is triggered manually when commissioning. The phasors of the unbalance current and one phase current are recorded. This is because one polarizing measurement is needed. When the phasor of the unbalance current is always related to I_{L1}, the frequency changes or deviations have no effect on the protection.

After recording the measured unbalance current corresponds the zero-level and therefore, the setting of the stage can be very sensitive.

Compensation and location

The most sophisticated method is to use the same compensation method as mentioned above, but the add-on feature is to locate the branch of each faulty element or to be more precise, the broken fuse.

This feature is implemented to the stage I_0>>>>, while the other stage I_0>>> can still function as normal unbalance protection stage with compensation method. Normally, the I_0>>>> could be set as an alarming stage while stage I_0>>> will trip the circuit-breaker.

The stage I_0>>>> should be set based on the calculated unbalance current change of one faulty element. This can be easily calculated. However, the setting must be, say 10% smaller than the calculated value, since there are some tolerances in the primary equipment as well as in the relay measurement circuit. Then, the time setting of I_0>>>> is not used for tripping purposes. The time setting specifies, how long the device must wait until it is certain that there is a faulty element in the bank. After this time has elapsed, the stage I_0>>>> makes a new compensation automatically, and the measured unbalance current for this stage is now zero. Note, the automatic compensation does not effect on the measured unbalance current of stage I_0>>>.

If there is an element failure in the bank, the algorithm checks the phase angle of the unbalance current related to the phase angle of the phase current I_{L1}. Based on this angle, the algorithm can increase the corresponding faulty elements counter (there are six counters).

The user can set for the stage I_0>>>> the allowed number of faulty elements, e.g. if set to three elements, the fourth fault element will issue the trip signal.

The fault location is used with internal fused capacitor and filter banks. There is no need to use it with fuseless or external fused capacitor and filter banks, nor with the reactor banks.

Setting parameters of capacitor bank unbalance protection:

I_0>>>, I_0>>>> (50N/51N)

Parameter	Value	Unit	Default	Description
Io>>>	0.01 … 20.00	pu	0.10	Setting value
Io>>>>	0.01 … 20.00	Pu	0.20	Setting value
t>	0.08 … 300.00	s	0.50 (Io>>>), 1.00 (Io>>>>)	Definite operating time
Input	Io1; Io2; IoCalc	-	Io2	Current measurement input. **NOTE!** Do not use the calculated value which is only for earth fault protection purposes
CMode	Off; On (Io>>>); Off; Normal; Location(Io>>>>)	-	Off	Compensation selection
SaveBa	-; Get	-	-	Trigg the phasor recording
SetBal	0.010 … 3.000	pu	0.050	Compensation level
S_On	On; Off	-	On	Start on event
S_Off	On; Off	-	On	Start off event
T_On	On; Off	-	On	Trip on event

Parameter	Value	Unit	Default	Description
T_Off	On; Off	-	On	Trip off event
DIoSav	On; Off	-	Off	Recording trigged event
DIoSav	On; Off	-	Off	Recording ended event

Measured and recorded values of capacitor bank unbalance protection:

I_0>>>, I_0>>>> (50N/51N)

	Parameter	Value	Unit	Description
Measured values	Io		Pu	unbalance current (including the natural unbalance current)
	dIo		A	Compensated unbalance current
Display	Io>>>, Io>>>>		A	Setting value
Recorded values	SCntr		-	Cumulative start counter
	TCntr		-	Cumulative trip counter
	Flt		pu	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping
	Isaved		A	Recorded natural unbalance current
	SavedA		deg	Recorded phase angle of natural unbalance current
	Faults (Io>>>>only)		-	Allowed number of element failures
	Total (Io>>>>only)		-	Actual number of element failures in the bank
	Clear (Io>>>>only)	-; Clear	-	Clear the element counters
	L1-B1 (Io>>>>only)		-	Number of element failures in phase L1 in brach 1 (left side)
	L1-B2 (Io>>>>only)		-	Number of element failures in phase L1 in brach 2 (right side)
	L2-B1 (Io>>>>only)		-	Number of element failures in phase L2 in brach 1 (left side)
	L2-B2 (Io>>>>only)		-	Number of element failures in phase L2 in brach 2 (right side)
	L3-B1 (Io>>>>only)		-	Number of element failures in phase L3 in brach 1 (left side)
	L3-B2 (Io>>>>only)		-	Number of element failures in phase L3 in brach 2 (right side)
	Locat (Io>>>>only)		-	Changed unbalance current (after automatic compensation)
	LocAng (Io>>>>only)		-	Changed phase angle of the unbalance current (after automatic compensation)

2.16. Capacitor overvoltage protection U_C> (59C)

This protection stage calculates the voltages of a three phase Y-connected capacitor bank using the measured currents of the capacitors. No voltage measurements are needed.

Especially in filter applications there exist harmonics and depending of the phase angles the harmonics can increase the peak voltage. This stage calculates the worst case overvoltage in per unit using Equation 2.16-1(IEC 60871-1). Harmonics up to 15[th] are taken into account.

Equation 2.16-1

$$U_C = \frac{X_C}{U_{CLN}} \sum_{n=1}^{15} \frac{I_n}{n}$$ where

Equation 2.16-2

$$X_C = \frac{1}{2\pi fC}$$

U_C	=	Amplitude of a pure fundamental frequency sine wave voltage, which peak value is equal to the maximum possible peak value of the actual voltage – including harmonics - over a Y-coupled capacitor.
X_C	=	Reactance of the capacitor at the measured frequency
U_{CLN}	=	Rated voltage of the capacitance C.
n	=	Order number of harmonic. n=1 for the base frequency component. n=2 for 2[nd] harmonic etc.
I_n	=	n[th] harmonic of the measured phase current. n = 1 ... 15.
f	=	Average measured frequency.
c	=	Single phase capacitance between phase and star point. This is the setting value C_{SET}.

The Equation 2.16-1 gives the maximum possible voltage, while the actual voltage depends on the phase angles of the involved harmonics.

The protection is sensitive for the highest of the three phase-to-neutral voltages. 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 definite operation delay setting, a trip signal is issued.

Reactive power of the capacitor bank

The rated reactive power is calculated as follows

Equation 2.16-3

$$Q_N = 2\pi f_N U_{CLN}^2 C_{SET}$$ where

Q_N	=	Rated reactive power of the three phase capacitor bank
f_N	=	Rated frequency. 50 Hz or 60 Hz. This is detected automatically or in special cases given by the user with parameter adapted frequency.
U_{CLN}	=	Rated voltage of a single capacitor.
C_{SET}	=	Capacitance setting which is equal to the single phase capacitance between phase and the star point.

Three separate capacitors connected in wye (III Y)

In this configuration the capacitor bank is built of three single phase sections without internal interconnections between the sections. The three sections are externally connected to a wye (Y). The single phase to star point capacitance is used as setting value.

Equation 2.16-4

$$C_{SET} = C_{NamePlate}$$ where

$C_{NamePlate}$ is the capacitance of each capacitor.

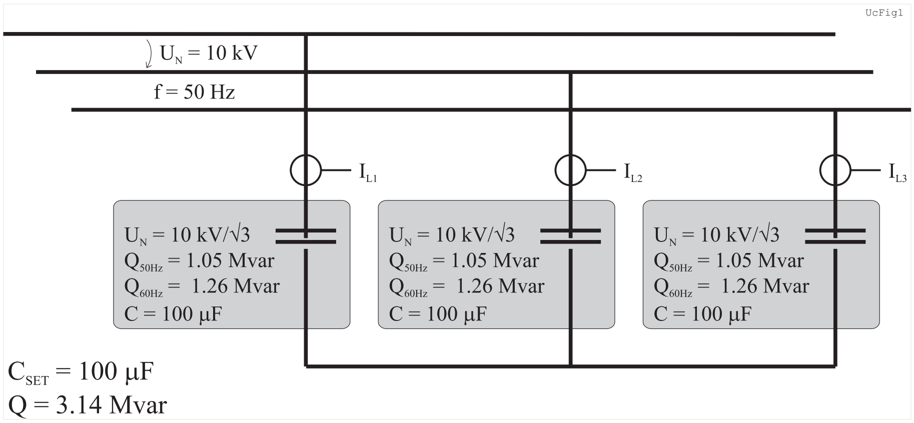


Figure 2.16-1 Capacitor bank built of three single phase units connected in wye (III Y). Each capacitor is 100 µF and this value is also used as the setting value.

Three phase capacitor connected internally in wye (Y)

In this configuration the capacitor bank consists of a three phase capacitor connected internally to a wye (Y).

The single phase to star point capacitance is used as setting value.

Equation 2.16-5

$$C_{SET} = 2C_{AB} \quad \text{where}$$

C_{AB} is the name plate capacitance which is equal to capacitance between phases A and B.

The reactive power is calculated using Equation 2.16-3.

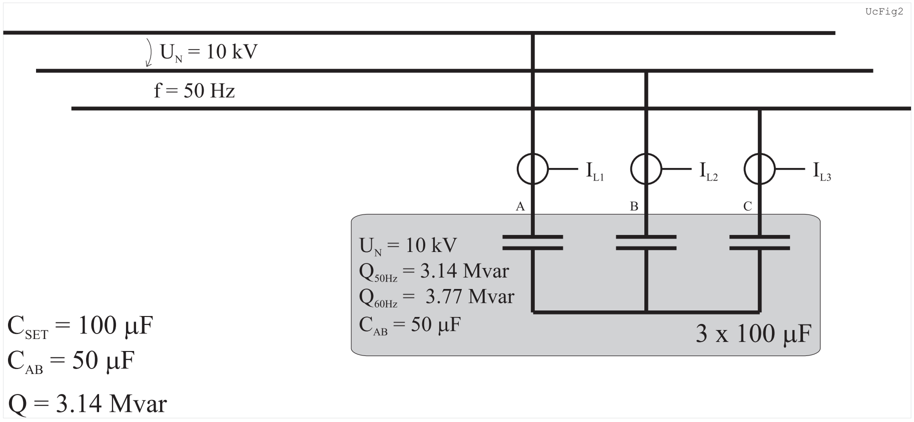


Figure 2.16-2 Three phase capacitor bank connected internally in wye (Y). Capacitance between phases A and B is 50 µF and the equivalent phase-to-neutral capacitance is 100 µF, which value is also used as the setting value.

Overvoltage and reactive power calculation example

The capacitor bank is built of three separate 100 µF capacitors connected in wye (Y). The rated voltage of the capacitors is 8000 V, the measured frequency is 50.04 Hz and the rated frequency is 50 Hz.

The measured fundamental frequency current of phase L1 is:

$I_{L1} = 181$ A

and the measured relative 2nd harmonic is

2 % = 3.62 A

and the measured relative 3rd harmonic is

7 % = 12.67 A

and the measured relative 5th harmonic is

5 % = 9.05 A

According Equation 2.16-4 the line-to-star point capacitance is C_{SET} = 100 µF (see Figure 2.16-1).

The rated power will be (Equation 2.16-3)

Q_N = 2011 kvar

According Equation 2.16-2 the reactance will be

$X = 1/(2\pi \times 50.04 \times 100{*}10^{-6}) = 31.806\ \Omega$.

According Equation 2.16-1 a pure fundamental voltage U_C having equal peak value than the highest possible voltage with corresponding harmonic content than the measured reactive capacitor currents, will be

U_{CL1} = 31.806*(181/1 + 3.62/2 + 12.67/3 + 9.05/5) = 6006 V

And in per unit values:

U_{CL1} = 6006/8000 = 0.75 pu

The phases L2 and L3 are calculated similarly. The highest value of the three will be compared against the pick up setting.

Setting groups

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

Parameters of the capacitor bank overvoltage stage U_C> (59C)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F F
SCntr			Cumulative start counter	Clr
TCntr			Cumulative trip counter	Clr
SetGrp	1 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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
UcL1 UcL2 UcL3		pu	The supervised values in per unit values. 1 pu = UcLN. (Equation)	
Uc>		pu	Pick-up setting	Set
t>		s	Definite operation time	Set
C		uF	Value of a phase to star point capacitor	Set

Parameter	Value	Unit	Description	Note
UcLN		V	Rated voltage for phase to star point capacitor = 1 pu	Set
Qcn		kvar	Rated power of the capacitor bank. (Equation 2.16-3)	
fn	50 or 60	Hz	System frequency used to calculate rated power Qcn. Automatically set according the adapted frequency.	
Xc		ohm	Reactance of the capacitor(s)	
fXc		Hz	Measured average frequency for Xc and UcLN calculation	
UcLL		V	√3 x UcLN	

For details of setting ranges see chapter 9.3.

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 type, fault voltage, elapsed delay and setting group in use.

Recorded values of the overvoltage stage (8 latest faults) U_C> (59C)

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		Single phase fault
	2-N		Single phase fault
	3-N		Single phase fault
	1-2		Two phase fault
	2-3		Two phase fault
	3-1		Two phase fault
	1-2-3		Three phase fault
Flt		pu	Maximum fault voltage
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during the fault

2.17. 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 3n 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 measured with three voltage transformers (e.g. broken delta connection), one voltage transformer between the motor's neutral point and earth. (see chapter 4.7):

- 1LL / 1LN: the zero sequence voltage is disabled due to no U_0 measured.
- 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 VT0 secondary voltage defined in configuration.

NOTE! The U_0 signal must be connected according the connection diagram (Figure 8.10-1Figure) in order to get a correct polarization. Please note that actually the negative U_0, $-U_0$, is to be connected to the device.

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 adjust-table zero sequence voltage stages (stage U_0> and U_0>>).

Setting groups

There are two settings groups available for both stages. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually.

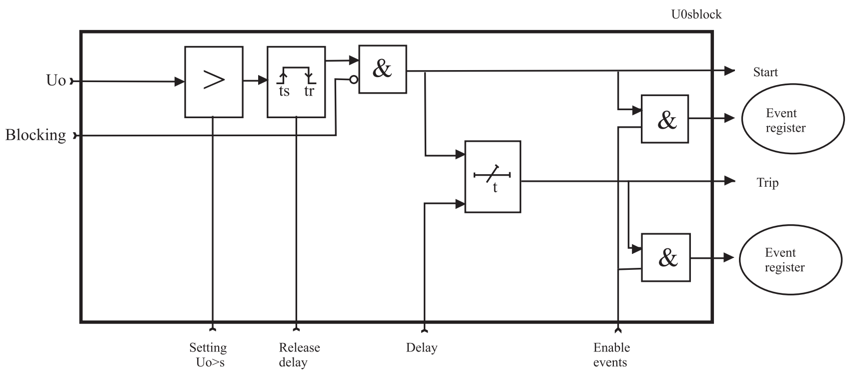


Figure 2.17-1. Block diagram of the zero sequence voltage stages U_0> and U_0>>

Parameters of the residual overvoltage stages U_0>, U_0>> (59N)

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 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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/√3	
Uo>, Uo>>		%	Pick-up value relative to Un/√3	Set
t>, t>>		s	Definite operation time	Set

For details of setting ranges see chapter 9.3.

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.

Recorded values of the residual overvoltage stages U_0>, U_0>> (59N)

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/√3
EDly		%	Elapsed time of the operating time setting. 100% = trip
SetGrp	1 2		Active setting group during fault

2.18. Thermal overload protection T> (49)

The thermal overload function protects the motor in the motor mode or cables in the feeder mode 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: $$t = \tau \cdot \ln \frac{I^2 - I_P^{\ 2}}{I^2 - a^2}$$

Alarm: $a = k \cdot k\Theta \cdot I_{mode} \cdot alarm$ (Alarm 60% = 0.6)

Trip: $a = k \cdot k\Theta \cdot I_{mode}$

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

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

Start release: $a = \sqrt{0.95} \times k \times I_n \times alarm$ (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%→ $\theta = 1.2$). 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)

k_Θ	=	Ambient temperature factor (Permitted current due to tamb) Figure 2.18-1.
I_{MODE}	=	The rated current (I_N or I_{MOT})
C_τ	=	Relay cooling time constant (Setting value)

Time constant for cooling situation

If the motor's fan is stopped, the cooling will be slower than with an active fan. Therefore there is a coefficient c_τ for thermal constant available to be used as cooling time constant, when current is less than $0.3 x I_{MOT}$.

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 motor or 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.

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

The value of ambient temperature compensation factor k_Θ depends on the ambient temperature Θ_{AMB} and settings I_{MAX40} and I_{MAX70}. See Figure 2.18-1. Ambient temperature is not in use when $k_\Theta = 1$. This is true when

- IMAX40 is 1.0
- Samb is “n/a” (no ambient temperature sensor)
- TAMB is +40 °C.

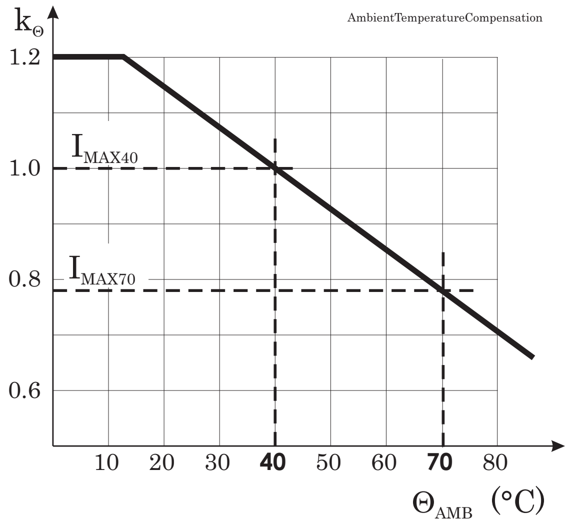


Figure 2.18-1 Ambient temperature correction of the overload stage T>.

Example of a behaviour of the thermal model

Figure 2.18-2 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 $0.85xI_{MODE}$ 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.

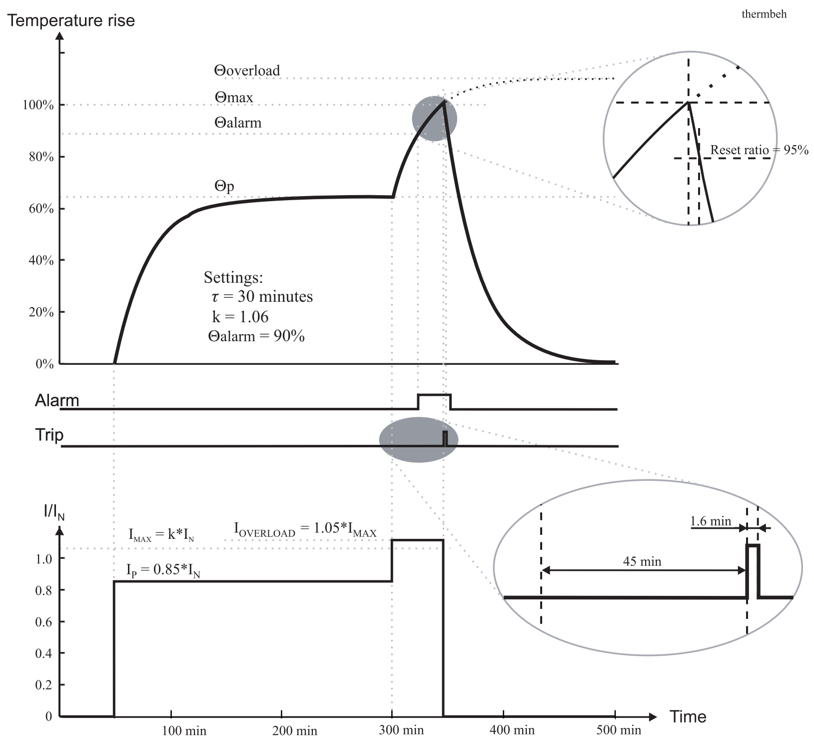


Figure 2.18-2. Example of the thermal model behaviour.

Parameters of the thermal overload stage T> (49)

Parameter	Value	Unit	Description	Note
Status	- Blocked Start Trip		Current status of the stage	 F 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	kxIn. Current corresponding to the 100 % temperature rise.	
k>		xImode	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		xImode	Ambient temperature corrected max. allowed continuous current	
Imax40		%Imode	Allowed load at Tamb +40 °C. Default = 100 %.	Set
Imax70		%Imode	Allowed load at Tamb +70 °C.	Set
Tamb		°C	Ambient temperature. Editable Samb=n/a. Default = +40 °C	Set
Samb	 n/a ExtAI1...16		Sensor for ambient temperature No sensor in use for Tamb External Analogue input 1...16	 Set

For details of setting ranges see chapter 9.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

2.19. Single-phase overvoltage protection U> (59)

The single-phase overvoltage function consists of three separately adjustable overvoltage stages (stage U>, U>> and U>>>).

The device measures the fundamental frequency component of a single phase-to-neutral (1LN) or a line-to-line (1LL) voltage. Then the three-phase voltage calculation is done, assuming that all the voltages are symmetrical, i.e. no zero sequence voltage is present. The protection stages operate with definite time characteristics.

The function starts if the measured value exceeds the setting value. If an overvoltage situation continues after the operation time has elapsed, the function trips.

The overvoltage stages have a fixed start delay. If a delayed alarm about a voltage fault is required, a settable start delay and trip time can be obtained by combining two stages. See Figure 2.19-1. Both the stages detect the overvoltage, but the start signals are ignored. The trip signal of stage U> is used as an alarm signal, and the trip information from stage U>> is used for the actual trip. The overvoltage setting value for stage U>> has to be higher than the setting value for stage U> to ensure an alarm before trip.

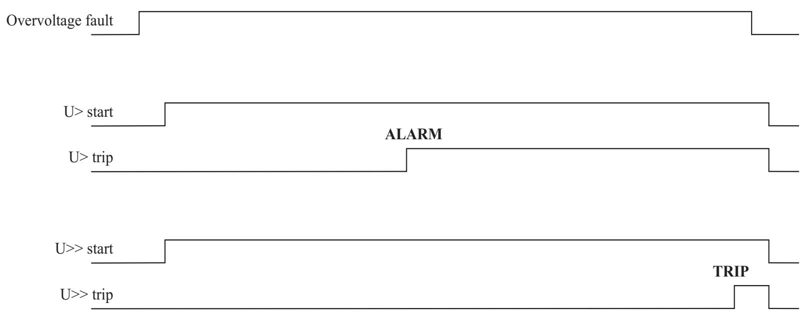


Figure 2.19-1 Settable start delay is obtained by combining two protection stages

The U> stage has a settable release delay, which enables detecting instantaneous faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets only after the release delay has elapsed. If the fault appears again before the delay time has elapsed, the delay counter continues from the previous value. This means that the function trips after a certain number of instantaneous faults.

Figure 2.19-2 shows the functional block diagram of the overvoltage function stages U>, U>> and U>>>.

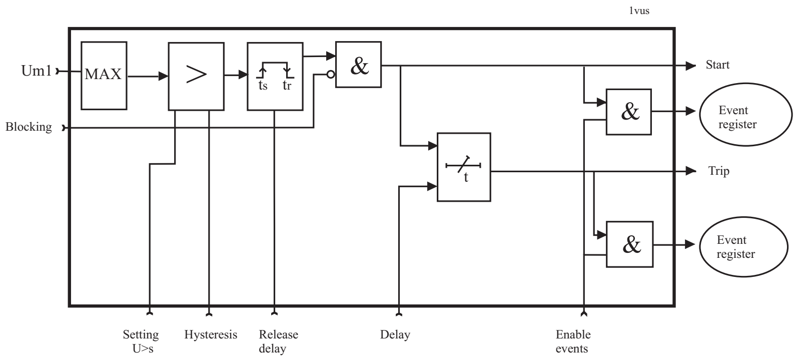


Figure 2.19-2 Block diagram of the single-phase overvoltage stages U>, U>> and U>>>

Setting parameters of single-phase overvoltage stages:

U>, U>>, U>>> (59)

Parameter	Value	Unit	Default	Description
U>, U>>, U>>>	50 … 150 (U>); 50 … 160 (U>>,U>>>)	%Un	120 (U>) 130 (U>>, U>>>)	Overvoltage setting
t>, t>>, t>>>	0.08 … 300.0 (U>,U>>); 0.06 … 300.00 (U>>>)	s	0.20 (U>) 0.10 (U>>, U>>>)	Definite operation time
ReleaseDly	0.06 … 300.0	s	-	Release delay [s] (only U>)
Hysteresis	0.1 … 20.0	%	-	Deadband (only U>)
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

Measured and recorded values of single-phase overvoltage stages:

U>, U>>, U>>> (59)

	Parameter	Value	Unit	Description
Measured value	Umax		V	Maximum value of line voltages
Recorded values	SCntr		-	Start counter (Start) reading
	TCntr		-	Trip counter (Trip) reading
	Flt		%Un	The max. fault value
	EDly		%	Elapsed time as compared to the set operating time; 100% = tripping

2.20. Single-phase undervoltage protection U< (27)

The single-phase undervoltage function consists of three separately adjustable undervoltage stages (stage U<, U<< and U<<<).

The device measures the fundamental frequency component of a single phase-to-neutral (1LN) or a line-to-line (1LL) voltage. Then the three-phase voltage calculation is done, assuming that all the voltages are symmetrical, i.e. no zero sequence voltage is present. The protection stages operate with definite time characteristics.

The function starts, if the measured or calculated line-to-line voltage drops below the setting value. If the undervoltage situation continues after the start delay has elapsed, the function trips.

The undervoltage stage U< has a settable release delay, which enables detecting instantaneous faults. This means that the time counter of the protection function does not reset immediately after the fault is cleared, but resets only after the release delay has elapsed. If the fault appears again before the delay time has elapsed, the trip counter continues from the previous fault value. This means that the function trips after a certain number of instantaneous faults.

The undervoltage function can be blocked with an external digital signal for example if the secondary voltage of the measuring transformers disappears (e.g. fuse failure). The undervoltage function can also be blocked with an internal blocking signal, which is defined during the parameterisation. Further, the function can be blocked with a separate NoCmp setting. With this setting, all the protection stages are blocked even when the actual values for all the phases fall below the set value.

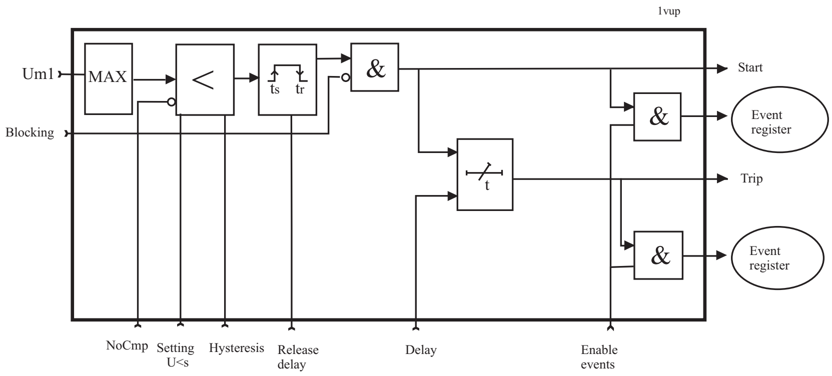


Figure 2.20-1 Block diagram of the single-phase undervoltage stages U<, U<< and U<<<

Setting parameters of single-phase undervoltage stages:

U<, U<<, U<<< (27)

Parameter	Value	Unit	Default	Description
U<, U<<, U<<<	20 … 120	%Un	80 (U<) 70 (U<<, U<<<)	Undervoltage setting
t<, t<<, t<<<	0.08 … 300.00 0.06 … 300.00	s	20.00 (U<) 2.00 (U<<, U<<<)	Definite operation time
NoCmp	0 … 80	%Un	10	Self-blocking value
ReleaseDly	0.06 … 300.0	s	-	Release delay (only U<)
Hysteresis	0.1 … 20.0	%	-	Deadband (only U<)
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

Measured and recorded values of single-phase undervoltage stages:

U<, U<<, U<<< (27)

	Parameter	Value	Unit	Description
Measured value	Umin		V	Minimum value of line voltages
Recorded values	SCntr		-	Start counter (Start) reading
	TCntr		-	Trip counter (Trip) reading
	Flt		%Un	The min. fault value
	EDly		%	Elapsed time as compared to the set operating time, 100% = tripping

2.21. Reverse power and under power protection P< (32)

NOTE! The reverse power and underpower stages are based on three- phase active power. Since VAMP 40 is only measuring one voltage, any asymmetry in voltages will distort the power calculation. For example, if the voltage asymmetry U_2/U_1 is 5%, the power may have an error up to 10%.

Reverse power function can be used for example to disconnect a motor in case the supply voltage is lost and thus prevent power generation by the motor. Under power function can also be used to detect loss of load of a motor.

Reverse power and under power function is sensitive to active power. For reverse power function the pick-up value is negative. For under power function a positive pick-up value is used. Whenever the active power goes under the pick-up value, the stage picks up and issues a start signal. If the fault situation stays on longer than the delay setting, a trip signal is issued.

The pick-up setting range is from –200 % to +200 % of the nominal apparent power Sn. The nominal apparent power is determined by the configured voltage and current transformer values.

Equation 2.21-1

$$S_n = VT_{Rated\ Primary} \cdot CT_{Rated\ Primary} \cdot \sqrt{3}$$

There are two identical stages available with independent setting parameters.

Setting parameters of reverse/under power P< and P<< stages (32):

Parameter	Value	Unit	Default	Description
P<, P<<	-200.0 ... 200.0	%Sn	-4.0 (P<), -20.0(P<<)	P<,P<< pick-up setting
t<	0.3 … 300.0	s	1.0	P<, P<< operational delay
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

Measured and recorded values of reverse/under power P< and P<< stages (32):

	Parameter	Value	Unit	Description
Measured value	P		kW	Active power
Recorded values	SCntr		-	Start counter (Start) reading
	TCntr		-	Trip counter (Trip) reading
	Flt		%Sn	Max value of fault
	EDly		%	Elapsed time as compared to the set operating time, 100% = tripping

2.22. Circuit breaker failure stage 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 relay. See chapter 5.4 for details about the output matrix and the trip relays.

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	1 - 4		The supervised output relay*). Relay T1 – T4	Set
t>		s	Definite operation time.	Set

For details of setting ranges see chapter 9.3.

Set = An editable parameter (password needed)

C = Can be cleared to zero

F = Editable when force flag is on

*) This setting is used by the circuit breaker condition monitoring, too. See chapter 3.5.

Recorded values of the latest eight faults

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

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

2.23. Programmable stages (99)

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

The following parameters are available:

- **Priority**
  If operation times less than 60 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.
- **Link**
  The name of the supervised signal (see table below).
- **Cmp**
  Compare mode. '>' for over or '<' for under comparison.
- **Pick-up**
  Limit of the stage. The available setting range and the unit depend on the selected signal.
- **T**
  Definite time operation delay
- **Hyster**
  Dead band (hysteresis)
- **NoCmp**
  Only used with compare mode under ('<'). This is the limit to start the comparison. Signal values under NoCmp are not regarded as fault.

Available signals to be supervised by the programmable stages

IL1, IL2, IL3	Phase currents
Io1	Residual current input I_{01}
Io2	Residual current input I_{02}
U12, U23, U31	Line-to-line voltages
UL1, UL2, UL3	Phase-to-ground voltages
Uo	Zero-sequence voltage
f	Frequency
P	Active power
Q	Reactive power
S	Apparent power
Cos Fii	Cosine φ
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
U1	Positive sequence voltage
U2	Negative sequence voltage
U2/U1	Relative negative sequence voltage
IL	Average $(I_{L1} + I_{L2} + I_{L3})/3$
Uphase (U_{LN})	Average $(U_{L1} + U_{L2} + U_{L3})/3$
Uline (U_{LL})	Average $(U_{12} + U_{23} + U_{31})/3$
TanFii	Tangent φ [=tan(arccosφ)]
Prms	Active power rms value
Qrms	Reactive power rms value
Srms	Apparent powre rms value
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 input U_a
IL1rms	IL1 RMS for average sampling
IL2rms	IL2 RMS for average sampling
IL3rms	IL3 RMS for average sampling

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 two settings groups available. Switching between setting groups can be controlled by digital inputs, virtual inputs (communication, logic) and manually.

There are two identical stages available with independent setting parameters.

Parameters of the programmable stages PrgN (99)

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 or 2		Active setting group	Set
SGrpDI	 - DIx VIx LEDx VOx		Digital signal to select the active setting group None Digital input Virtual input LED indicator signal Virtual output	Set
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
Link	(See table above)		Name for the supervised signal	Set
(See table above)			Value of the supervised signal	
Cmp	 > <		Mode of comparison Over protection Under protection	Set
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.

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		Active setting group during fault

2.24. Arc fault protection (50ARC/50NARC)-optional

The arc option module (VP 40) is connected to the back of the VAMP 40 protection relay. The RJ 45 connector is plugged to the X20 connector and the module is fasted to the back of VAMP 40 with one screw.

The optional arc protection module VP 40 includes two arc sensor channels. The arc sensors are connected to the VP 40 terminals 12-11 and 8-7.

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.

Connections:

1	Binary output +
2	Binary output -
5	Binary input +
6	Binary input –
7-8	Arc sensor 2 (VA 1 DA)
11-12	Arc sensor 1 (VA 1 DA)

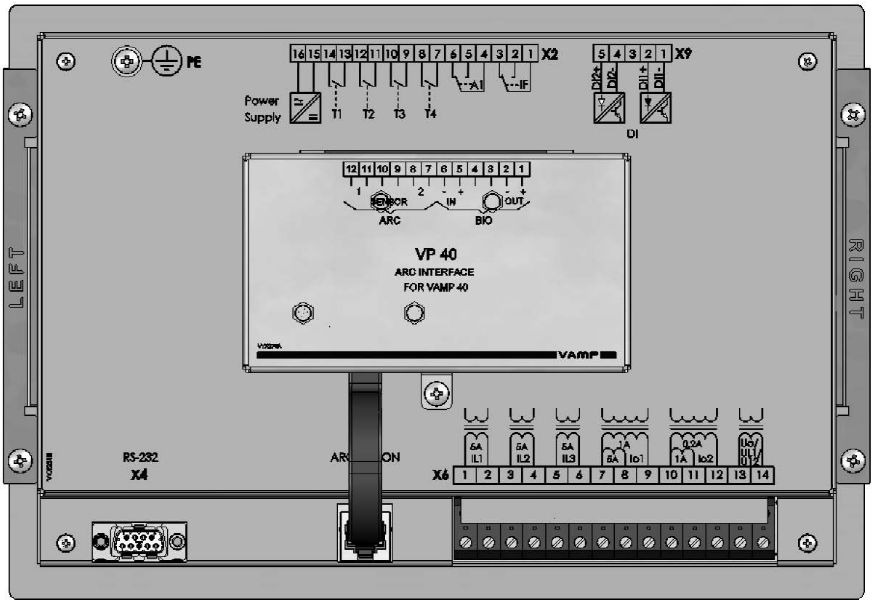


Figure 2.24-1 VP 40 is attached at the back side of the VAMP 40.

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.

Binary input

The binary input (BI) on the arc option card (see chapter 8.6) can be used to get the light indication from another relay to build selective arc protection systems. The BI signal can also be connected to any of the output relays, BO, indicators etc. offered by the output matrix (See chapter 5.4). BI is a dry input for 48 Vdc 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 8.6) 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 output matrix (See chapter 5.4). BO is an internally wetted 48 Vdc signal for BI of other VAMP relays or dedicated arc protection devices by VAMP.

Delayed light indication signal

There is a delayed light indication output signal available for building selective arc protection systems. Any light source combination and a delay can be configured. 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 = 1xI_N = rated phase current CT value

ArcI_{01}>: 1 pu = 1xI_{01N} = rated residual current CT value for input I_{01}.

ArcI_{02}>: 1 pu = 1xI_{02N} = rated residual current CT value for input I_{02}.

Parameters of arc protection stages
ArcI>, ArcI_{01}A, ArcI_{02}> (50ARC/50NARC)

Parameter	Value	Unit	Description	Note
Status	- Start Trip		Current status of the stage Light detected according ArcIn Light and overcurrent detected	 F F
LCntr			Cumulative light indication counter. S1, S2 or BI.	C
SCntr			Cumulative light indication counter for the selected inputs according parameter ArcIn	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
 ILmax Io1 Io2			Value of the supervised signal Stage ArcI> Stage ArcI_{01}> Stage ArcI_{02}>	
ArcI> ArcIo1> ArcIo2>		pu pu pu	Pick up setting xI_N Pick up setting xI_{01N} Pick up setting xI_{02N}	Set
ArcIn	 – S1 S2 S1/S2 BI S1/BI S2/BI S1/S2/BI		Light indication source selection No sensor selected Sensor 1 at terminals X6:4-5 Sensor 2 at terminals X6:6-7 Terminals X6:1-3	Set

Parameter	Value	Unit	Description	Note
Delayed light signal output				
Ldly		s	Delay for delayed light output signal	Set
LdlyCn			Light indication source selection	Set
	–		No sensor selected	
	S1		Sensor 1 at terminals X6:4-5	
	S2		Sensor 2 at terminals X6:6-7	
	S1/S2			
	BI		Terminals X6:1-3	
	S1/BI			
	S2/BI			
	S1/S2/BI			

For details of setting ranges see chapter 9.3.

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 type, fault value, load current before the fault and elapsed delay.

Recorded values of the arc protection stages ArcI>, ArcI$_{01}$A, ArcI$_{02}$> (50ARC/50NARC)

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

2.25. Inverse time operation

The inverse time operation - i.e. inverse delay 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 2.25.1.
- 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 2.25.2.
- 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 2.25.3.

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 $50xI_N$ and the maximum directly measured earth fault current is $10xI_{0N}$ for residual current inputs. 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.

Table 2.25-1

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_{01} 5 A	50 A	2.5 A
I_{01} 1 A and I_{02} 1 A	10 A	0.5 A
I_{02} 0.2 A	2 A	0.1 A

Example 1 of limitation

CT = 750/5

Application mode is Feeder

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

The CT_0 is connected to a 1 A terminals of input I_{01} or I_{02}.

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 $A_{Primary}$.

Example 2 of limitation

CT = 750/5

Application mode is Motor

Rated current of the motor = 600 A

I_{0Calc} (= I_{L1} +I_{L2} +I_{L3}) is used for residual current

At secondary level the rated motor current is 600/750*5 = 4 A

For overcurrent stage I> the table above gives 12.5 A. Thus the maximum setting giving full inverse delay range is 12.5 A / 4 A = 3.13 xI_{MOT} = 1875 $A_{Primary}$.

For earth fault stage I_0> the table above gives 12.5 A. Thus the maximum setting for I_0> stage giving full inverse delay range is 12.5 A / 5 A = 2.5 xI_{0N} = 1875 $A_{Primary}$.

2.25.1. 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 2.25 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 2.25 for more details.

Table 2.25.1-1. 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				
NI1	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 2.25.1-1. 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 2.25.1-1

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

t = Operation delay in seconds
k = User's multiplier
I = Measured value
Ipickup = User's pick up setting
A, B = Constants parameters according Table 2.25.1-2.

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 2.25.1-2 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 2.25.1-1.

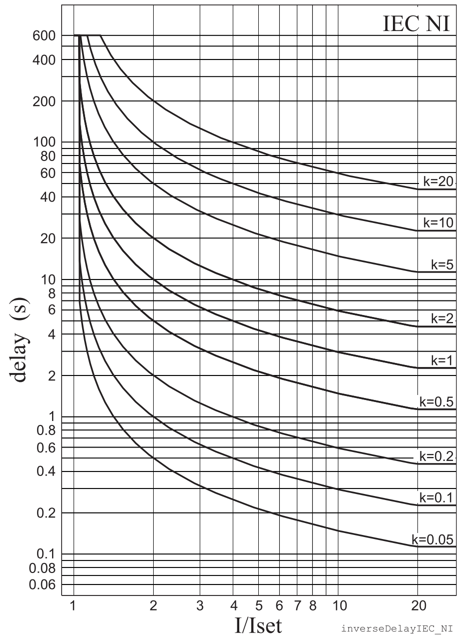


Figure 2.25.1-1 IEC normal inverse delay.

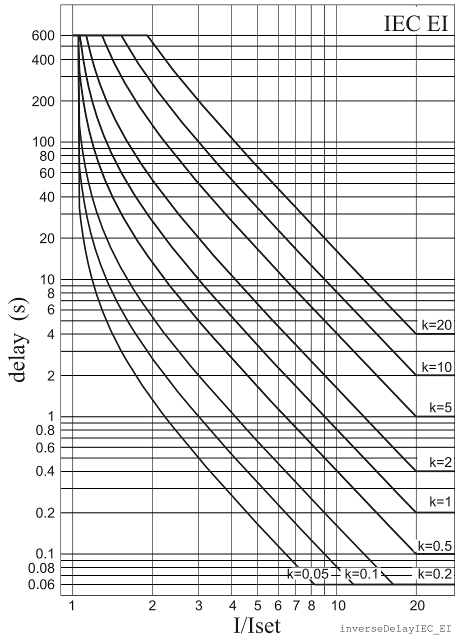


Figure 2.25.1-2 IEC extremely inverse delay.

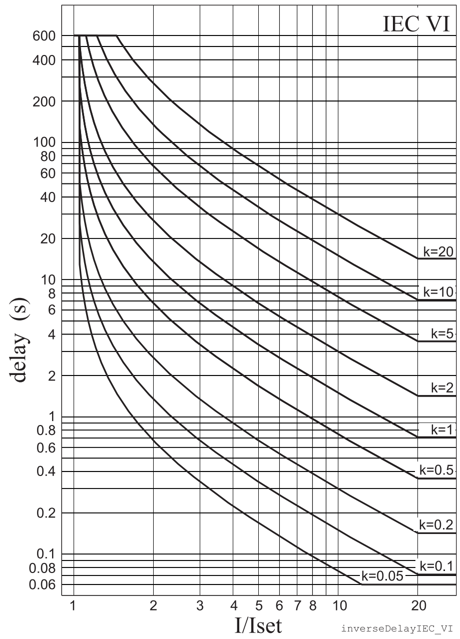


Figure 2.25.1-3 IEC very inverse delay.

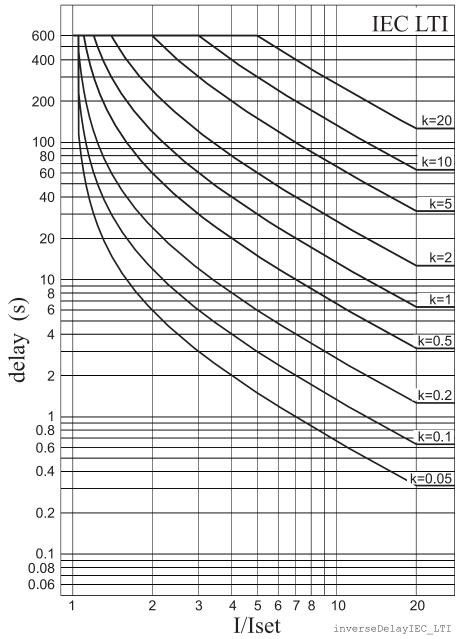


Figure 2.25.1-4 IEC long time inverse delay.

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 2.25.1-3. 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 2.25.1-2. 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 2.25.1-2

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

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 2.25.1-3.

Table 2.25.1-3 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 2.25.1-8.

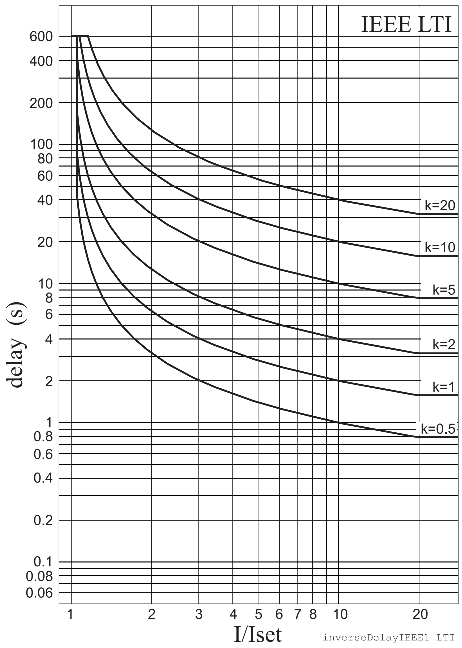


Figure 2.25.1-5 ANSI/IEEE long time inverse delay

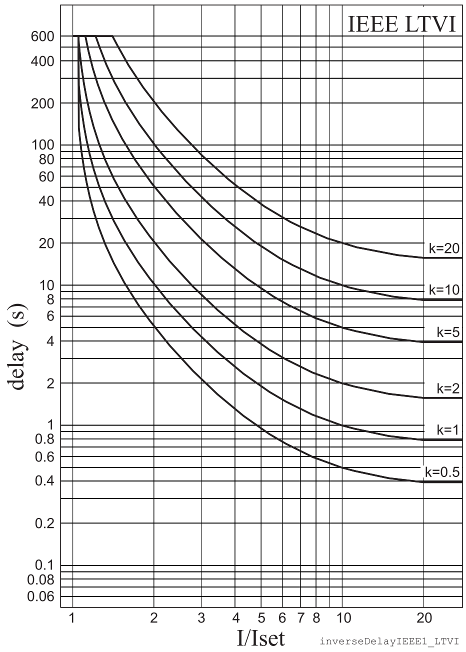


Figure 2.25.1-6 ANSI/IEEE long time very inverse delay

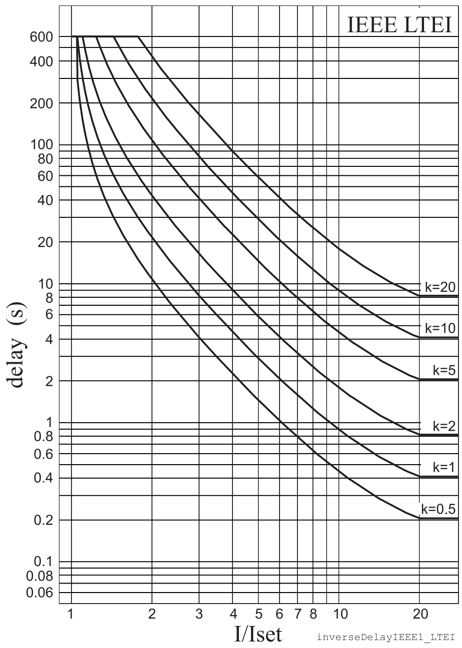


Figure 2.25.1-7 ANSI/IEEE long time extremely inverse delay

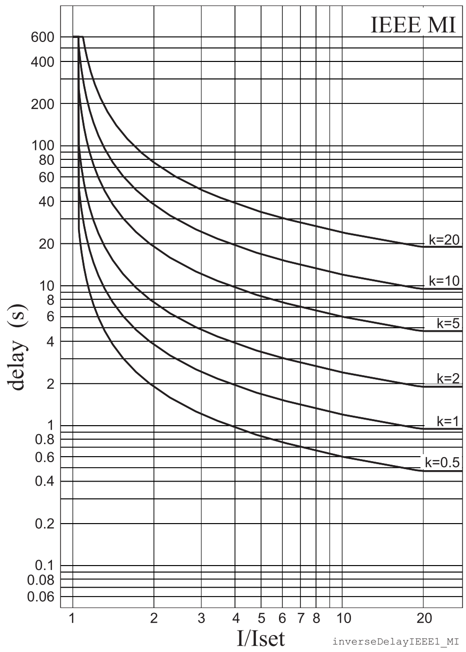


Figure 2.25.1-8 ANSI/IEEE moderately inverse delay

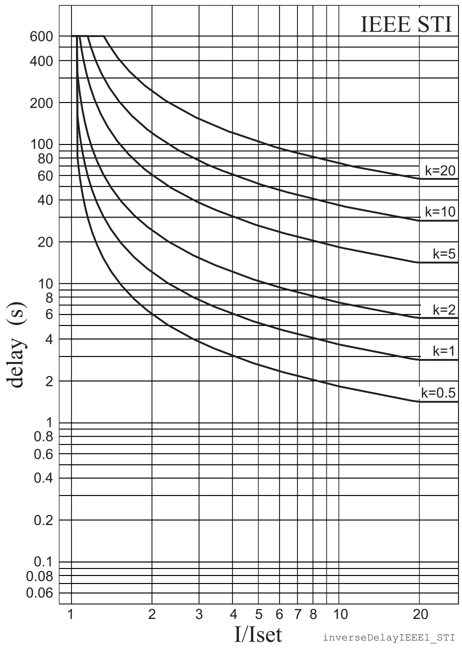


Figure 2.25.1-9 ANSI/IEEE short time inverse delay

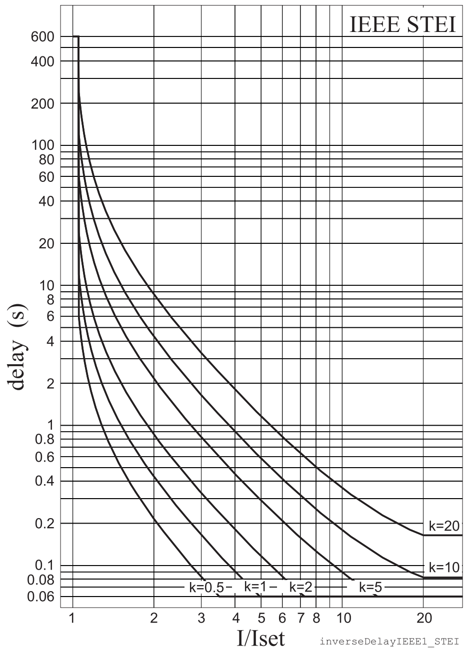


Figure 2.25.1-10 ANSI/IEEE short time extremely inverse delay

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 2.25.1-3, 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 2.25.1-4. 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 2.25.1-3. 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 2.25.1-3

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

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 2.25.1-4.

Table 2.25.1-4 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	-.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 2.25.1-11.

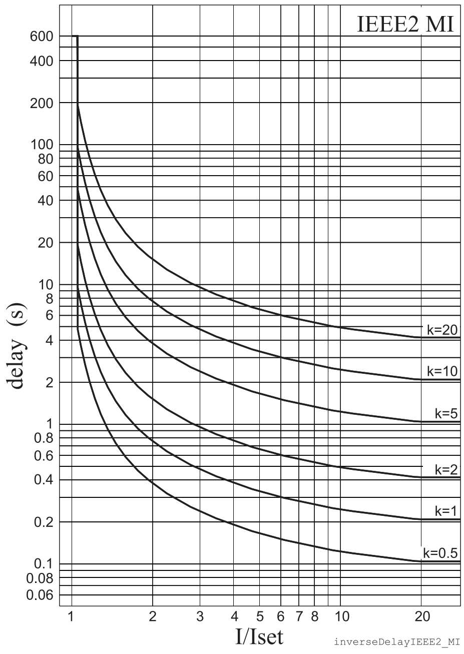


Figure 2.25.1-11 IEEE2 moderately inverse delay

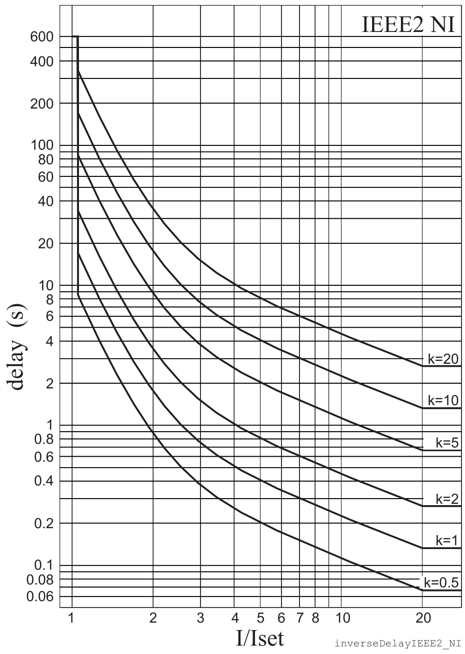


Figure 2.25.1-12 IEEE2 normal inverse delay

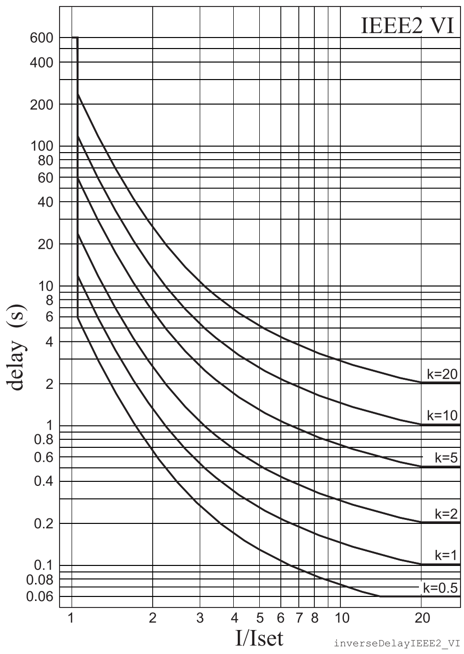


Figure 2.25.1-13 IEEE2 very inverse delay

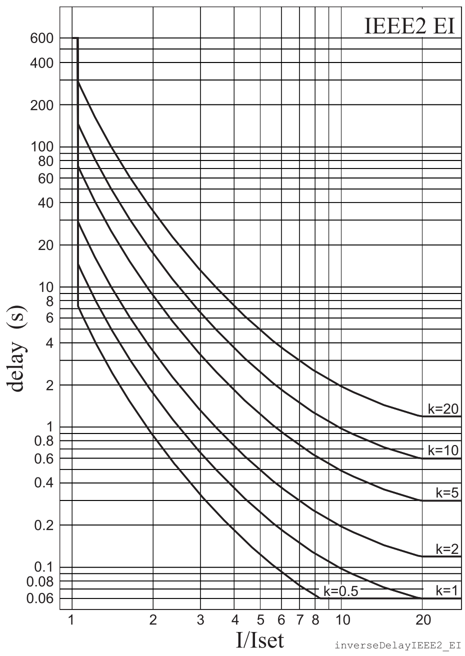


Figure 2.25.1-14 IEEE2 extremely inverse delay

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 2.25.1-4 and Equation 2.25.1-5. 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 2.25.1-4 RI

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

Equation 2.25.1-5 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 2.25.1-15.

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 2.25.1-16.

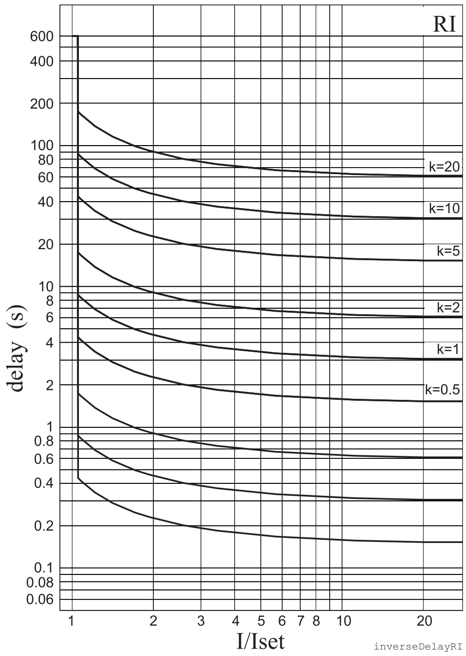


Figure 2.25.1-15 Inverse delay of type RI.

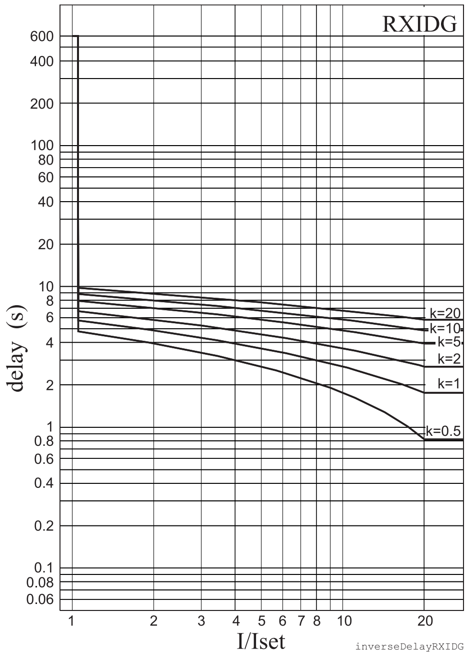


Figure 2.25.1-16 Inverse delay of type RXIDG.

2.25.2. Free parametrisation 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 2.25 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 2.25 for more details.

2.25.3. 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 $I/I_{pick\text{-}up}$	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 2.25 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 2.25 for more details.

3. Supporting functions

3.1. 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. The event codes are listed in a separate document Modbus_Profibus_Spabus_event.pdf.

As an example of information included with a typical event an overvoltage trip event of the first 59 stage U> is shown in the following table.

EVENT	Description	Local panel	Communication protocols
Code: 1E2	Channel 30, 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: U12,23,31	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 VAMSET 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 error, the latest event can be reread any number of times using an other 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.

There are room for 200 latest events in the event buffer. 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 10 ms or 20 ms resolution. The absolute accuracy of all time stamps depends on the time synchronizing of the relay. See chapter 3.7 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, the event buffer will eventually overflow. On the local screen this is indicated with string "OVF" after the event code.

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	PU Pri	Scaling of event fault value Per unit scaling Primary scaling	Set
Display Alarms	On Off	Alarm pop-up display is enabled No alarm 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 3.7)	
hh:mm:ss.nnn		Time	

3.2. Disturbance recorder

The disturbance recorder can be used to record all the measured signals, that is, currents, voltages and the status information of digital inputs (DI) and digital outputs (DO). The digital inputs include also the arc protection signals S1, S2, BI and BO, if the optional arc protection is available.

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 means that also 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 is also 12 (limited in waveform recording). The 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.

Disturbance recorder parameters

Parameter	Value	Unit	Description	Note
Mode	 Saturated Overflow		Behaviour in memory full situation: No more recordings are accepted The oldest recorder will be overwritten	Set
SR	 32/cycle 16/cycle 8/cycle 1/10ms 1/20ms 1/200ms 1/1s 1/5s 1/10s 1/15s 1/30s 1/1min		Sample rate Waveform Waveform Waveform One cycle value *) One cycle value **) Average Average Average Average Average Average Average	Set
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.	

Parameter	Value	Unit	Description	Note
Status			Status of recording	
	–		Not active	
	Run		Waiting a triggering	
	Trig		Recording	
	FULL		Memory is full in saturated mode	
ManTrig			Manual triggering	Set
	–			
	Trig			
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.	
AddCh			Add one channel. Maximum simultaneous number of channels is 12.	Set
	IL1, IL2, IL3		Phase current	
	Io1, Io2		Measured residual current	
	U12, U23, U31		Line-to-line voltage	
	UL1, UL2, UL3		Phase-to-neutral voltage	
	Uo		Zero sequence voltage	
	f		Frequency	
	P, Q, S		Active, reactive, apparent power	
	P.F.		Power factor	
	CosFii		cosφ	
	IoCalc		Phasor sum Io = ($\underline{I}$L1+$\underline{I}$L2+$\underline{I}$L3)/3	
	I1		Positive sequence current	
	I2		Negative sequence current	
	I2/I1		Relative current unbalance	
	I2/In		Current unbalance [xI_{GN}]	
	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	
	DI		Digital inputs	

	TanFii		tanφ	
	THDIL1		Total harmonic distortion of IL1	
	THDIL2		Total harmonic distortion of IL2	
	THDIL3		Total harmonic distortion of IL3	
	THDUa		Total harmonic distortion of input Ua	
	THDUb		Total harmonic distortion of input Ub	
	THDUc		Total harmonic distortion of input Uc	
	Prms		Active power rms value	
	Qrms		Reactive power rms value	
	Srms		Apparent power rms value	
	fy		Frequency behind circuit breaker	
	fz		Frequency behind 2nd circuit breaker	
	U12y		Voltage behind circuit breaker	
	U12z		Voltage behind 2nd circuit breaker	
	IL1RMS		IL1 RMS for average sampling	
	IL2RMS		IL2 RMS for average sampling	
	IL3RMS		IL3 RMS for average sampling	
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.

3.3. 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.

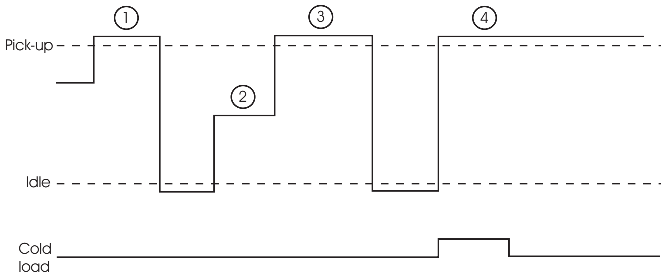
Inrush current detection

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 Pickupf2 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.



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 3.3-1 Functionality of cold load / inrush current feature.

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)

3.4. Current transformer supervision

The relay supervise the external wiring between the relay terminals and current transformers (CT) and the CT them selves. 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.

Setting parameters of CT supervisor:

CTSV ( )

Parameter	Value	Unit	Default	Description
Imax>	0.0 … 10.0	xIn	2.0	Upper setting for CT supervisor
Imin<	0.0 … 10.0	xIn	0.2	Lower setting for CT supervisor
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

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

3.5. 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 2.22 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 3.5-1). 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 3.5-1. 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 3.5-1. Thus they are set to 100 kA and one operation in the table to be discarded by the algorithm.

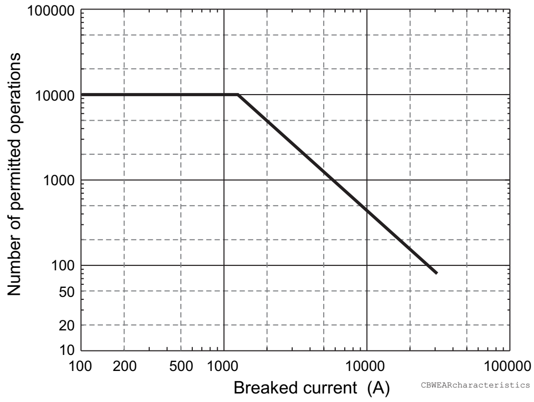


Figure 3.5-1. An example of a circuit breaker wearing characteristic graph.

Table 3.5-1. An example of circuit breaker wearing characteristics in a table format. The value 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 3.5-1

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

C = permitted operations

I = interrupted current

a = constant according Equation 3.5-2

n = constant according Equation 3.5-3

Equation 3.5-2

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

Equation 3.5-3

$$a = C_k I_k^2$$

ln = natural logarithm function

C_k = permitted operations. k = row 2...7 in Table 3.5-1.

I_k = corresponding current. k = row 2...7 in Table 3.5-1.

C_{k+1} = permitted operations. k = row 2...7 in Table 3.5-1.

I_{k+1} = corresponding current. k = row 2...7 in Table 3.5-1.

Example of the logarithmic interpolation

Alarm 2 current is set to 6 kA. What is the maximum number of operations according Table 3.5-1.

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 3.5-2 and Equation 3.5-3, 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 3.5-1 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 3.5-1. 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 much are Alarm2 counters decremented ?

Using Equation 3.5-1 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 3.5-4

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

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

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.

$$\Delta_{L3} = 1$$

Local panel parameters of CBWEAR function

Parameter	Value	Unit	Description	Set
CBWEAR STATUS				
 Al1L1 Al1L2 Al1L3 Al2L1 Al2L2 Al2L3			Operations left for - Alarm 1, phase L1 - Alarm 1, phase L2 - Alarm 1, phase L3 - Alarm 2, phase L1 - Alarm 2, phase L2 - Alarm 2, phase L3	
Latest trip				
Date time			Time stamp of the latest trip operation	
IL1 IL2 IL3		A A A	Broken current of phase L1 Broken current of phase L2 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.

3.6. Energy pulse outputs

The device can be configured to send a pulse whenever certain amount of energy has been imported or exported. The principle is presented in Figure 3.6-1. Each time the energy level reaches the pulse size, an output relay is activated and the relay will be active as long as defined by a pulse duration setting.

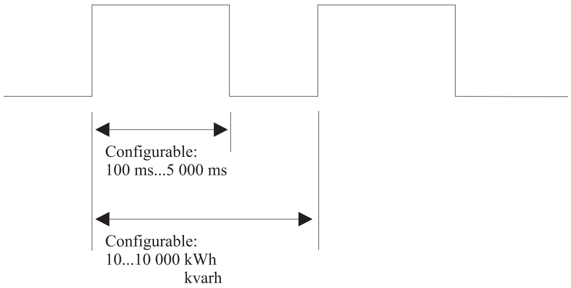


Figure 3.6-1. Principle of energy pulses

The relay has four energy pulse outputs. The output channels are:

- Active exported energy
- Reactive exported energy
- Active imported energy
- Reactive imported energy

Each channel can be connected to any combination of the output relays using output matrix. The parameters for the energy pulses can be found in the E menu under the submenus E-PULSE SIZES and E-PULSE DURATION.

Energy pulse output parameters

	Parameter	Value	Unit	Description
E-PULSE SIZES	E+	10 … 10 000	kWh	Pulse size of active exported energy
	Eq+	10 … 10 000	kvarh	Pulse size of reactive exported energy
	E-	10 … 10 000	kWh	Pulse size of active imported energy
	Eq-	10 … 10 000	kvarh	Pulse size of reactive imported energy
E-PULSE DURATION	E+	100 … 5000	ms	Pulse length of active exported energy
	Eq+	100 … 5000	ms	Pulse length of reactive exported energy
	E-	100 … 5000	ms	Pulse length of active imported energy
	Eq-	100 … 5000	ms	Pulse length of reactive imported energy

Scaling examples

Example 1.

Average active exported power is 250 MW.

Peak active exported power is 400 MW.

Pulse size is 250 kWh.

The average pulse frequency will be 250/0.250 = 1000 pulses/h.

The peak pulse frequency will be 400/0.250 = 1600 pulses/h.

Set pulse length to 3600/1600 – 0.2 = 2.0 s or less.

The lifetime of the mechanical output relay will be $50 \times 10^6/1000$ h = 6 a.

This is not a practical scaling example unless an output relay lifetime of about six years is accepted.

Example 2.

Average active exported power is 100 MW.

Peak active exported power is 800 MW.

Pulse size is 400 kWh.

The average pulse frequency will be 100/0.400 = 250 pulses/h.

The peak pulse frequency will be 800/0.400 = 2000 pulses/h.

Set pulse length to 3600/2000 – 0.2 = 1.6 s or less.

The lifetime of the mechanical output relay will be $50 \times 10^6/250$ h = 23 a.

Example 3.

Average active exported power is 20 MW.

Peak active exported power is 70 MW.

Pulse size is 60 kWh.

The average pulse frequency will be 25/0.060 = 416.7 pulses/h.

The peak pulse frequency will be 70/0.060 = 1166.7 pulses/h.

Set pulse length to 3600/1167 – 0.2 = 2.8 s or less.

The lifetime of the mechanical output relay will be $50 \times 10^6/417$ h = 14 a.

Example 4.

Average active exported power is 1900 kW.

Peak active exported power is 50 MW.

Pulse size is 10 kWh.

The average pulse frequency will be 1900/10 = 190 pulses/h.

The peak pulse frequency will be 50000/10 = 5000 pulses/h.

Set pulse length to 3600/5000 – 0.2 = 0.5 s or less.

The lifetime of the mechanical output relay will be $50 \times 10^6/190$ h = 30 a.

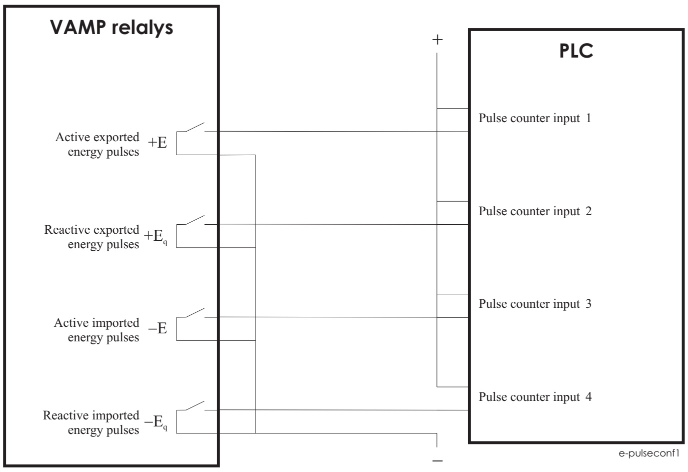


Figure 3.6-2. Application example of wiring the energy pulse outputs to a PLC having common plus and using an external wetting voltage

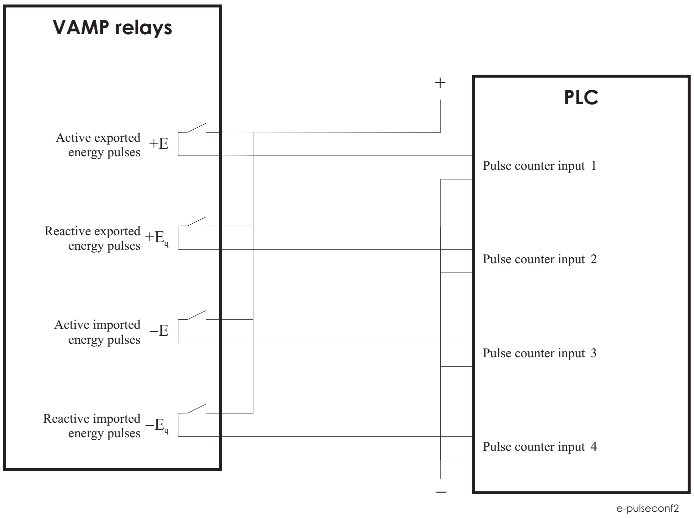


Figure 3.6-3. Application example of wiring the energy pulse outputs to a PLC having common minus and using an external wetting voltage

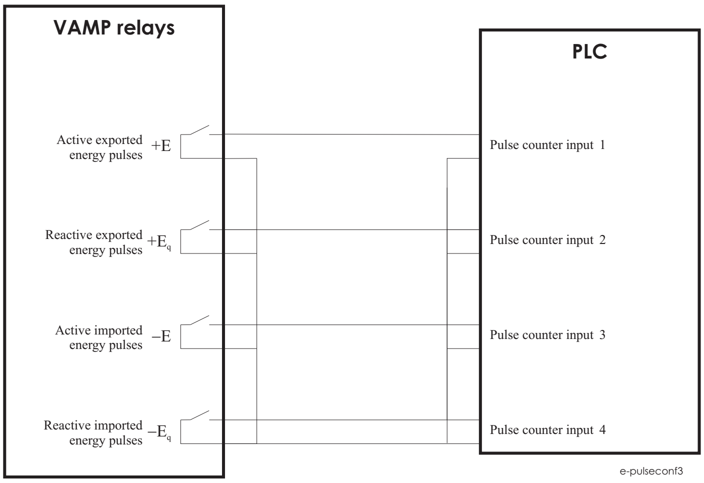


Figure 3.6-4. Application example of wiring the energy pulse outputs to a PLC having common minus and an internal wetting voltage.

3.7. 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.

Adapting auto adjust

During tens of hours of synchronizing the device will learn its average error 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 error 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

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

$$AvDrft = Lead$$

NOTE! 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.

System clock parameters

Parameter	Value	Unit	Description	Note
Date			Current date	Set
Time			Current time	Set
Style	 y–d–m d.m.y m/d/y		Date format Year-Month-Day Day.Month.Year Month/Day/Year	Set
SyncDI	 – DI1, DI2		The digital input used for clock synchronisation. DI not used for synchronizing Minute pulse input	***)
TZone	–12.00 ... +14.00 *)		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

Parameter	Value	Unit	Description	Note
SySrc			Clock synchronisation source	
	Internal		No sync recognized since 200 s	
	DI		Digital input	
	SNTP		Protocol sync	
	SpaBus		Protocol sync	
	ModBus		Protocol sync	
	ProfibusDP		Protocol sync	
	IEC-103		Protocol sync	
	IEC101		Protocol sync	
	DNP3		Protocol sync	
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 error in the synchronizing source.	Set
AAIntv	±10000	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).

*) Astronomically a range –11 ... +12 h would be enough, but for political and geographical reasons a larger range is needed.

**) If external synchoronization 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.

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.

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 errors 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.

3.8. 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.

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)
	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, DI2, VI1…VI4, LedAl, LedTr, LedA, LedB, LedC, LedD, LedE, LedF, LedDR VO1…VO6		Select the supervised signal None Physical inputs Virtual inputs Output matrix out signal Al Output matrix out signal Tr Output matrix out signal LA Output matrix out signal LB Output matrix out signal LC Output matrix out signal DR Virtual outputs	Set

Parameter	Value	Unit	Description	Note
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.

3.9. 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.

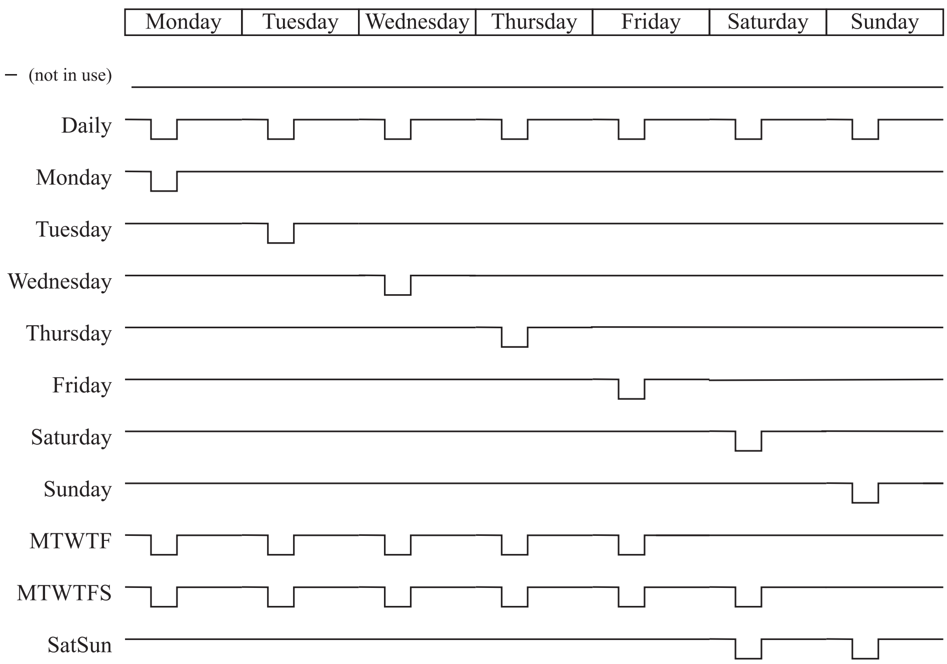


Figure 3.9-1. Timer output sequence in different modes.

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.

Setting parameters of timers

Parameter	Value	Description
TimerN	 – 0 1	Timer status Not in use Output is inactive Output is active
On	hh:mm:ss	Activation time of the timer
Off	hh:mm:ss	De-activation time of the timer
Mode	 – Daily Monday Tuesday Wednesday Thursday Friday Saturday Sunday MTWTF MTWTFS SatSun	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. The timer switches on and off once every day. The timer switches on and off every Monday. The timer switches on and off every Tuesday. The timer switches on and off every Wednesday. The timer switches on and off every Thursday. The timer switches on and off every Friday. The timer switches on and off every Saturday. The timer switches on and off every Sunday. The timer switches on and off every day except Saturdays and Sundays The timer switches on and off every day except Sundays. The timer switches on and off every Saturday and Sunday.

3.10. Combined overcurrent status

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

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	

Parameter	Value	Unit	Description	Note
OCs	 0 1		Combined overcurrent start status. AlrL1=AlrL2=AlrL3=0 AlrL1=1 orAlrL2=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 orFltL2=1 or FltL3=1	
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

Parameter	Value	Unit	Description	Note
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.

3.11. Self-supervision

The functions of the micro controller 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 a fault situation. If the restarting fails, the watchdog issues a self-supervision alarm indicating a permanent internal fault.

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 relay disappear, an alarm is automatically given because the internal fault (IF) output relay functions on a working current principle. This means that the IF relay is energized when the auxiliary supply is on and no internal fault is detected.

3.11.1. Diagnostics

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

Fatal errors

If fatal error has been detected, the device releases IF relay contact and error led is set on. Local panel will also display an error message about the detected fault. Fatal error state is entered when the device is not able to handle protections.

Runtime errors

When self-diagnostic function detects a fault, **Selfdiag Alarm** matrix signal is set and an event (E56) is generated. In case the error was only temporary, an off event is generated (E57). Self diagnostic error can be reset via local panel interface.

Error registers

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

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

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

4. Measurement functions

All the direct measurements are based on fundamental frequency values. The exceptions are frequency and instantaneous current for arc protection. Most protection functions are also based on the fundamental frequency values.

The device calculates the active (P), reactive (Q), apparent power (S) and energy measures (E+, Eq+, E-, Eq-) from voltage and current measurements when voltage measurement mode is set to 1LL (line-to-line voltage) or 1LN (phase-to-neutral voltage).

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.

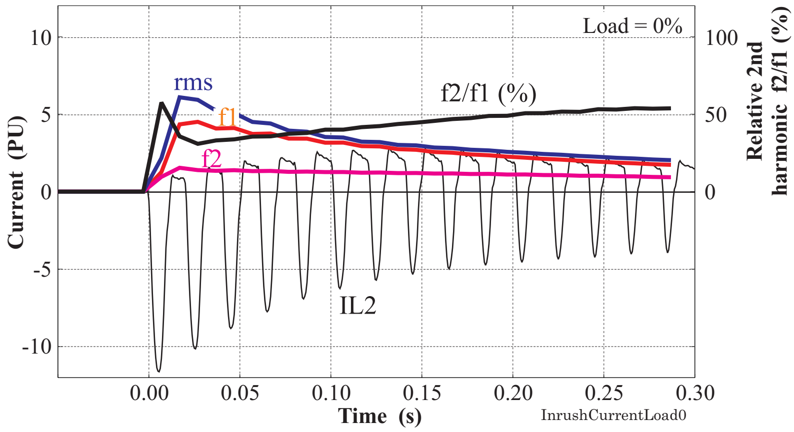


Figure 4-1 Example of various current values of a transformer inrush current.

4.1. Measurement accuracy

Phase current inputs I_{L1}, I_{L2}, I_{L3}

Measuring range	0 – 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.

Voltage input U

The usage of voltage inputs depends on the configuration parameter voltage measurement mode. For example, U is the zero sequence voltage input U_0 if the mode "U_0" is selected.

Measuring range	0 – 160 V
Inaccuracy	0.5 % or 0.3 V

The specified frequency range is 45 Hz – 65 Hz.

Residual current inputs I_{01}, I_{02}

Measuring range		0 – 10 xI_n
Inaccuracy	$I \le 1.5\ xI_n$	0.3 % of value or 0.2 % of I_n
	$I > 1.5\ xI_n$	3 % of value

The specified frequency range is 45 Hz – 65 Hz.

The rated input I_n is 5A, 1 A or 0.2 A. It is specified in the order code of the relay.

Frequency

Measuring range	16 Hz – 75 Hz
Inaccuracy	10 mHz

The frequency is measured from current signals.

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.

4.2. 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 4.5).

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

RMS voltages

The device calculates the RMS value of each voltage input. The minimum and the maximum of RMS values are recorded and stored (see chapter 4.5).

$$U_{rms} = \sqrt{U_{f1}^{\,2} + U_{f2}^{\,2} + \ldots + U_{f15}^{\,2}}$$

4.3. Harmonics and Total Harmonic Distortion (THD)

The device calculates the THDs as percentage of the base frequency for currents and voltages.

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 using equation

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

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 %.

4.4. Demand values

The relay calculates average i.e. demand values of phase currents I_{L1}, I_{L2}, I_{L3} and power values S, P and Q. The demand time is configurable from 10 minutes to 30 minutes with parameter "Demand time".

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	
Pda		kW	Demand of active power P	
PFda			Demand of power factor PF	
Qda		kvar	Demand of reactive power Q	
Sda		kVA	Demand of apparent power S	
RMS values				
IL1da		A	Demand of phase current IL1	
IL2da		A	Demand of phase current IL2	
IL3da		A	Demand of phase current IL3	

4.5. 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
Io1, Io2	Residual current
U12, U23, U31	Line-to-line voltage
Uo	Zero sequence voltage
f	Frequency
P, Q, S	Active, reactive, apparent power
IL1da, IL2da, IL3da	Demand values of phase currents
IL1da, IL2da, IL3da (rms value)	Demand values of phase currents, rms values
PFda	Power factor demand value

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

Parameters

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

4.6. Maximum values of the last 31 days and twelve months

Some 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
IL1, IL2, IL3	X		Phase current (fundamental frequency value)
Io1, Io2	X		Residual current
S	X		Apparent power
P	X	X	Active power
Q	X	X	Reactive power

The value can be a one cycle value or an average according parameter "Timebase".

Parameters of the day and month registers

Parameter	Value	Description	Set
Timebase		Parameter to select the type of the registered values.	S
	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 (see chapter 4.4)	
ResetDays		Reset the 31 day registers	S
ResetMon		Reset the 12 month registers	S

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

4.7. Voltage measurement modes

Depending on the application and available voltage transformers, the relay can be connected either to zero-sequence voltage, one line-to-line voltage or one phase-to-ground voltage. The configuration parameter "Voltage measurement mode" must be set according the used connection.

The available modes are:

- "U_0"
  The device is connected to zero sequence voltage. Directional earth fault protection is available. Line voltage measurement, energy measurement and over- and undervoltage protection are not possible (see Figure 4.7-1).
- "1LL"
  The device is connected to one line-to-line voltage. Single phase voltage measurement and over- and undervoltage protection are available. Directional earth fault protection is not possible (see Figure 4.7-2 and Figure).
- "1LN"
  The device is connected to one phase-to-ground voltage. Single phase voltage measurement is available. In low impedance grounded networks over- and undervoltage protection are available. Directional earth fault protection is not possible (see Figure 4.7-3 and Figure).

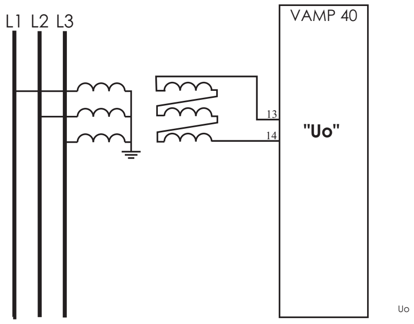


Figure 4.7-1 VAMP 40 Broken delta connection in voltage measurement mode “U_0”.

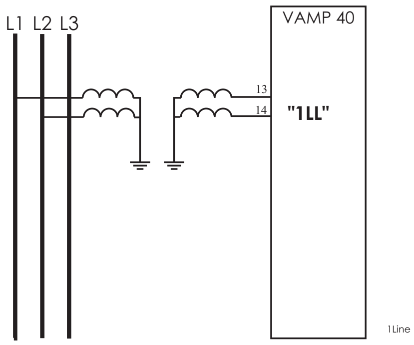


Figure 4.7-2 VAMP 40 line-to-line voltage in voltage measurement mode “1LL”.

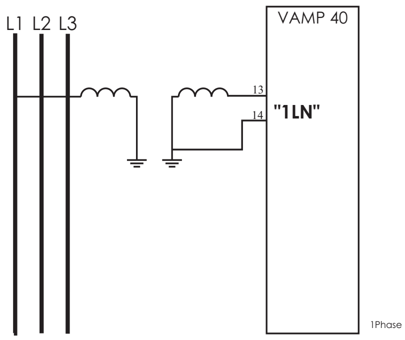


Figure 4.7-3 VAMP 40 phase-to-neutral voltage in voltage measurement mode “1LN”.

4.8. Power calculations

NOTE! These calculations is available when voltage measurement mode is 1LL (line-to-line voltage, see Figure) or 1LN (phase-to-neutral voltage, see Figure).

The power calculations in the VAMP 40 are dependant on the voltage measurement mode. The formulas used by the VAMP 40 for power calculations are found in this chapter

Line to line voltages measured (1LL mode)

As the device is measuring U_{12} only, the U_{23} voltage is calculated by assuming that voltages are symmetrical.

$$a = 1\angle 120^{\circ}$$

$$U_{23} = a^2 U_{12}$$

$$\overline{S} = \overline{U}_{12} \cdot \bar{I}^*_{L1} - \overline{U}_{23} \cdot \bar{I}^*_{L3}$$

where,

$\overline{U}_{12}$ = Measured line voltage L1-L2 phasor, fundamental frequency component.

$\bar{I}^*_{L1}$ = Complex conjugate of the measured phase L1 current phasor.

$\overline{U}_{23}$ = Measured line voltage L2-L3 phasor, fundamental frequency component

$\bar{I}^*_{L3}$ = Complex conjugate of the measured phase L3 current phasor.

$$P = real(\overline{S})$$

$$Q = imag(\overline{S})$$

$$\cos\varphi = \frac{P}{\left|\overline{S}\right|}$$

Phase to neutral voltages measured (1LN mode)

Active power calculation for one phase:

$$P_{L1} = U_{L1} \cdot I_{L1} \cdot \cos\varphi$$

Reactive power calculation for one phase:

$$Q_{L1} = U_{L1} \cdot I_{L1} \cdot \sin\varphi$$

where,

U_{L1} = Measured L1 phase voltage

I_{L1} = Measured L1 current

φ = Angle between U_{L1} and I_{L1}

Active, reactive and apparent power are calculated as follows:

$$P = 3P_{L1}$$

$$Q = 3Q_{L1}$$

$$S = \sqrt{P^2 + Q^2}$$

$$\cos\varphi = \frac{P}{S}$$

4.9. Direction of power and current

Figure 4.9-1 shows the concept of three phase current direction and sign of cosφ and power factor PF. Figure 4.9-2 shows the same concepts, but on a PQ-power plane.

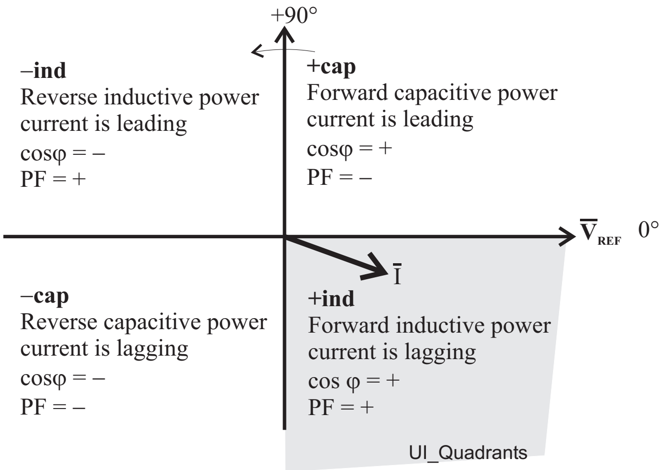


Figure 4.9-1 Quadrants of voltage/current phasor plane

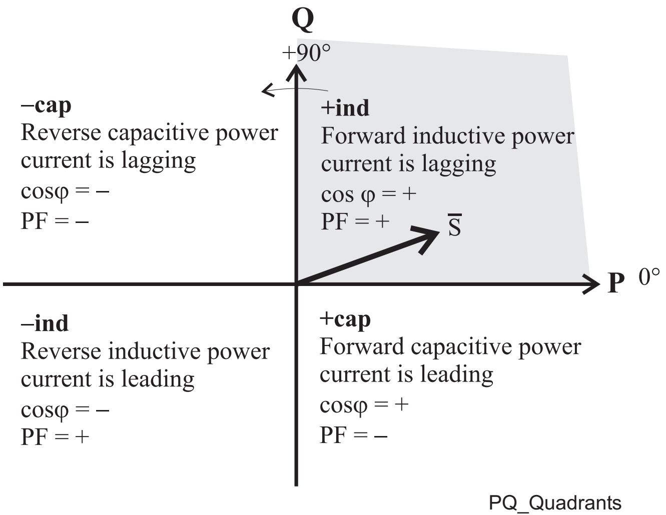


Figure 4.9-2 Quadrants of power plane

Table of power quadrants

Power quadrant	Current related to voltage	Power direction	cosφ	Power factor PF
+ inductive	Lagging	Forward	+	+
+ capacitive	Leading	Forward	+	–
– inductive	Leading	Reverse	–	+
– capacitive	Lagging	Reverse	–	–

4.10. 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:

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

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

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

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

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

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

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

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

4.11. 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, VT in feeder mode and furthermore motor name plate values in motor mode.

The following scaling equations are useful when doing secondary testing.

4.11.1. Current scaling

NOTE! The rated value of the relay's current input 5 A, does not have any effect in the scaling equations, but it defines the measurement range and the maximum allowed continuous current. See chapter 9.1.1 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 currents to inputs I_{01} or I_{02} use the corresponding CT_{PRI} and CT_{SEC} values. For earth fault stages using I_{0Calc} signals use the phase current CT values for CT_{PRI} and CT_{SEC}.

Example 1: Secondary to primary.

CT = 500/5

Current to the relay's input is 4 A.

⇒ Primary current is I_{PRI} = 4x500/5 = 400 A

Example 2: Primary to secondary.

CT = 500/5

The relay displays I_{PRI} = 400 A

⇒ Injected current is I_{SEC} = 400x5/500 = 4 A

Per unit [pu] scaling

For phase currents excluding ArcI> stage
1 pu = 1xI_{MODE} = 100 %, where
I_{MODE} is the rated current of the motor or the nominal value of the feeder.

For residual currents and ArcI> stage
1 pu = 1xCT_{SEC} for secondary side and
1 pu = 1xCT_{PRI} for primary side.

	Phase current scaling excluding ArcI> stage	Residual current ($3I_0$) scaling and phase current scaling for ArcI> stage
secondary ⇒ per unit	$I_{PU} = \frac{I_{SEC} \cdot CT_{PRI}}{CT_{SEC} \cdot I_{MODE}}$	$I_{PU} = \frac{I_{SEC}}{CT_{SEC}}$
per unit ⇒ secondary	$I_{SEC} = I_{PU} \cdot CT_{SEC} \cdot \frac{I_{MODE}}{CT_{PRI}}$	$I_{SEC} = I_{PU} \cdot CT_{SEC}$

Example 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} = 7x750/(5x525) = 2.00 pu = 2.00 xI_{MODE} = 200 %

Example 2: Secondary to per unit for ArcI>.

CT = 750/5

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

⇒ Per unit current is
I_{PU} = 7/5 = 1.4 pu = 140 %

Example 3: Per unit to secondary for phase currents excluding ArcI>.

CT = 750/5

I_{MODE} = 525 A

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

⇒ Secondary current is
I_{SEC} = 2x5x525/750 = 7 A

Example 4: Per unit to secondary for ArcI>.

CT = 750/5

The relay setting is 2 pu = 200 %.

⇒ Secondary current is
I_{SEC} = 2x5 = 10 A

Example 5: Secondary to per unit for residual current.

Input is I_{01} or I_{02}.

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 %

Example 6: Per unit to secondary for residual current.

Input is I_{01} or I_{02}.

CT_0 = 50/1

The relay setting is 0.03 pu = 3 %.

⇒ Secondary current is
I_{SEC} = 0.03x1 = 30 mA

Example 7: 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 %

Example 8: 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
$I_{SEC} = 0.1x5 = 0.5$ A

4.11.2. Voltage scaling

Primary/secondary scaling of line-to-line voltages

	Line-to-line voltage scaling	
	Voltage measurement mode = "1LL"	Voltage measurement mode = "1LN"
secondary ⇒ primary	$U_{PRI} = U_{SEC} \cdot \frac{VT_{PRI}}{VT_{SEC}}$	$U_{PRI} = \sqrt{3} \cdot U_{SEC} \cdot \frac{VT_{PRI}}{VT_{SEC}}$
primary ⇒ secondary	$U_{SEC} = U_{PRI} \cdot \frac{VT_{SEC}}{VT_{PRI}}$	$U_{SEC} = \frac{U_{PRI}}{\sqrt{3}} \cdot \frac{VT_{SEC}}{VT_{PRI}}$

Example 1: Secondary to primary. Voltage measurement mode is "1LL".

VT = 12000/110

Voltage connected to the relay's input is 100 V.
⇒ Primary voltage is U_{PRI} = 100x12000/110 = 10909 V

Example 2: Secondary to primary. Voltage measurement mode is "1LN".
VT = 12000/110

The voltage connected to the relay's input is 57.7 V.
⇒ Primary voltage is U_{PRI} = √3x58x12000/110 = 10902 V

Example 3: Primary to secondary. Voltage measurement mode is "1LL".

VT = 12000/110

The relay displays U_{PRI} = 10910 V.
⇒ Secondary voltage is U_{SEC} = 10910x110/12000 = 100 V

Example 4: Primary to secondary. Voltage measurement mode is "1LN".

VT = 12000/110

The relay displays $U_{12} = U_{23} = U_{31} = 10910$ V.
⇒ Secondary voltage is
$U_{SEC} = 10910/\sqrt{3}x110/12000 = 57.7$ V4

Per unit [pu] scaling of line-to-line voltages

One per unit = 1 pu = $1xU_N$ = 100 %, where U_N = rated voltage of the VT.

	Line-to-line voltage scaling	
	Voltage measurement mode = "1LL"	Voltage measurement mode = "1LN"
secondary ⇒ per unit	$U_{PU} = \frac{U_{SEC}}{VT_{SEC}}$	$U_{PU} = \sqrt{3} \cdot \frac{U_{SEC}}{VT_{SEC}}$
per unit ⇒ secondary	$U_{SEC} = U_{PU} \cdot VT_{SEC}$	$U_{SEC} = U_{PU} \cdot \frac{VT_{SEC}}{\sqrt{3}}$

Example 1: Secondary to per unit. Voltage measurement mode is "1LL".

VT = 12000/110

$U_N = VT_{PRI}$

Voltage connected to the relay's input is 110 V.
⇒ Per unit voltage is

$U_{PU} = 110/110 = 1.00$ pu $= 1.00xU_{MODE} = 100$ %

Example 2: Secondary to per unit. Voltage measurement mode is "1LN".

VT = 12000/110

Phase-to-neutral voltage connected to the relay's input is 63.5 V.
⇒ Per unit voltage is

$U_{PU} = \sqrt{3}x63.5/110x12000/11000 = 1.00$ pu $= 1.00xU_N =100$ %

Example 3: Per unit to secondary. Voltage measurement mode is "1LL".

VT = 12000/110

The relay displays 1.00 pu = 100 %.
⇒ Secondary voltage is

$U_{SEC} = 1.00x110x11000/12000 = 100.8$ V

Example 4: Per unit to secondary. Voltage measurement mode is "1LN".

VT = 12000/110

The relay displays 1.00 pu = 100 %.

⇒ Phase-to-neutral voltage connected to the relay's input is

U_{SEC} = 1.00x110/√3x11000/12000 = 63.5 V

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	$U_{SEC} = U_{PU} \cdot U_{0SEC}$

Example 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 earth fault.)

Voltage connected to the relay's input is 22 V.

⇒ Per unit voltage is

U_{PU} = 22/110 = 0.20 pu = 20 %

5. Control functions

5.1. 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 output matrix for more details.

The difference between trip contacts and alarm contacts is the DC breaking capacity. See chapters 9.1.4 and 9.1.5 for details. The contacts are SPST normal open type (NO), except alarm relay A1 which has change over contact (SPDT).

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
IF	0 1		Status of the internal fault indication relay	F
Force	On Off		Force flag for output relay forcing for test purposes. This is a common flag for all output relays and protection stage status, too. Any forced relay(s) and this flag are automatically reset by a 5-minute timeout.	Set
REMOTE PULSES				
T3, T4, A1	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 "Alarm relay n", n=1	Set

Set = An editable parameter (password needed)

F = Editable when force flag is on

5.2. 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.

The digital inputs need an external control voltage:
ON ≥ 18Vdc (≥ 50Vac)
OFF ≤ 10Vdc (≤ 5Vac)

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.

Parameters of digital inputs

Parameter	Value	Unit	Description	Set
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 yes		For normal open contacts (NO). Active edge is 0⇒1 For normal closed contacts (NC) Active edge is 1⇒0	Set
Alarm display	no yes		No pop-up display Alarm pop-up display is activated at active DI edge	Set
On event	On Off		Active edge event enabled Active edge event disabled	Set
Off event	On Off		Inactive edge event enabled Inactive edge event disabled	Set

Parameter	Value	Unit	Description	Set
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)

5.3. Virtual inputs and outputs

There are four virtual inputs and six virtual outputs. The four 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.

Parameters of virtual inputs

Parameter	Value	Unit	Description	Set
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.

5.4. 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, front panel indicators, virtual outputs etc.

There are two LED indicators named "Alarm" and "Trip" on the front panel. Furthermore there are six general purpose LED indicators – "A", "B", "C", "D", "E" and "F" – available for customer-specific indications. In addition, the triggering of the disturbance recorder (DR) and virtual outputs are configurable in the output matrix. See an example in Figure 5.4-1.

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.

There is a common "release latched" signal to release all the latched relays. This release signal resets all the latched output relays and indicators. The reset signal can be given via a digital input, via a keypad or through communication. Any digital input can be used for resetting. The selection of the input is done with the VAMPSET software under the menu "Release output matrix latches". Under the same menu, the "Release latches" parameter can be used for resetting.

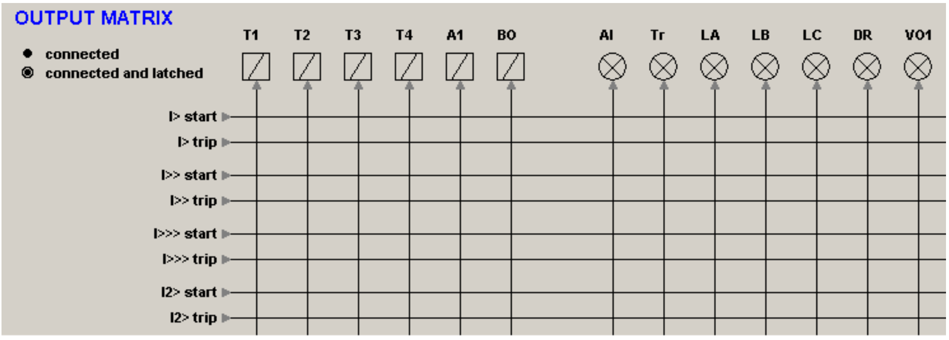


Figure 5.4-1 Output matrix.

5.5. 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 5.5-1 an active blocking is indicated with a black dot (•) in the crossing point of a blocking signal and the signal to be blocked.

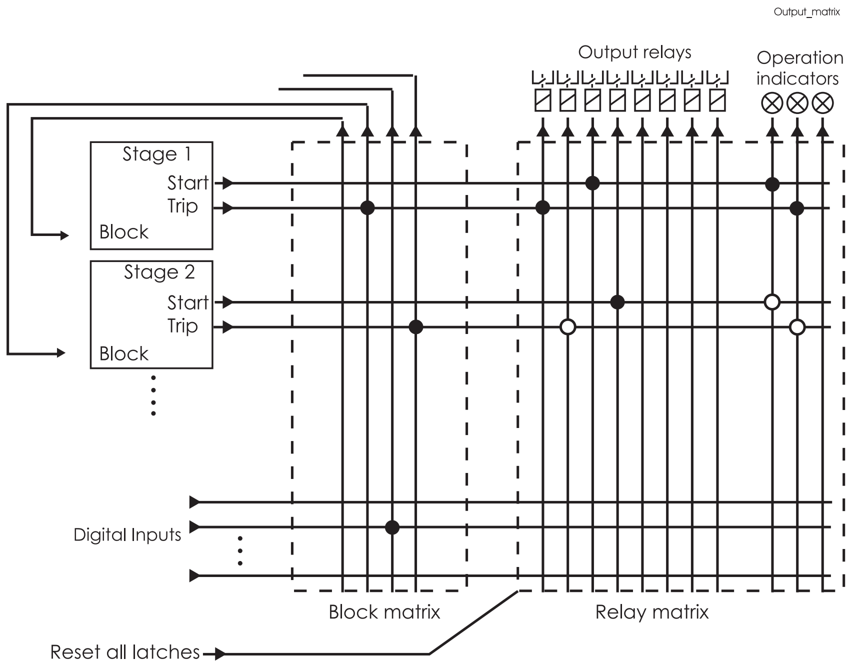


Figure 5.5-1 Blocking matrix and output matrix

5.6. Controllable objects

The device allows controlling of six objects, that is, circuit-breakers, disconnectors and earthing switches. Controlling can be done by "select-execute" or "direct control" principle.

The 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:

- o through the local HMI
- o through a remote communication
- o through a digital input.

The connection of an object to specific output relays is done via an output matrix (object 1-6 open output, object 1-65 close output). There is also an output signal “Object failed”, which is activated if the control of an object fails.

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 fails 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.

Output signals of controllable objects

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

Each read-only 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
Object timeout	0.02 … 600 s	Timeout for state changes

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

Controlling with DI (firmware version >= 5.53)

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 control	In remote state
DI for remote close control	
DI for local open control	In local state
DI for local close control	

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.

5.6.1. 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.

5.7. Auto-reclose function (79)

The auto-reclose (AR) matrix in the following Figure 5.7-1 describes the start and trip signals forwarded to the auto-reclose function.

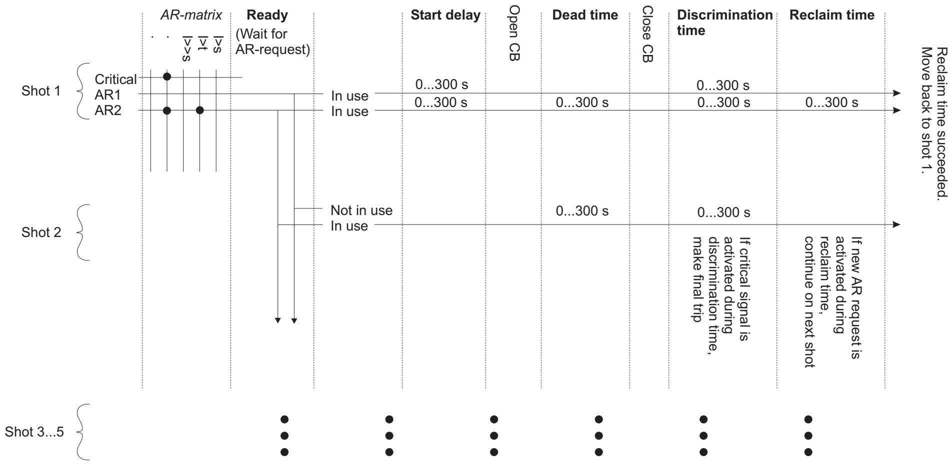


Figure 5.7-1 Auto-reclose matrix

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, AR will function as follows:

Firmware version	Functioning
>= 5.31	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.
< 5.31	Reclaim-state is activated. Within the reclaim time any AR request (1…4) will cause final tripping.

Manual opening

Manual CB open command during AR sequence will stop the sequence and leaves the CB open.

Reclaim time setting

Firmware version	Settings
>= 5.53	**Use shot specific reclaim time : No** Reclaim time setting defines reclaim time between different shots during sequence and also reclaim time after manual closing. AR works exactly like in older firmwares.
	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.
< 5.53	Reclaim time setting defines reclaim time between different shots during sequence and also reclaim time after manual closing.

Support for 2 circuit breakers (firmware version >= 5.31)

AR function can be configured to handle 2 controllable objects. Object 1 is always used as 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 or virtual output. AR controls CB2 when the input defined by **Input for selecting CB2** setting is active. Control is changed to another object only if the current object is not close.

Blocking of AR shots (firmware version >= 5.57)

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 (firmware version >= 5.1)

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 AR sequence (firmware version < 5.1)

If more than one AR requests are active, a request of the highest priority is selected. AR1 has the highest priority and AR4 has the lowest priority. After the start delay of shot 1 has elapsed, AR opens the CB and starts counting dead time.

Starting sequence at shot 2…5 & skipping of AR shots (firmware version >= 5.1)

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.

For older firmware versions (< 5.1) starting at other shot than shot 1 or skipping shots is not possible. AR request lines must be enabled to consecutive shots starting from shot 1. If AR sequence is not yet started, an AR request which is not enabled for shot 1 will cause final tripping. During sequence run an AR request which is not enabled for the next shot will cause final tripping.

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 acceptance depends on the firmware version:

Firmware version	Critical signal is accepted during
>= 5.31	Dead time and discrimination time
< 5.31	Discrimination time only

Shot active matrix signals (firmware version >= 5.53)

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…4 and 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.

Setting parameters of AR function:

Parameter	Value	Unit	Default	Description
ARena	ARon; ARoff	-	ARon	Enabling/disabling the autoreclose
Block	None, any digital input, virtual input or virtual output	-	-	The digital input for block information. This can be used, for example, 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.
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
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
CRITri	On; Off	-	On	AR critical final trip off event
AR1Tri	On; Off	-	On	AR AR1 final trip off event
AR2Tri	On; Off	-	On	AR AR2 final trip off 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
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
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

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.

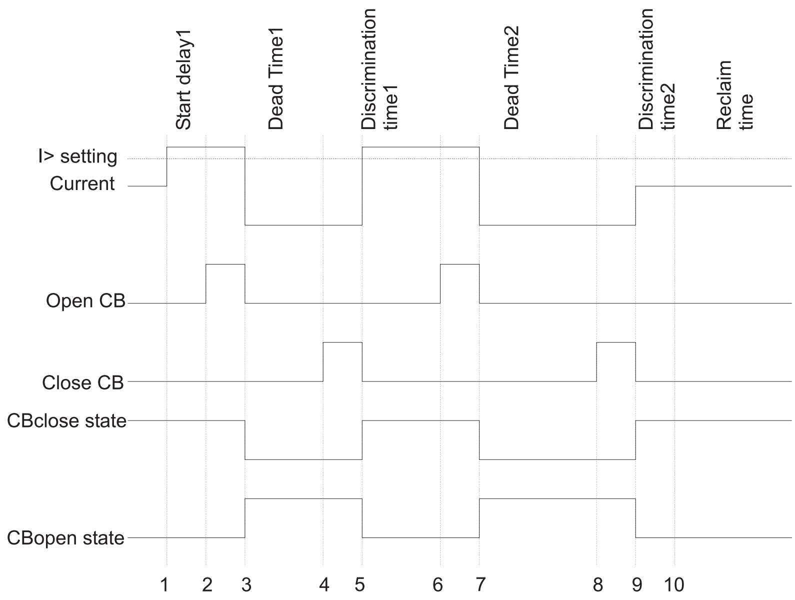


Figure 5.7-2 Example sequence of two shots. After shot 2 the fault is cleared.

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.

5.8. Logic functions

The device supports customer-defined programmable logic for boolean signals. The logic is designed by using the VAMPSET setting tool and downloaded to the device. Functions available are:

- AND
- OR
- XOR
- NOT
- COUNTERs
- RS & D flip-flops

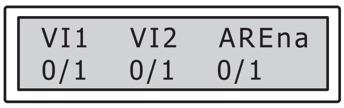
Maximum number of outputs is 20. Maximum number of input gates is 31. An input gate can include any number of inputs.

For detailed information, please refer to the VAMPSET manual (VMV.EN0xx).

5.9. Function keys

The function keys can be activated from the CONF menus DEVICE SETUP submenu, by pushing the DOWN button until item FuncBtns appears. If the value is On, then the function keys are enabled.

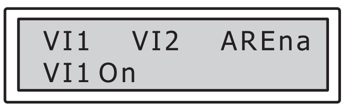
The function keys can be used in the default display or the main menu, by pressing and holding down the INFO key (see Figure 5.9-1).



Functionkeyscreen

Figure 5.9-1 Function key screen.

Still holding down the INFO key and at the same time pressing one of the keys CANCEL, UP or ENTER will toggle the above items, i.e. INFO + CANCEL will either enable or disable Virtual Input 1. The subsequent action will be briefly shown in the lower row of the display (see Figure 5.9-2).



Functionkeyexecution

Figure 5.9-2 Function key execution.

6. Communication

6.1. Communication ports

The relay has two communication ports. See Figure 6.1-1.

There is one physical port in the rear panel. The X4 connector includes two ports: local port and remote port. The front panel RS-232 port will shut off the local port on the rear panel when a VX003 cable is inserted.

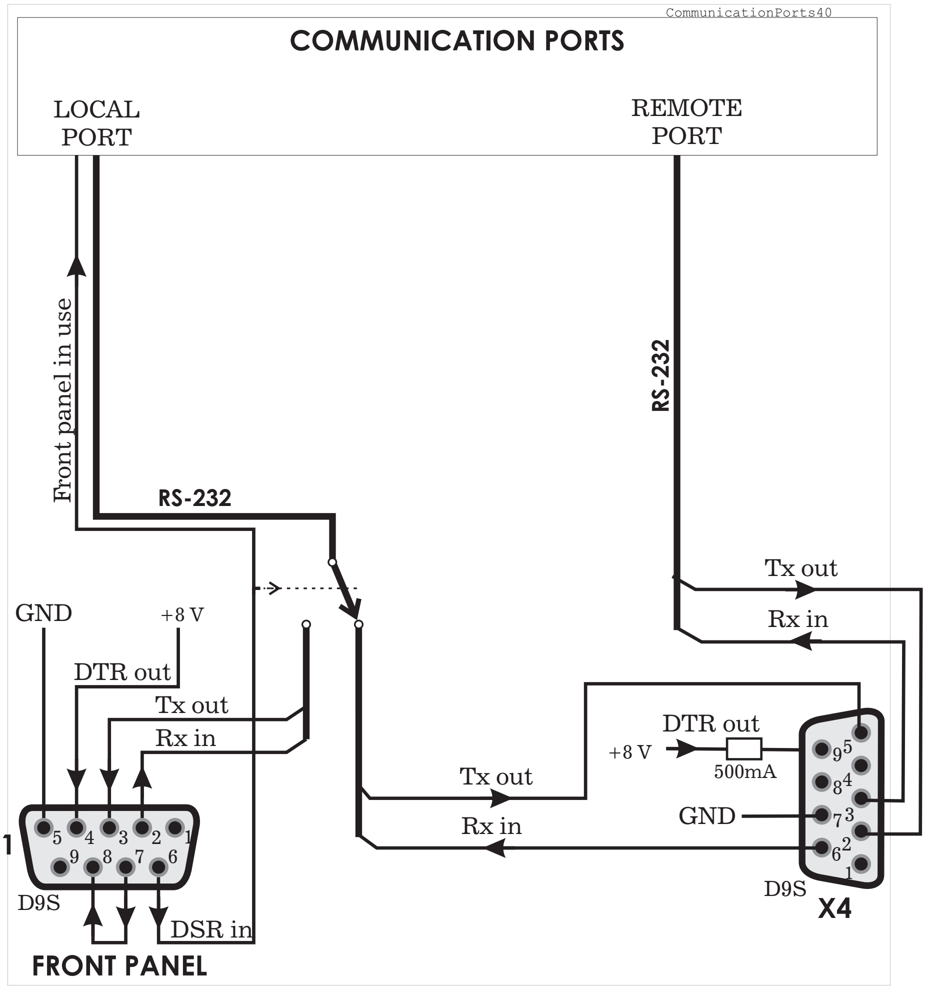


Figure 6.1-1. Communication ports and connectors. The DSR signal from the front panel port selects the active connector for the RS232 local port.

6.1.1. Local port (Front panel and X4)

The local port has two connectors:

- On the front panel
- X4 the rear panel (D9S pins 5, 6 and 7)

Only one can be used at a time.

NOTE! The remote port is locating in the same X4 connector.

NOTE! When the VX003 cable is inserted to the front panel connector it activates the front panel port and disables the rear panel local port by connecting the DTR pin 6 and DSR pin 4 together. See Figure 6.1-1.

Protocol for the local port

The front panel port is always using the command line protocol for VAMPSET regardless of the selected protocol for the rear panel local port.

If other than "None" protocol is selected for the rear panel local port, the front panel connector, when activated, is still using the plain command line interface with the original speed, parity etc. For example if the rear panel local port is used for remote VAMPSET communication using SPA-bus default 9600/7E1, it is possible to temporarily connect a PC with VAMPSET to the front panel connector with the default 38400/8N1. While the front panel connector is in use, the rear panel local port is disabled. The communication parameter display on the local display will show the active parameter values for the local port.

Physical interface

The physical interface of this port is RS-232.

Parameters

Parameter	Value	Unit	Description	Note
Protocol	 None SpaBus ProfibusDP ModbusSla ModbusTCPs IEC-103 ExternalIO DNP3		Protocol selection for the rear panel local port. Command line interface for VAMPSET SPA-bus (slave) Profibus DB (slave) Modbus RTU slave Modbus TCP slave IEC-60870-5-103 (slave) Modbus RTU master for external I/O-modules DNP 3.0	Set
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr
	   speed/DPS Default = 38400/8N1 for VAMPSET		Display of actual communication parameters. speed = bit/s D = number of data bits P = parity: none, even, odd S = number of stop bits	1)
VAMPSET communication (Direct or SPA-bus embedded command line interface)				
Tx	bytes/size		Unsent bytes in transmitter buffer/size of the buffer	
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) The communication parameters are set in the protocol specific menus. For the local port command line interface the parameters are set in configuration menu.

6.1.2. Remote port X4 (pin 2 & 3)

Physical interface

The physical interface of this port is RS-232. See Figure 6.1-1.

Parameters

Parameter	Value	Unit	Description	Note
Protocol	 None SPA-bus ProfibusDP ModbusSla ModbusTCPs IEC-103 ExternalIO DNP3		Protocol selection for remote port - SPA-bus (slave) Profibus DB (slave) Modbus RTU slave Modbus TCP slave IEC-60870-5-103 (slave) Modbus RTU master for external I/O-modules DNP 3.0	Set
Msg#	0 ... 2^{32}–1		Message counter since the device has restarted or since last clearing	Clr
Errors	0 ... 2^{16}–1		Protocol errors since the device has restarted or since last clearing	Clr
Tout	0 ... 2^{16}–1		Timeout errors since the device has restarted or since last clearing	Clr
	speed/DPS		Display of current communication parameters. speed = bit/s D = number of data bits P = parity: none, even, odd S = number of stop bits	1)
Debug	 No Binary ASCII		Echo to local port No echo For binary protocols For SPA-bus protocol	Set

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) The communication parameters are set in the protocol specific menus. For the local port command line interface the parameters are set in configuration menu.

6.1.3. Optional 61850 interface

With this option the relay has two communication connectors in the rear panel: X5 RJ-45 connector (61850 interface, Ethernet 10/100-Base T) and X4 D-connector (Local port and Extension port).

6.2. Communication protocols

The protocols enable the transfer of the following type of data:

- events
- status information
- measurements
- control commands.
- clock synchronizing
- Settings (SPA-bus and embedded SPA-bus only)

6.2.1. PC communication

PC communication is using a VAMP specified command line interface. The VAMPSET program can communicate using the local RS-232 port or using TCP/IP and ethernet interface. It is also possible to select SPA-bus protocol for the local port and configure the VAMPSET to embed the command line interface inside SPA-bus messages. For TCP/IP configuration see chapter 6.2.8.

6.2.2. 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. A separate document Modbus data.pdf is also available.

The Modbus communication is activated usually for remote port via a menu selection with parameter "Protocol". See chapter 6.1.

For TCP/IP configuration see chapter 6.2.8.

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)

6.2.3. Profibus DP

The Profibus DP protocol is widely used in industry. An external VPA 3CG is required.

Device profile "continuous mode"

In this mode the device is sending a configured set of data parameters continuously to the Profibus DP master. The benefit of this mode is the speed and easy access to the data in the Profibus master. The drawback is the maximum buffer size of 128 bytes, which limits the number of data items transferred to the master. Some PLCs have their own limitation for the Profibus buffer size, which may further limit the number of transferred data items.

Device profile "Request mode"

Using the request mode it is possible to read all the available data from the VAMP device and still use only a very short buffer for Profibus data transfer. The drawback is the slower overall speed of the data transfer and the need of increased data processing at the Profibus master as every data item must be separately requested by the master.

NOTE! In request more it is not possible to read continuously only one single data item. At least two data items must be read in turn to get updated data from the device.

There is a separate document ProfiBusDPdeviceProfilesOf-VAMPdevices.pdf available of the continuous mode and request mode.

Available data

VAMPSET will show the list of all available data items for both modes. A separate document VAMP2xx-Profibus_.pdf is also available.

The Profibus DP communication is activated usually for remote port via a menu selection with parameter "Protocol". See chapter 6.1.

Parameters

Parameter	Value	Unit	Description	Note
Mode	 Cont Reqst		Profile selection Continuous mode Request mode	Set
bit/s	2400	bps	Communication speed from the main CPU to the Profibus converter. (The actual Profibus bit rate is automatically set by the Profibus master and can be up to 12 Mbit/s.)	
Emode	 Channel (Limit60) (NoLimit)		Event numbering style. Use this for new installations. (The other modes are for compatibility with old systems.)	(Set)
InBuf		bytes	Size of Profibus master's Rx buffer. (data to the master)	1) 3)
OutBuf		bytes	Size of Profibus master's Tx buffer. (data from the master)	2) 3)
Addr	1 – 247		This address has to be unique within the Profibus network system.	Set
Conv	 – VE		Converter type No converter recognized Converter type "VE" is recognized	 4)

Set = An editable parameter (password needed)

Clr = Clearing to zero is possible

1) In continuous mode the size depends of the biggest configured data offset of a data item to be send to the master. In request mode the size is 8 bytes.

2) In continuous mode the size depends of the biggest configured data offset of a data to be read from the master. In request mode the size is 8 bytes.

3) When configuring the Profibus master system, the length of these buffers are needed. The device calculates the lengths according the Profibus data and profile configuration and the values define the in/out module to be configured for the Profibus master.

4) If the value is "–", Profibus protocol has not been selected or the device has not restarted after protocol change or there is a communication problem between the main CPU and the Profibus ASIC.

6.2.4. SPA-bus

The device has full support for the SPA-bus protocol including reading and writing the setting values. Also reading of multiple consecutive status data bits, measurement values or setting values with one message is supported.

Several simultaneous instances of this protocol, using different physical ports, are possible, but the events can be read by one single instance only.

There is a separate document VAMP2xx-Spabus.pdf of SPA-bus data items available.

Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 899		SPA-bus address. Must be unique in the system.	Set
bit/s	1200 2400 4800 9600 (default) 19200	bps	Communication speed	Set
Emode	Channel (Limit60) (NoLimit)		Event numbering style. Use this for new installations. (The other modes are for compatibility with old systems.)	(Set)

Set = An editable parameter (password needed)

6.2.5. IEC 60870-5-103

The IEC standard 60870-5-103 "*Companion standard for the informative interface of protection equipment*" provides standardized communication interface to a primary system (master system).

The unbalanced transmission mode of the protocol is used, and the device functions as a secondary station (slave) in the communication. Data is transferred to the primary system using "data acquisition by polling"-principle. The IEC functionality includes the following application functions:

- station initialization
- general interrogation
- clock synchronization and
- command transmission.

It is not possible to transfer parameter data or disturbance recordings via the IEC 103 protocol interface.

The following ASDU (Application Service Data Unit) types will be used in communication from the device:

- ASDU 1: time tagged message
- ASDU 3: Measurands I
- ASDU 5: Identification message
- ASDU 6: Time synchronization and
- ASDU 8: Termination of general interrogation.

The device will accept:

- ASDU 6: Time synchronization
- ASDU 7: Initiation of general interrogation and
- ASDU 20: General command.

The data in a message frame is identified by:

- type identification
- function type and
- information number.

These are fixed for data items in the compatible range of the protocol, for example, the trip of I> function is identified by: type identification = 1, function type = 160 and information number = 90. "Private range" function types are used for such data items, which are not defined by the standard (e.g. the status of the digital inputs and the control of the objects).

The function type and information number used in private range messages is configurable. This enables flexible interfacing to different master systems.

Parameters

Parameter	Value	Unit	Description	Note
Addr	1 – 254		An unique address within the system	Set
bit/s	 9600 19200	bps	Communication speed	Set
MeasInt	200 – 10000	ms	Minimum measurement response interval	Set
SyncRe	 Sync Sync+Proc Msg Msg+Proc		ASDU6 response time mode	Set

Set = An editable parameter (password needed)

Parameters for disturbance record reading

Parameter	Value	Unit	Description	Note
ASDU23	On Off		Enable record info message	Set
Smpls/msg	1–25		Record samples in one message	Set
Timeout	10–10000	s	Record reading timeout	Set
Fault			Fault identifier number for IEC-103. Starts + trips of all stages.	
TagPos			Position of read pointer	
Chn			Active channel	
ChnPos			Channel read position	
Fault numbering				
Faults			Total number of faults	
GridFlts			Fault burst identifier number	
Grid			Time window to classify faults together to the same burst.	Set

Set = An editable parameter (password needed)

6.2.6. 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 for VAMP 2xx.

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.

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)

6.2.7. IEC 60870-5-101

The IEC 60870-5-101 standard is derived from the IEC 60870-5 protocol standard definition. In Vamp devices, IEC 60870-5-101 communication protocol is available via menu selection. The Vamp unit works as a controlled outstation (slave) unit in unbalanced mode.

Supported application functions include process data transmission, event transmission, command transmission, general interrogation, clock synchronization, transmission of integrated totals, and acquisition of transmission delay.

For more information on IEC 60870-5-101 in Vamp devices refer to the Profile checklist document.

Parameters

Parameter	Value	Unit	Description	Note
bit/s	1200 2400 4800 9600	bps	Bitrate used for serial communication.	Set
Parity	None Even Odd		Parity used for serial communication	Set
LLAddr	1 - 65534		Link layer address	Set
LLAddrSize	1 – 2	bytes	Size of Link layer address	Set
ALAddr	1 – 65534		ASDU address	Set
ALAddrSize	1 – 2	Bytes	Size of ASDU address	Set
IOAddrSize	2 - 3	Bytes	Information object address size. (3-octet addresses are created from 2-octet addresses by adding MSB with value 0.)	Set
COTsize	1	Bytes	Cause of transmission size	
TTFormat	Short Full		The parameter determines time tag format: 3-octet time tag or 7-octet time tag.	Set
MeasFormat	Scaled Normalized		The parameter determines measurement data format: normalized value or scaled value.	Set
DbandEna	No Yes		Dead-band calculation enable flag	Set
DbandCy	100 - 10000	ms	Dead-band calculation interval	Set

Set = An editable parameter (password needed)

6.2.8. TCP/IP

Modbus TCP uses TCP/IP protocol. Also VAMPSET and SPA-bus and DNP 3.0 communication can be directed via TCP/IP.

VSE 005-1 external adaptor is designed for TCP/IP protocol. (See chapter 11 for more information.)

Parameters

Parameter	Value	Unit	Description	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
NameSv	default = 0.0.0.0		Name server (set with VAMPSET)	Set
NTPSvr	n.n.n.n		Network time protocol server (set with VAMPSET) 0.0.0.0 = no SNTP	Set
Port	502 = default		Port 502 is reserved for Modbus TCP	Set

Set = An editable parameter (password needed)

6.2.9. External I/O (Modbus RTU master)

External Modbus I/O devices can be connected to the relay using this protocol. (See chapter 8.7.1 External input / output modulefor more information).

6.2.10. IEC 61850

IEC 61850 protocol is available with the optional 61850 interface. The protocol can be configured to transfer the same information which is available with the IEC 103 protocol. Configuration is described in document “IEC 61850 communication VAMP relays/VSE 006, Configuration instructions”. When IEC 61850 is used the Remote port protocol of the relay is set to IEC-103.

7. Applications

The following chapters illustrate the versatile functions of the feeder and motor protection relay VAMP 40 in different applications

7.1. Substation feeder protection

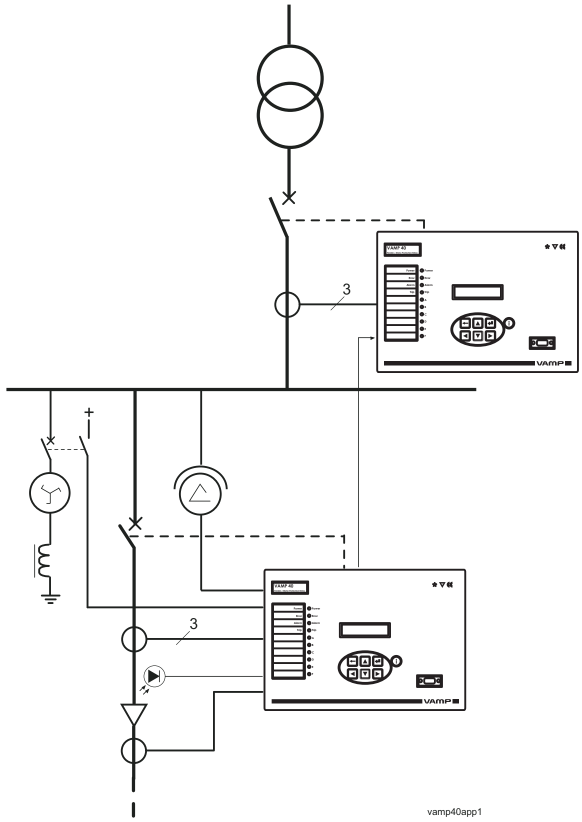


Figure 7.1-1 VAMP device used in substation feeder protection

The device includes three-phase overcurrent protection, directional earth fault protection and fast arc protection. At the incoming feeder, the instantaneous stage I>>> of the VAMP feeder device is blocked with the start signal of the overcurrent stage. This prevents the trip signal if the fault occurs on the outgoing feeder.

For the directional function of earth fault function, the status information (on/off) of the Petersen coil is routed to one of the digital inputs of the feeder device so that either $I_{0sin\varphi}$ or $I_{0cos\varphi}$ function is obtained.

The function $I_{0sin\varphi}$ is used in isolated networks, and the function $I_{0cos\varphi}$ is used in resistance or resonant earthed networks.

7.2. Industrial feeder protection

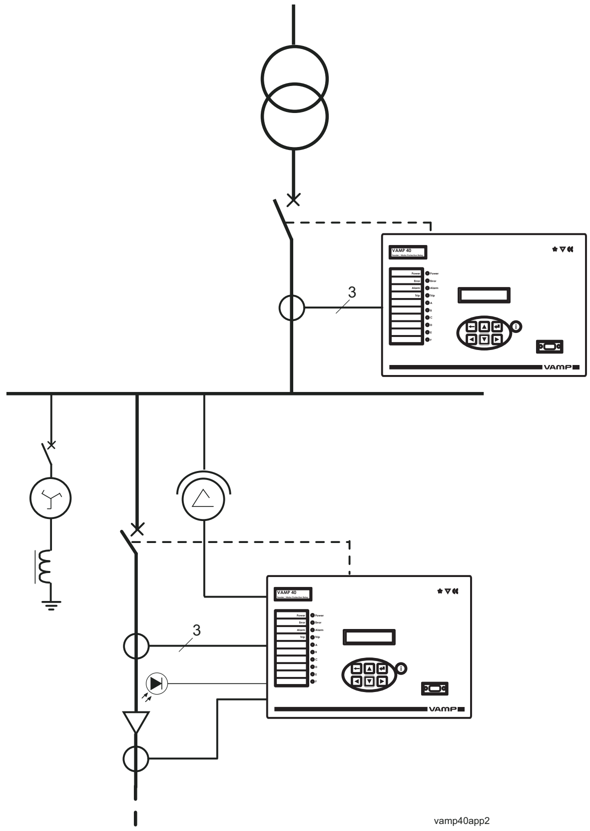


Figure 7.2-1 VAMP device used in cable protection of an industry plant network

Directional earth fault protection and three-phase overcurrent protection is required in a cable feeder. Furthermore, the thermal stage can be used to protect the cable against overloading. This example also includes fast arc protection.

7.3. Trip circuit supervision

Trip circuit supervision is used to ensure that the wiring from a protective relay to a circuit-breaker is in order. This circuit is unused most of the time, but when a feeder relay 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.

The digital inputs of the relay can be used for trip circuit monitoring.

7.3.1. Trip circuit supervision with one digital input

- The digital input is connected parallel with the trip contacts (Figure 7.3.1-1).
- 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 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.

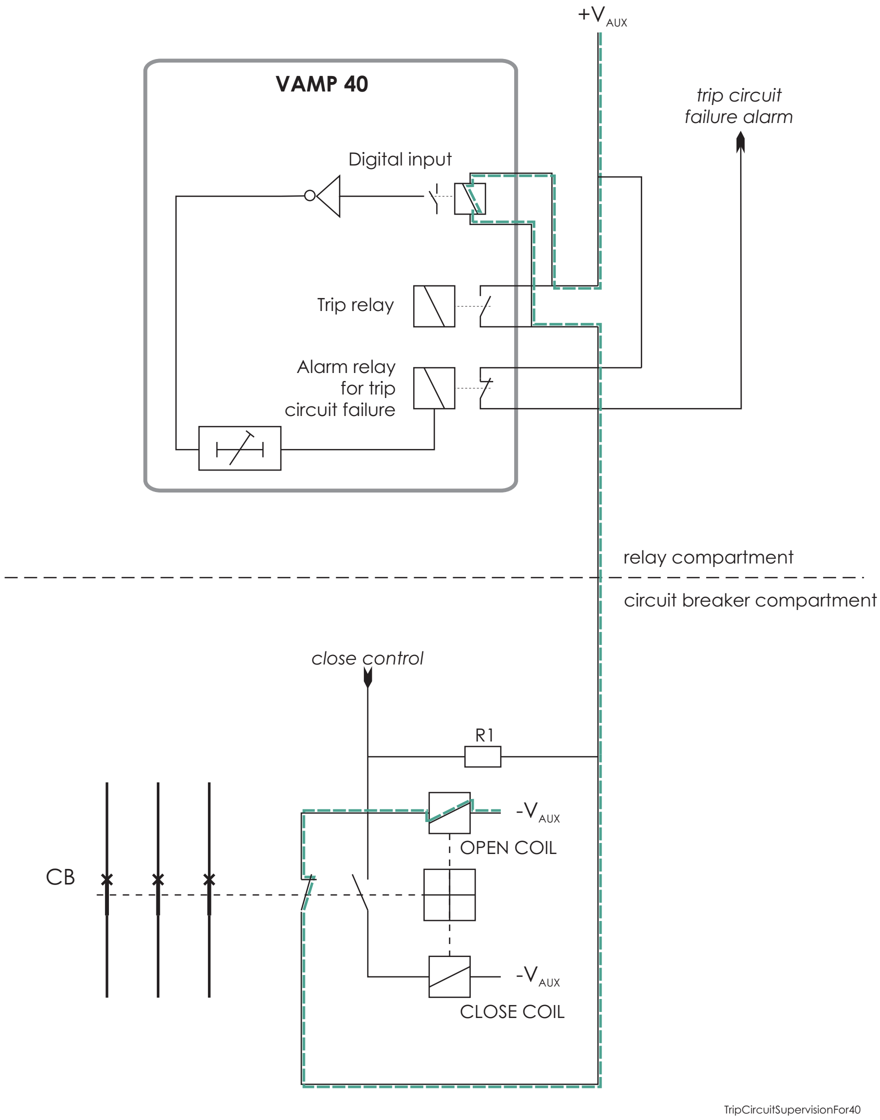


Figure 7.3.1-1. Trip circuit supervision when the circuit-breaker is closed. The supervised circuitry in this CB position is double-lined. The digital input is in active state. For the application to work when the circuit-breaker is opened, a resistor R1 must be placed. The value for it can be calculated from the external wetting supply, so that the current over R1 is >1 mA.

7.3.2. Trip circuit supervision with two digital inputs

- The first digital input is connected parallel with the trip contacts (Figure 7.3.2-1)
- The second digital input is connected parallel with the auxiliary contact of the circuit breaker.
- Both inputs are 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 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.

Both digital inputs must have their own common potential.

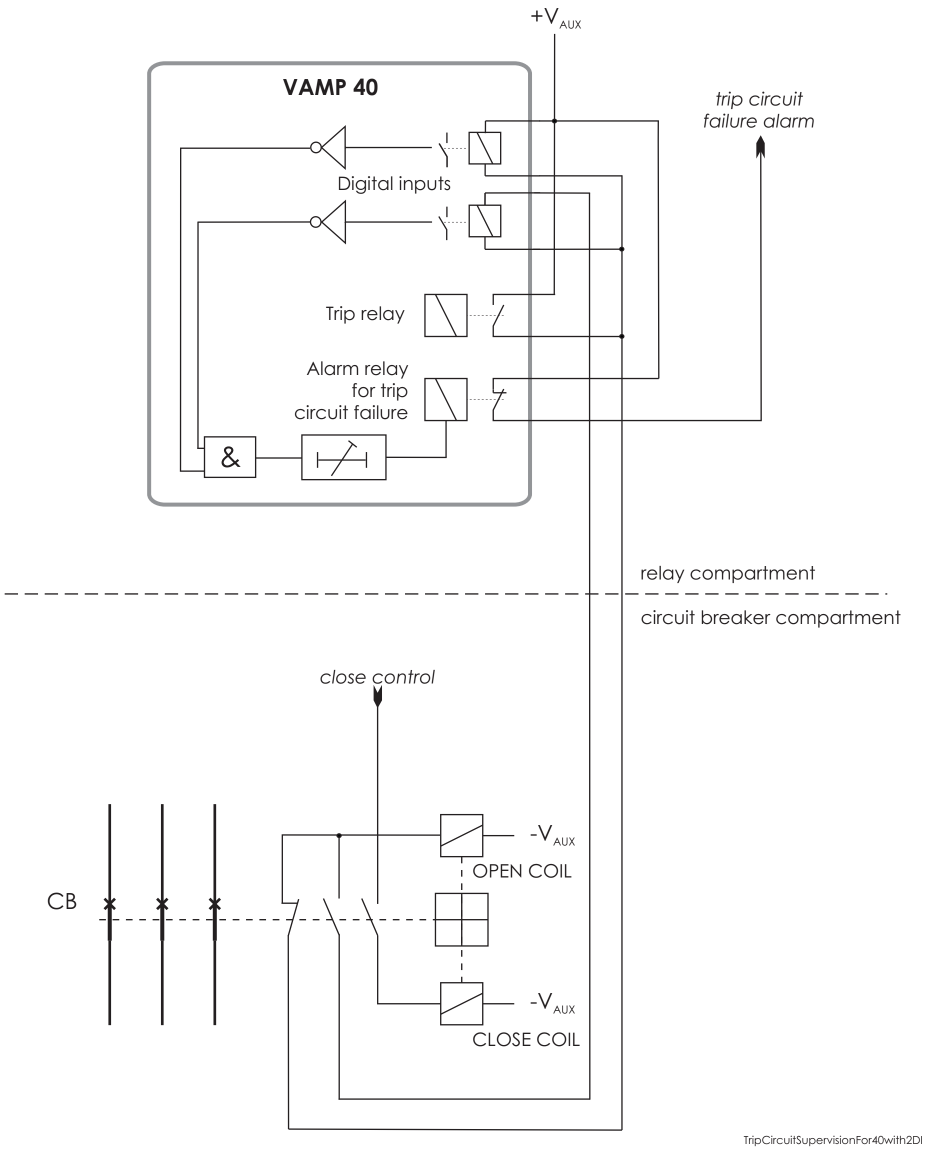


Figure 7.3.2-1. Trip circuit supervision with two digital inputs.

8. Connections

8.1. Rear panel view

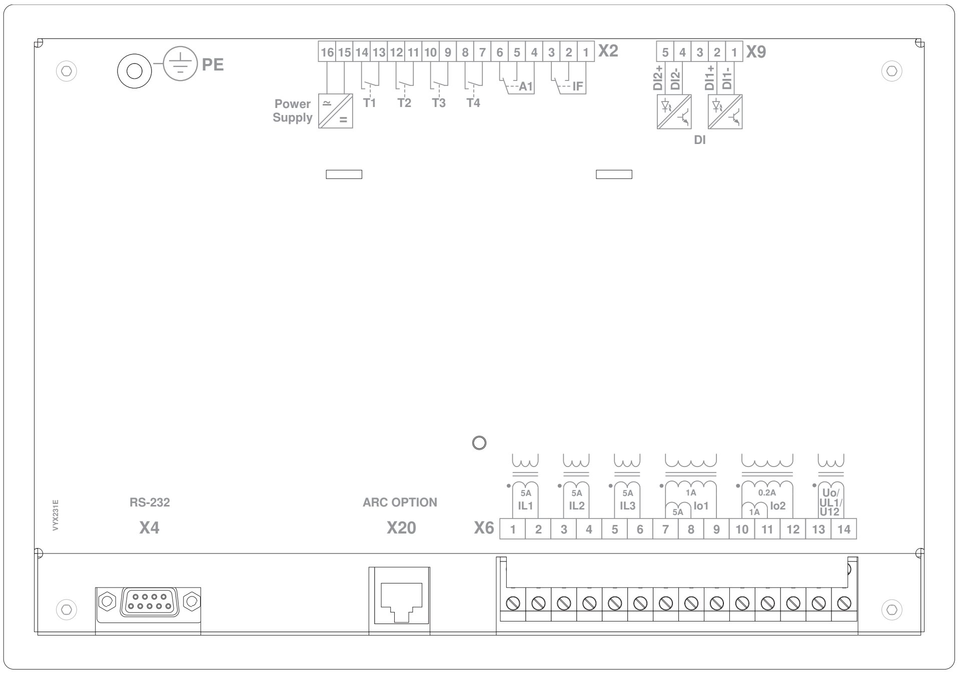
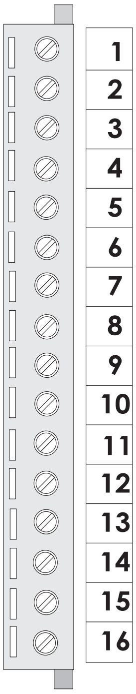


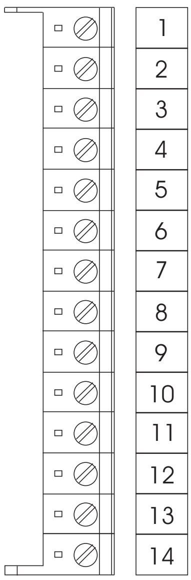
Figure 8.1-1. Connections on the rear panel of the VAMP 40.

Terminal X2



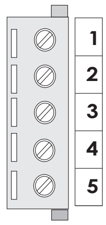
No	Symbol	Description
1	IF COM	Internal fault relay, common connector
2	IF NO	Internal fault relay, normal open connector
3	IF NC	Internal fault relay, normal closed connector
4	A1 COM	Alarm relay 1, common connector
5	A1 NO	Alarm relay 1, normal open connector
6	A1 NC	Alarm relay 1, normal closed connector
7	T4	Trip relay 4
8	T4	Trip relay 4
9	T3	Trip relay 3
10	T3	Trip relay 3
11	T2	Trip relay 2
12	T2	Trip relay 2
13	T1	Trip relay 1
14	T1	Trip relay 1
15	Uaux	Auxiliary voltage
16	Uaux	Auxiliary voltage

Terminal X6



No	Symbol	Description
1	IL1(S1)	Phase current L1 (S1)
2	IL1(S1)	Phase current L1 (S1)
3	IL2(S1)	Phase current L2 (S1)
4	IL2(S1)	Phase current L2 (S1)
5	IL3(S1)	Phase current L3 (S1)
6	IL3(S1)	Phase current L3 (S1)
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	Io2	Residual current Io2 common for 0.2 A and 1 A
11	Io2/1A	Residual current Io2 1 A (S2)
12	Io2/0.2A	Residual current Io2 0.2 A (S2)
13	Uo/U12/UL1	Phase to neutral voltage L1 (a) or phase to phase voltage U12 or zero sequence voltage Uo(da)
14	Uo/U12/UL1	Phase to neutral voltage L1 (a) or phase to phase voltage U12 or zero sequence voltage Uo(dn)

Terminal X9



No	Symbol	Description
1	DI1 -	Digital input 1 -
2	DI1 +	Digital input 1 +
3		
4	DI2 -	Digital input 2 -
5	DI2 +	Digital input 2 +

8.2. Digital inputs

Further, the relay can collect status information and alarm signals via 2 digital inputs. The digital inputs can also be used to block protection stages under certain conditions.

Potential-free contacts must be available in the protected object for transferring status information to the relay.

Wetting voltage for the digital inputs :

ON ≥18 V dc (≥ 50 V ac)

OFF ≤ 10 V dc (≤ 5 V ac)

The digital input signals can also be used as blocking signals and control signals for the output relays.

Summary of digital inputs:

DI	Polarity	Terminal	Operating voltage
1	DC – or AC	X9:1	External 18…265 VDC 50…250 VAC
	DC + or AC	X9:2	
2	DC – or AC	X9:4	
	DC + or AC	X9:5	

8.3. Auxiliary voltage

The external auxiliary voltage U_{aux} (19…265 V ac or dc) for the terminal is connected to the terminals X2: 15-16.

8.4. Output relays

The terminal is equipped with 5 configurable output relays, and a separate output relay for the self-supervision system.

- Trip relays T1 – T4 (terminals X2: 7-14)
- Alarm relay A1 (terminals X2: 4-6)
- Self-supervision system output relay IF (terminals X2: 1-3)

8.5. Serial communication connection

- RS 232 serial communication connection for computers, connector LOCAL (RS 232).
- Remote control connection with the following options:
  RS-232 (9-pin)
  RS-485, external adapter
  Plastic fibre, external adapter
  Glass fibre, external adapter
  Profibus RS-485 (9-pin), external adapter

8.5.1. Pin assignments of communication ports

The pin assignments of different remote port options are presented in the following tables.

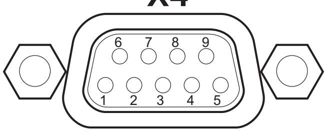


Figure 8-1. Pin numbering of the rear communication port, X4

Pin/ Terminal	RS-232
1	
2	Remote TX/RS-232 out
3	Remote RX/RS-232 in
4	
5	Local TX/RS-232 out
6	Local RX/RS-232 in
7	GND
8	
9	+8V

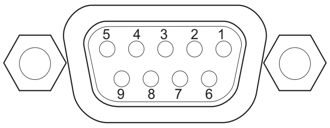


Figure 8-2. Pin numbering of the front communication port

Pin	Signal
1	
2	RX /RS-232 in
3	TX /RS-232 out
4	DTR / +8Vout
5	GND
6	DSR / in
7	
8	
9	

8.6. Arc protection (option)

The arc option module (VP 40) is connected to the back of the VAMP 40 protection relay. The RJ 45 connector is plugged to the X20 connector and the module is fasted to the back of VAMP 40 with one screw.

The optional arc protection module VP 40 includes two arc sensor channels. The arc sensors are connected to the VP 40 terminals 12-11 and 8-7.

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.

Connections:

1	Binary output +
2	Binary output -
5	Binary input +
6	Binary input –
7-8	Arc sensor 2 (VA 1 DA)
11-12	Arc sensor 1 (VA 1 DA)

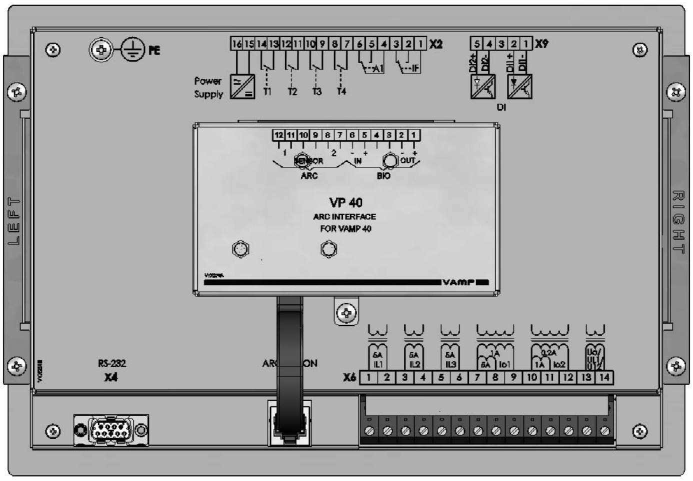


Figure 8.6-1 VP 40 is attached at the back side of the VAMP 40.

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.

8.7. External option modules

8.7.1. External input / output module

The feeder and motor relay supports now also external input / output modules used to extend the number of digital inputs and outputs. Other modules have analogue 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 IO modules. This port is found in the LOCAL connector of the relay backplane and IO devices should be connected to the port with VSE003 adapter.

NOTE! If ExternalIO protocol is not selected to any communication port, VAMPSET doesn't display the menus required for configuring the IO devices. After changing EXTENSION port protocol to ExternalIO, restart the relay and read all settings with VAMPSET.

External analog inputs configuration (VAMPSET only)

EXTERNAL ANALOG INPUTS

AI Enabled	AI Meas	AI Unit	AI Slave Address	AI ModBus Address	AI Register Type	AI Offset	x1	y1	x2	y2	AI Error Counter
On	0.00 C	C	1	1	HoldingR	0	0	0	1	1	0
Off	0.00 C	C	1	2	HoldingR	0	0	0	1	1	0
Off	0.00 C	C	1	3	HoldingR	0	0	0	1	1	0

	AI Enabled	AI Meas	AI Unit	AI Slave Address	AI ModBus Address	AI Register Type	AI Offset	x1, y1, x2, y2	AI Error Counter
Range	On / Off		C, F, K, or V/A	1…247	1…9999	InputR or HoldingR	-32000…32000	X: -32000…32000 Y: -1000…1000	
Description	Enabling for measurement	Active value	Unit selection	Modbus address of the IO device	Modbus register for the measurement	Modbus register type	offset: Subtracted from Modbus value, before running XY scaling	Scaling (see below)	Communication read errors

Scaling:

X1	Modbus value	Point 1
Y1	Scaled value	Point 1
X2	Modbus value	Point 2
Y2	Scaled value	Point 2
offset	Subtracted from Modbus value, before running XY scaling	

Alarms for external analog inputs

EXTERNAL ANALOG INPUT ALARMS

AI Enabled	AI Slave Address	AI ModBus Address	AI Meas	External AI Alarm State >	Alarm Limit >	External AI Alarm State >>	Alarm Limit >>	Alarm Hysteresis
On	1	1	0.00 C	-	0.0	-	0.0	1.0
Off	1	2	0.00 C	-	0.0	-	0.0	1.0
Off	1	3	0.00 C	-	0.0	-	0.0	1.0

	AI Enabled	AI Slave Address	AI ModBus Address	AI Meas	Alarm >		Alarm >>		Alarm Hysteresis
Range	On / Off	1…247	1…9999		- / Alarm	-21x107… …21x107	- / Alarm	-21x107… …21x107	0…10000
Description	Enabling for measurement	Modbus address of the IO device	Modbus register for the measurement	Active value	Active state	Limit setting	Active state	Limit setting	Hysteresis for alarm limits

Analog input alarms have also matrix signals, “Ext. AIx Alarm1” and “Ext. AIx Alarm2”.

External digital inputs configuration (VAMPSET only)

EXTERNAL DIGITAL INPUTS

DI Enabled	DI State	DI Slave Address	DI ModBus Address	DI Register Type	DI Selected Bit	DI Error Counter
On	0	1	1	CoilS	1	0
Off	0	1	2	CoilS	1	0
Off	0	1	3	CoilS	1	0

	DI Enabled	DI State	DI Slave Address	DI ModBus Address	DI Register Type	DI Selected Bit	DI Error Counter
Range	On / Off	0 / 1	1…247	1…9999	CoilS, InputS, InputR or HoldingR	1…16	
Description	Enabling for input	Active state	Modbus address of the IO device	Modbus register for the measurement	Modbus register type	Bit number of Modbus register value	Communication read errors

External digital outputs configuration (VAMPSET only)

EXTERNAL DIGITAL OUTPUTS

DO Enabled	DO State	DO Slave Address	DO ModBus Address	DO Error Counter
On	0	1	1	0
Off	0	1	2	0
Off	0	1	3	0

	DO Enabled	DO State	DO Slave Address	DO ModBus Address	DO Error Counter
Range	On / Off	0 / 1	1…247	1…9999	
Description	Enabling for output	Output state	Modbus address of the IO device	Modbus register for the measurement	Communication errors

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

Parameter	Range	Description
AO Enabled	On / Off	Enabling for measurement
mA Output		Active value
mA Min, mA Max	-21x107… …+21x107	Minimum & maximum output values
AO Link		Link selection
Linked Val. Min	0…42x108, -21…+21x108	Minimum limit for lined value, corresponding to "Modbus Min"
Linked Val. Max	0…42x108, -21…+21x108	Maximum limit for lined value, corresponding to "Modbus Max"
AO Slave Address	1…247	Modbus address of the IO device
AO ModBus Address	1…9999	Modbus register for the output
AO Register Type	InputR or HoldingR	Modbus register type
ModBus Min	-32768…+32767 (0…65535)	Modbus value corresponding Linked Val. Min
ModBus Max	-32768…+32767 (0…65535)	Modbus value corresponding Linked Val. Max
AO Error Counter		Communication errors

8.8. Block diagrams

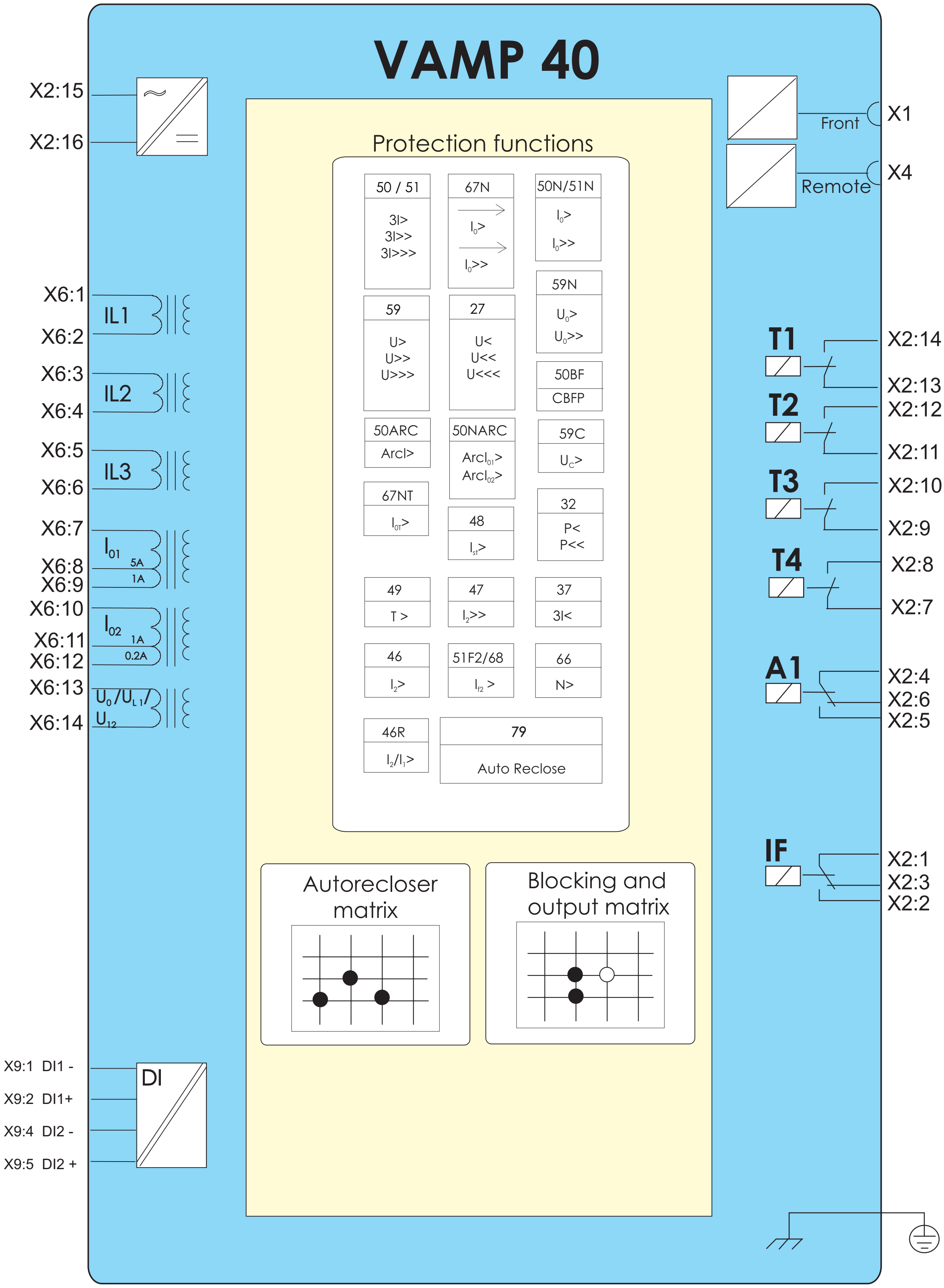


Figure 8.8-1. Block diagram of the feeder and motor protection relay VAMP 40.

8.9. Block diagrams of optional arc modules

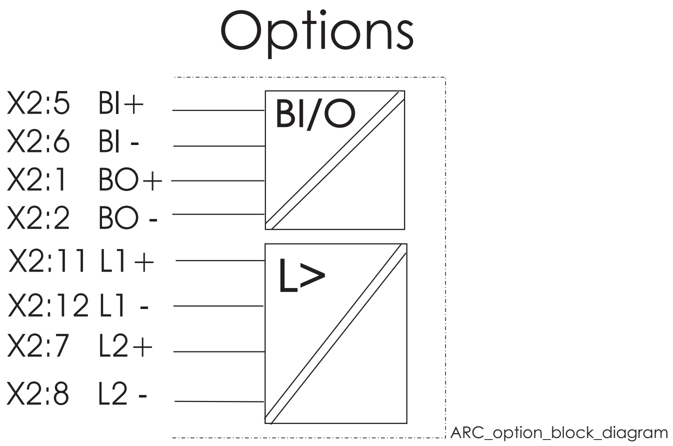


Figure 8.9-1 Block diagram of optional arc protection module.

8.10. Connection examples

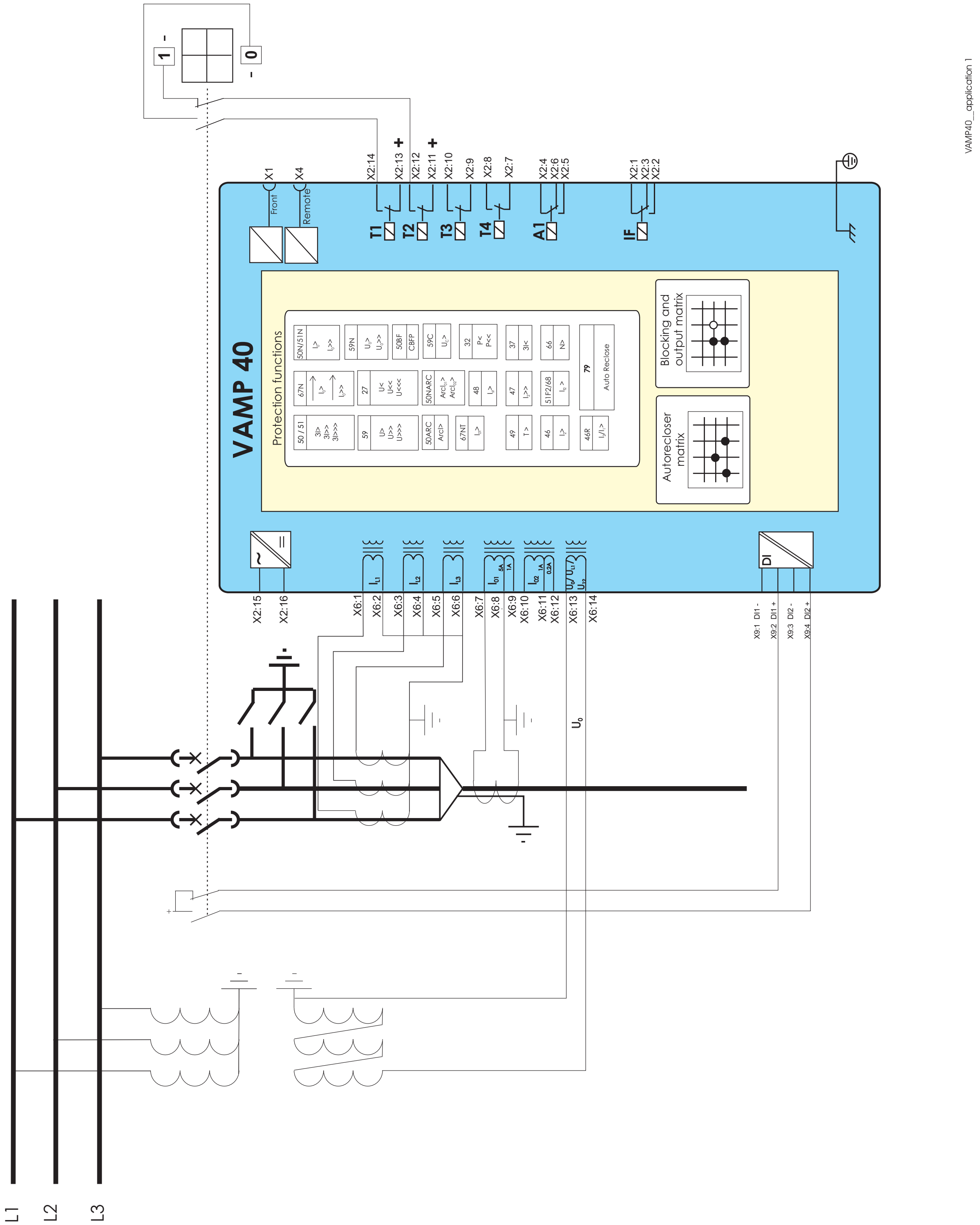


Figure 8.10-1 Connection example of feeder and motor protection relay VAMP 40, using U_0. The voltage meas. Mode is set to "U_0".

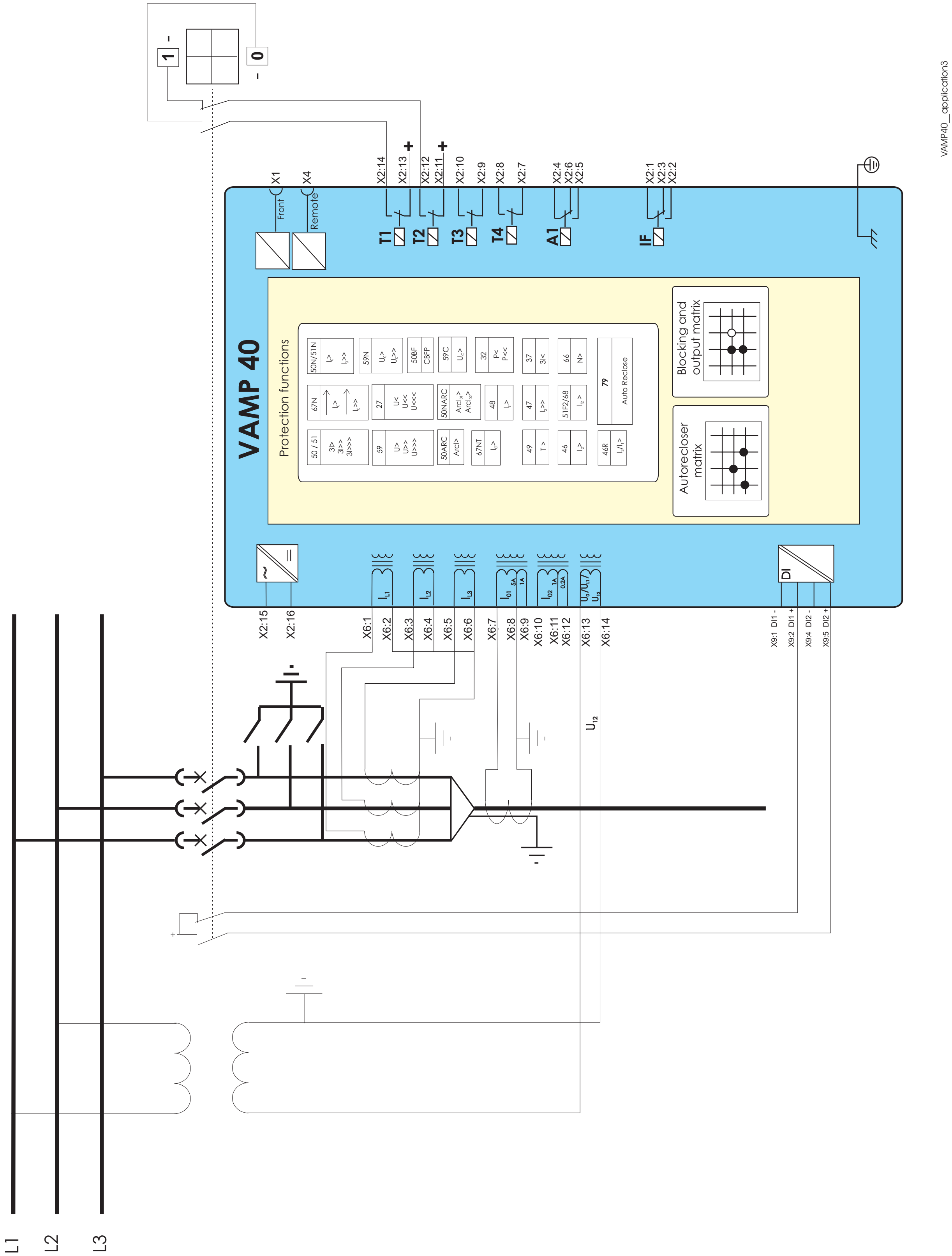


Figure 8.10-2. Connection example of feeder and motor protection relay VAMP 40, using U_{12}. The voltage meas. mode is set to "1LL".

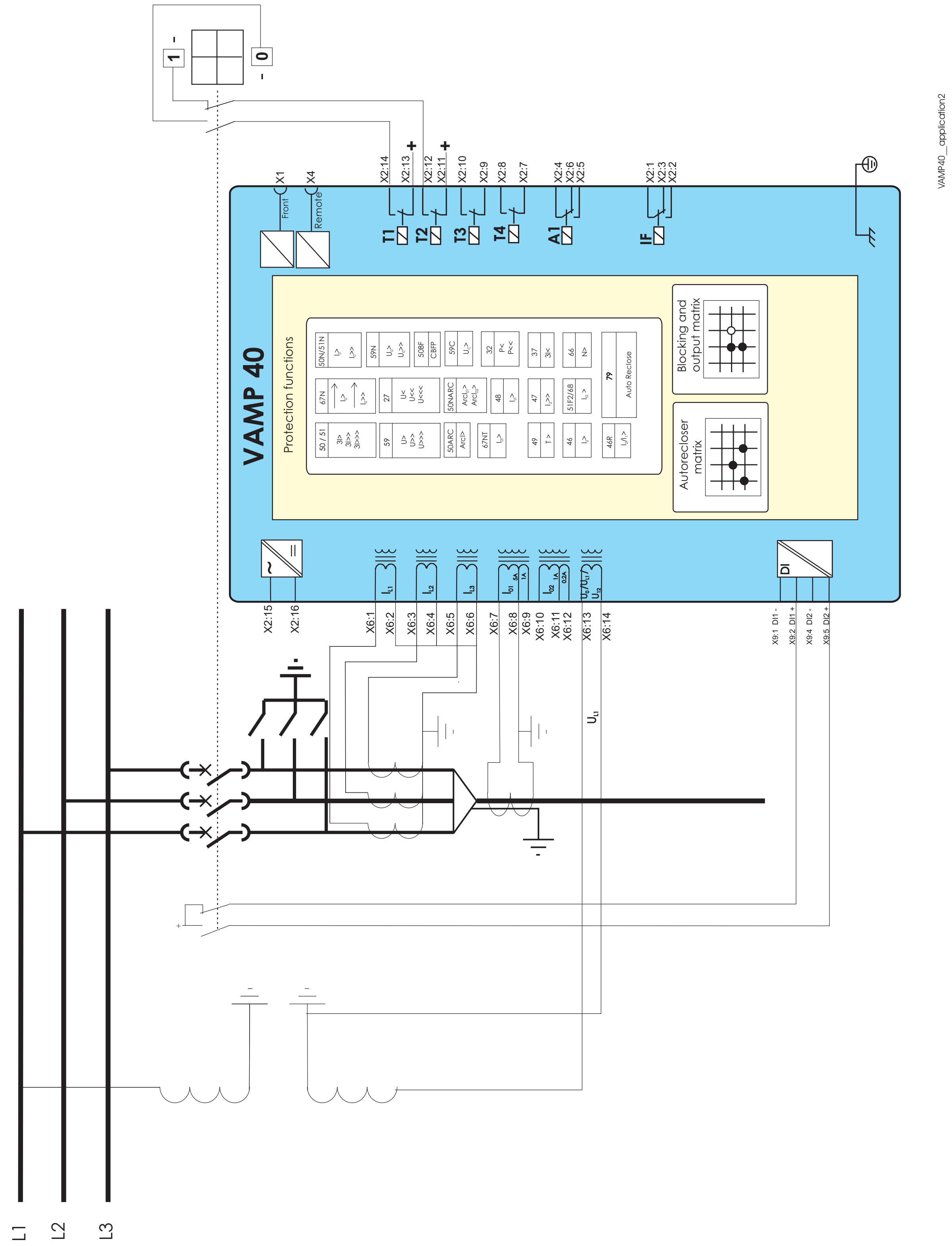


Figure 8.10-3 Connection example of feeder and motor protection relay VAMP 40, using UL_1. The voltage meas. mode is set to "1LN".

9. Technical data

9.1. Connections

9.1.1. Measuring circuitry

Rated current I_n - Current measuring range - Thermal withstand - Burden	5 A (configurable for CT secondaries 1 – 10 A) 0…250 A 20 A (continuously) 100 A (for 10 s) 500 A (for 1 s) < 0.2 VA
Rated current I_{0n} - Current measuring range - Thermal withstand - Burden	5 A / 1 A 0…50 A / 10 A 4 x I_{0n} (continuously) 20 x I_{0n} (for 10 s) 100 x I_{0n} (for 1 s) < 0.2 VA
Rated current I_{02n} - Current measuring range - Burden	1 A / 0.2 A 0…10 A / 2 A 4 x I_{02n} (continuously) 20 x I_{02n} (for 10 s) 100 x I_{02n} (for 1 s) < 0.2 VA
Rated voltage U_n - Voltage measuring range - Continuous voltage withstand - Burden	100 V (configurable for VT secondaries 50 – 120 V) 0 - 160 V 250 V < 0.5 VA
Rated frequency f_n - Frequency measuring range	45 - 65 Hz 16 - 75 Hz
Terminal block: - Solid or stranded wire	Maximum wire dimension: 4 mm² (10-12 AWG)

9.1.2. Auxiliary voltage

Rated voltage U_{aux}	19 … 265 V ac/dc For rated voltages 24 … 240 V ac /dc
Power consumption Max. permitted interruption time	< 7 W (normal conditions) < 15 W (output relays activated) < 50 ms (110 V dc)
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm² (13-14 AWG)

9.1.3. Digital inputs

Internal operating voltage

Number of inputs	2
External operating voltage	18 V … 265 V dc
Current drain	approx. 2 mA
Terminal block:	Maximum wire dimension:
- Phoenix MVSTBW or equivalent	2.5 mm² (13-14 AWG)

9.1.4. Trip contacts

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: at 110 V dc: at 220 V dc	 5 A 3 A 1 A
Contact material	AgNi 90/10
Terminal block: - Phoenix MVSTBW or equivalent	Maximum wire dimension: 2.5 mm² (13-14 AWG)

9.1.5. Alarm contacts

Number of contacts:	2 change-over contacts (relays A1 and IF)
Rated voltage	250 V ac/dc
Continuous carry	5 A
Breaking capacity, DC (L/R=40ms) at 48 V dc: at 110 V dc: at 220 V dc	 1,3 A 0,4 A 0,2 A
Contact material	AgNi 0.15 gold plated
Terminal block - Phoenix MVSTBW or equivalent	Maximum wire dimension 2.5 mm² (13-14 AWG)

9.1.6. Local serial communication port

Number of ports	1 on front and 1 on rear panel
Electrical connection	RS 232
Data transfer rate	2 400 - 38 400 kb/s

9.1.7. Remote control connection

Number of ports	1 on rear panel
Electrical connection	RS 232
Data transfer rate	1 200 - 19 200 kb/s
Protocols	ModBus, RTU master ModBus, RTU slave SpaBus, slave IEC 60870-5-103 IEC 60870-5-101 ProfiBus DP (option) ModBus TCP (option, external module) IEC 61850 DNP 3.0

9.1.8. Arc protection interface (option)

Number of arc sensor inputs Sensor type to be connected Operating voltage level Current drain, when active Current drain range	2 VA 1 DA 12 V dc > 11.9 mA 1.3...31 mA (**Note!** If the drain is outside the range, either sensor or the wiring is defected)
Number of binary inputs Operating voltage level	1 (optically isolated) +48 V dc
Number of binary outputs Operating voltage level	1 (transistor controlled) +48 V dc

NOTE! Maximally three arc binary inputs can be connected to one arc binary output without an external amplifier.

9.2. Tests and environmental conditions

9.2.1. Disturbance tests

Emission - Conducted - Emitted	EN 61000-6-4 / IEC 60255-26 EN 55011 / IEC 60255-25 0.15 - 30 MHz EN 55011 / IEC 60255-25 30 - 1 000 MHz
Immunity - Static discharge (ESD) - Fast transients (EFT) - Surge - Conducted HF field - Emitted HF field	EN 61000-6-2 / IEC 60255-26 EN 61000-4-2 class IV / IEC 60255-22-2 8 kV contact discharge 15 kV air discharge EN 61000-4-4 class IV / IEC 60255-22-4, class A 4 kV, 5/50 ns, 2.5/5 kHz, +/- EN 61000-4-5 class IV / IEC 60255-22-5 4 kV, 1.2/50 µs, line-to-earth 2 kV, 1.2/50 µs, line-to-line EN 61000-4-6 class III / IEC 60255-22-6 0.15 - 80 MHz, 10 V EN 61000-4-3 class III / IEC 60255-22-3 80 - 1000 MHz, 10 V/m

9.2.2. Test voltages

Insulation test voltage (IEC 60255-5)	2 kV, 50 Hz, 1 min
Surge voltage (IEC 60255-5)	5 kV, 1.2/50 µs, 0.5 J

9.2.3. Mechanical tests

Vibration	IEC 60255-21-1, class I
Shock	IEC 60255-21-2, class I

9.2.4. Environmental conditions

Operating temperature	-10 to +65 °C
Transport and storage temperature	-40 to +70 °C
Relative humidity	< 75% (1 year, average value) < 90% (30 days per year, no condensation permitted)

9.2.5. Casing

Degree of protection (IEC 60529)	IP20 (IP54 with sealing)
Dimensions (W x H x D)	280 x 195 x 55 mm
Material	1 mm steel plate
Weight	2.0 kg
Colour code	RAL 7032 (Casing) / RAL 7035 (Back plate)

9.2.6. Package

Dimensions (W x H x D)	315 x 260 x 105 mm
Weight (Terminal, Package and Manual)	3.0 kg

9.3. Protection stages

NOTE! Please see chapater 2.4.2 for explanation of I_{MODE}.

9.3.1. Overcurrent protection

Overcurrent stage I> (50/51)

Pick-up current	0.10 – 5.00 x I_{MODE}
Definite time function: - Operating time	DT 0.08**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 0.97
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Operating time at definite time function - Operating time at IDMT function - Operating time at IDMT function	 ±3% of the set value ±1% or ±30 ms ±5% or at least ±30 ms **) ±5% or at least ±30 ms (I< 50 x I_{MODE})

*) 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.

Overcurrent stages I>> and I>>> (50/51)

Pick-up current	0.10 – 20.00 x I_{MODE} (I>>) 0.10 – 40.00 x I_{MODE} (I>>>)
Definite time function: - Operating time	 0.04**) – 300.00 s (step 0.01 s)
Start time Reset time Retardation time Reset ratio	Typically 60 ms <95 ms <50 ms 0.97
Transient over-reach, any τ	<10 %
Inaccuracy: - Starting - Operation time	 ±3% of the set value ±1% or ±25 ms

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Stall protection stage (48)

Setting range: - Motor start detection current - Nominal motor start current	 1.30 – 10.00 xI_{MOT} (step 0.01) 1.50 – 10.00 xI_{MOT} (step 0.01)
Definite time characteristic: - operating time	 1.0 – 300.0 s (step 0.1)
Inverse time characteristic: - 1 characteristic curve - Time multiplier t_{DT}>	 Inv 1.0 – 200.0 s (step 0.1)
- Minimum motor stop time to activate stall protection - Maximum current raise time from motor stop to start	500 ms 200 ms
Starting time Resetting time Resetting ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting - Operating time at definite time function - Operating time at IDMT function	 ±3% of the set value ±1% or at ±30 ms ±5% or at least ±30 ms *)

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Thermal overload stage T> (49)

Setting range: Alarm setting range: Time constant Tau: Cooling time coefficient: Max. overload at +40 °C Max. overload at +70 °C Ambient temperature Resetting ratio (Start & trip) Inaccuracy: - operating time	0.1 – 2.40 x I_{MOT} or I_N (step 0.01) 60 – 99 % (step 1%) 2 – 180 min (step 1) 1.0 – 10.0 xTau (step 0.1) 70 – 120 %I_{MOT} (step 1) 50 – 100 %I_{MOT} (step 1) -55 – 125 °C (step 1°) 0.95 ±5% or ±1 s

Unbalance stage I_2> (46)

Setting range:	2 – 70% (step 1%)
Definite time characteristic:	
- operating time	1.0 – 600.0s s (step 0.1)
Inverse time characteristic:	
- 1 characteristic curve	Inv
- time multiplier K_1	1 – 50 s (step 1)
- upper limit for inverse time	1 000 s
Start time	Typically 200 ms
Reset time	<450 ms
Reset ratio	0.95
Inaccuracy:	
- Starting	±1%-unit
- Operate time	±5% or ±200 ms

Incorrect phase sequence I_2>> (47)

Setting:	80 % (fixed)
Operating time	<120 ms
Reset time	<105 ms

Stage is blocked when motor has been running for 2 seconds.

Undercurrent protection stage I< (37)

Current setting range:	20 – 70 % I_{MODE} (step 1%)
Definite time characteristic:	
- operating time	0.3 – 300.0s s (step 0.1)
Block limit:	15 % (fixed)
Starting time	Typically 200 ms
Resetting time	<450 ms
Resetting ratio	1.05
Accuracy:	
- starting	±2% of set value
- operating time	±1% or ±150 ms

Unbalance / broken line protection I_2/I_1> (46R)

Settings: - Setting range I_2/ I_1>	 2 – 70 %
Definite time function: - Operating time	 1.0 – 600.0 s (step 0.1 s)
Start time Reset time Reset ratio	Typically 200 ms <450 ms 0.95
Inaccuracy: - Starting - Operate time	 ±1%-unit ±5%

Earth fault stage $I_0>$ (50N/51N)

Input signal	I_0 (input X6- 7 & 8 or X6- 7 & 9) I_{02} (input X6- 10 & 11 or X6- 10 & 12) I_{0CALC} (= $I_{L1}+I_{L2}+I_{L3}$)
Setting range $I_0>$	0.005 … 8.00 When I_0 or I_{02} 0.05 … 20.0 When I_{0CALC}
Definite time function: - Operating time	DT 0.08**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Reset ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting - Starting (Peak mode) - Operating time at definite time function - Operating time at IDMT function.	 ±2% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±1% or ±30 ms ±5% or at least ±30 ms **)

*) 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.

Earth fault stages $I_0>>$, $I_0>>>$, $I_0>>>>$ (50N/51N)

Input signal	I_0 (input X6- 7 & 8 or X6- 7 & 9) I_{02} (input X6- 10 & 11 or X6- 10 & 12) I_{0CALC} (= $I_{L1}+I_{L2}+I_{L3}$)
Setting range $I_0>>$	0.01 … 8.00 When I_0 or I_{02} 0.05 … 20.0 When I_{0CALC}
Definite time function: - Operating time	 0.08**) – 300.00 s (step 0.02 s)
Start time Reset time Reset ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting - Starting (Peak mode) - Operate time	 ±2% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±1% or ±30 ms

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

Directional intermittent transient earth fault stage I_{0T}> (67NT)

Input selection for I_0 peak signal	I_{01} Connectors X1-7&8 I_{02} Connectors X1-9&10
I_0 peak pick up level (fixed)	0.1 x I_{0N} @ 50 Hz
U_0 pickup level	10 – 100 % U_{0N}
Definite operating time	0.12 – 300.00 s (step 0.02)
Intermittent time	0.00 – 300.00 s (step 0.02)
Start time	<60 ms
Reset time	<60 ms
Reset ratio (hysteresis) for U_0	0.97
Inaccuracy:	
- starting	±3% for U_0. No inaccuracy defined for I_0 transients
- time	±1% or ±30 ms *)

*) The actual operation time depends of the intermittent behaviour of the fault and the intermittent time setting.

Directional earth fault stages $I_{0\varphi}$>, $I_{0\varphi}$>> (67N)

Pick-up current	0.01 - 8.00 x I_{0N} 0.05 … 20.0 When I_{0CALC}
Start voltage	1 – 20 %U_{0N}
Input signal	I_0 (input X6- 7 & 8 or X6- 7 & 9) I_{02} (input X6- 10 & 11 or X6- 10 & 12) I_{0CALC} (= I_{L1}+I_{L2}+I_{L3})
Mode	Non-directional/Sector/ResCap
Base angle setting range	-180° to + 179°
Operation angle	±88° (10°- 170°)
Definite time function: - Operating time	 0.10**) – 300.00 s (step 0.02 s)
IDMT function: - Delay curve family - Curve type - Time multiplier k	 (DT), IEC, IEEE, RI Prg EI, VI, NI, LTI, MI…depends on the family *) 0.05 – 20.0, except 0.50 – 20.0 for RXIDG, IEEE and IEEE2
Start time Reset time Reset ratio	Typically 60 ms <95 ms 0.95
Inaccuracy: - Starting Uo&Io (rated value I_n= 1 .. 5A) - Starting Uo&Io (Peak Mode when, rated value I_{0n}= 1 .. 10A) - Angle - Operate time at definite time function - Operate time at IDMT function	 ±3% of the set value or ±0.3% of the rated value ±5% of the set value or ±2% of the rated value (Sine wave <65 Hz) ±2° ±1% or ±30 ms ±5% or at least ±30 ms **)

*) 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.

9.3.2. Frequent start protection

Frequent start protection N> (66)

Settings: - Max motor starts - Min time between motor starts	 1 – 20 0.0 – 100 min. (step 0.1 min)
Operation time	<250 ms
Inaccuracy: - Min time between motor starts	 ±5% of the set value

9.3.3. Voltage protection

Capacitor overvoltage stage U_C> (59C)

Overvoltage setting range	0.10 – 2.50 pu (1 pu = U_{CLN})
Capacitance setting range	1.00 – 650.00 µF
Rated phase-to-star point capacitor voltage = 1 pu	100 – 260000 V
Definite time characteristic:	
- operating time	1.0 – 300.0 s (step 0.5)
Start time	Typically 1.0 s
Reset time	<2.0 s
Reset ratio (hysteresis)	0.97
Inaccuracy:	
- starting	±5% of the set value
- time	±1% or ±1 s

Single-phase overvoltage stages U>, U>> and U>>> (59) ***

Overvoltage setting range:	50 - 150 %U_N for U>, U>> **)
	50 - 160 % U_N for U>>> **)
Definite time characteristic:	
- operating time	0.08*) - 300.00 s (step 0.02) (U>, U>>)
	0.06*) - 300.00 s (step 0.02) (U>>>)
Starting time	Typically 60 ms
Resetting time U>	0.06 - 300.00 s (step 0.02)
Resetting time U>>, U>>>	<95 ms
Retardation time	<50 ms
Reset ratio	0.99 – 0.800 (0.1 – 20.0 %, step 0.1 %)
Inaccuracy:	
- starting	±3% of the set value **)
- operate time	±1% or ±30 ms

*) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

**) The measurement range is up to 160 V. This limits the maximum usable setting when rated VT secondary is more than 100 V.

***) Only when measurement option is 1Line (line-to-line voltage) or 1Phase (phase-to-neutral voltage). **A complete three phase voltage protection is not possible with VAMP 40.**

Single-phase undervoltage stages U<, U<< and U<<< (27) ***

Setting range	20 – 120%xU_N
Definite time function:	
- Operating time U<	0.08 *) – 300.00 s (step 0.02 s)
- Operating time U<< and U<<<	0.06 *) – 300.00 s (step 0.02 s)
Undervoltage blocking	0 – 80% x U_N
Start time	Typically 60 ms
Reset time for U<	0.06 – 300.00 s (step 0.02 s)
Reset time for U<< and U<<<	<95 ms
Retardation time	<50 ms
Reset ratio (hysteresis)	1.001 – 1.200 (0.1 – 20.0 %, step 0.1 %)
Reset ratio (Block limit)	0.5 V or 1.03 (3 %)
Inaccuracy:	
- starting	±3% of set value
- time	±1% or ±30 ms

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

***) Only when measurement option is 1Line (line-to-line voltage) or 1Phase (phase-to-neutral voltage). **A complete three phase voltage protection is not possible with VAMP 40.**

Zero sequence voltage stages U_0> and U_0>> (59N)

Zero sequence voltage setting range	1 – 60 %U_{0N}
Definite time function: - Operating time	 0.3 – 300.0 s (step 0.1 s)
Start time Reset time Reset ratio	Typically 200 ms <450 ms 0.97
Inaccuracy: - Starting - Starting UoCalc (3LN mode) - Operate time	 ±2% of the set value or ±0.3% of the rated value ±1 V ±1% or ±150 ms

NOTE! This is only available in voltage measurement mode U_0.

9.3.4. Power protection

Reverse power and under-power stages P<, P<< (32)

Pick-up setting range	–200.0 ... +200.0 %Pm
Definite time function: - Operating time	 0.3 – 300.0 s
Start time Reset time Reset ratio	Typically 200 ms <500 ms 1.05
Inaccuracy: - Starting - Operating time at definite time function	 ±3 % of set value or ±0.5 % of rated value ±1 % or ±150 ms

NOTE! When pick-up setting is +1 … +200% an internal block will be activated if max. voltage of all phases drops below 5% of rated.

9.3.5. Circuit-breaker failure protection

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)
Reset time	<95 ms
Inaccuracy - Operating time	 ±20 ms

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

9.3.6. Arc fault protection (option)

The operation of the arc protection depends on the setting value of the ArcI>, $ArcI_0$> and $ArcI_{02}$> current limits. The arc current limits cannot be set, unless the relay is provided with the optional arc protection card.

Arc protection stage ArcI> (50AR), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<80 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

Arc protection stage $ArcI_0$> (50AR), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<80 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

Arc protection stage $ArcI_{02}$> (50AR), option

Setting range	0.5 - 10.0 x I_N
Arc sensor connection	S1, S2, S1/S2, BI, S1/BI, S2/BI, S1/S2/BI
- Operating time (Light only)	13 ms
- Operating time (4xIset + light)	17ms
- Operating time (BIN)	10 ms
- BO operating time	<3 ms
Reset time	<95 ms
Reset time (Delayed ARC L)	<120 ms
Reset time (BO)	<80 ms
Reset ratio	0.90
Inaccuracy:	
- Starting	10% of the set value
- Operating time	±5 ms
- Delayed ARC light	±10 ms

9.4. Supporting functions

9.4.1. Disturbance recorder (DR)

The operation of disturbance recorder depends on the following settings. The recording time and the number of records depend on the time setting and the number of selected channels.

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
	(must be shorter than MAX time)
Pre-trigger rate	0 – 100%
Number of selected channels	0 – 12

9.4.2. Inrush current detection (68)

Settings:	
- Setting range 2.Harmonic	10 – 100 %
- Operating time	0.05** – 300.00 s (step 0.01 s)

**) This is the instantaneous time i.e. the minimum total operational time including the fault detection time and operation time of the trip contacts.

9.4.3. Transformer supervision

Current transformer supervision

Pick-up current	0.00 – 10.00 x I_N
Definite time function:	DT
- Operating time	0.06 – 600.00 s (step 0.02 s)
Reset time	<60 ms
Reset ratio Imax>	0.97
Reset ratio Imin<	1.03
Inaccuracy:	
- Activation	±3% of the set value
- Operating time at definite time function	±1% or ±30 ms

9.4.4. Voltage sag & swell

Voltage sag limit	10 – 120 %
Voltage swell limit	20 – 150 %
Definite time function: - Operating time	DT 0.08 – 1.00 s (step 0.02 s)
Low voltage blocking Reset time Reset ration: - Sag - Swell Block limit	0 – 50 % <60 ms 1.03 0.97 0.5 V or 1.03 (3 %)
Inaccuracy: - Activation - Activation (block limit) - Operating time at definite time function	 ±0.5 V or 3% of the set value ±5% of the set value ±1% or ±30 ms

If one of the phase voltages is below sag limit and above block limit but another phase voltage drops below block limit, blocking is disabled.

9.4.5. Voltage interruptions

Voltage low limit (U1)	10 – 120 %
Definite time function: - Operating time	DT <50 ms (Fixed)
Reset time Reset ratio:	<60 ms 1.03
Inaccuracy: - Activation	 3% of the set value

10. Abbreviations and symbols

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
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.
Hysteresis	I.e. dead band. Used to avoid oscillation when comparing two near by values.
I_{MODE}	Nominal current of the selected mode. In feeder mode, I_{MODE}= $VT_{primary}$. In motor mode, I_{MODE}= I_{MOT}.
I_{SET}	Another name for pick up setting value I>
I_{0SET}	Another name for pick up setting value I_0>
I_{01N}	Nominal current of the I_{01} input of the relay
I_{02N}	Nominal current of the I_{02} input of the relay
I_{0N}	Nominal current of I_0 input in general
I_{MOT}	Nominal current of the protected motor
I_N	Nominal current. Rating of CT primary or secondary.
IEC	International Electrotechnical Commission. An international standardization organisation.
IEEE	Institute of Electrical and Electronics Engineers

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
LAN	Local area network. Ethernet based network for computers and relays.
Latching	Output relays and indication LEDs can be latched, which means that they are not released when the control signal is releasing. Releasing of lathed devices is done with a separate action.
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 = $1xI_{MODE}$.
Q	Reactive power. Unit = [var] acc. IEC
RMS	Root mean square
S	Apparent power. Unit = [VA]
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 earth fault. (Used in voltage measurement mode "2LL+Uo")
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)
VT	Voltage transformer i.e. potential transformer PT
VT_{PRI}	Nominal primary value of voltage transformer
VT_{SEC}	Nominal secondary value of voltage transformer
WWW	World wide web ≈ internet

11. Construction

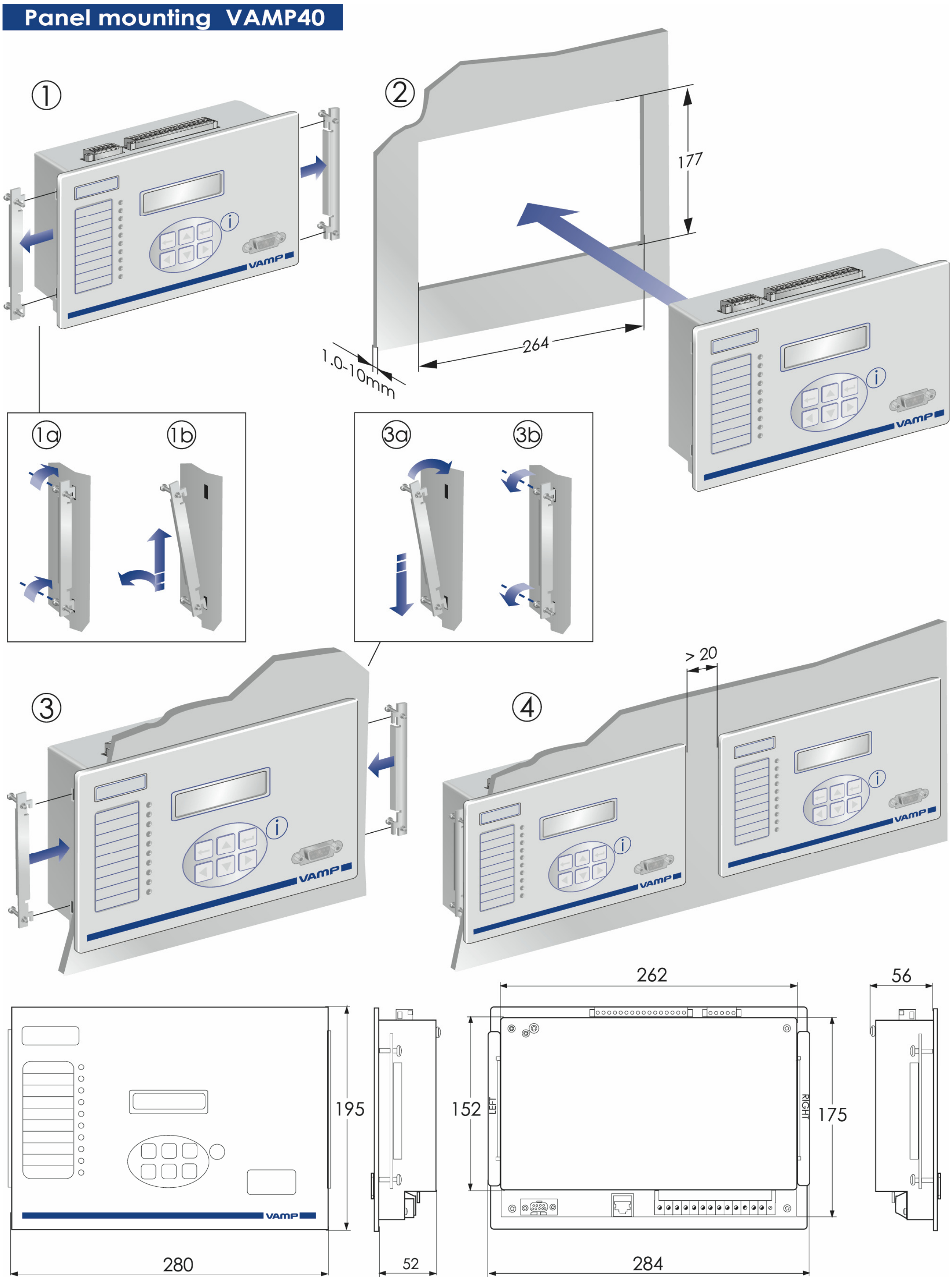


Figure 11-1 panel cut-out dimensions and Dimensional drawing

12. Order information

When ordering, please state:
Type designation: VAMP 40
Quantity:
Options (see respective ordering code):

12.1. Ordering codes of VAMP feeder and motor protection relay

Type	Description	Note
VAMP 40	Feeder / motor protection relay	

Accessories

VEA 3CG	Ethernet interface Module	
VPA 3CG	Profibus Interface Module	
VSE 001	Fiber optic Interface Module	
VSE 002	RS485 Interface Module	
VSE 004	VAMP 40 RS-485 module	
VSE 005-1	Ethernet and RS-485 module	
VSE 006	IEC 61850 module	
VX003-3	Programming Cable (VAMPSET)	Cable length 3m
VX028-3	Interface cable to VPA 3CG (Profibus adaptor)	Cable length 3m
VX030-3	Interface cable to VEA 3CG (Ethernet adaptor)	Cable length 3m
VX032-3	Rear panel programming cable	Cable length 3m
VYX256A	Optional seal for IP54	
VP 40	Arc option	
VA1DA-6	Arc Sensor	Cable length 6m
DI-934MB	RTD Input module	DataQ Instruments Inc.
Adam 4015-B	RTD Input module	Advantech Co.,Ltd

13. Revision history

13.1. Manual revision history

VM40.EN001	First revision
VM40.EN002	1Line & 1Phase voltage measurement modes added.
	Programmable inverse delay curves added.
VM40.EN004	VP 40 added.
VM40.EN005	Firmware version 6. Older versions of VAMPSET not compatible with this.
VM40.EN006	Intermittent transient earth fault protection added
	Capacitor overvoltage protection added
	Some adjustments in technical data

13.2. Firmware revision history

5.46	First release of VAMP 40
5.52	Extended auxiliary supply voltage range.
	1Line and 1Phase voltage measurement modes added.
	Function keys on HMI added.
	Support for Scandinavian characters.
	Arc interface support, VP40.
	Frequency measurement added.
5.56	Month max values added.
	Number of virtual outputs increased to 6.
	Number of logic outputs increased to 20.
	Auto-reclose updated (reclaim time setting and active signal for each shot).
5.68	DNP 3.0 protocol added.
	Extended self diagnostics.
	Inrush & cold load detection added (fast block operation).
	Running hour calculation added.
	Display backlight controlling with DI.
	Support for analog output modules added to External I/O protocol.
	Auto-reclose updated(blocking of shots)

5.75	Adjustable hysteresis for U>>, U>>>, U<<, U<<<.
	I_{02}> & I_{02}>> renamed as I_0>>> & I_0>>>>.
	Increased setting range for T>
	Voltage measurement mode description modified
6.6	IEC60870-5-101 (unbalanced) added.
	Auto detection added for External I/O (optional).
	NOTE! Requires VAMPSET (2.1.2) or newer version. Old files cannot be used with 6.x firmware.
6.12	IEC60870-5-101 (unbalanced) updated.
	Increased I_{0DIR}> setting range

14. Reference information

Documentation:

Mounting and Commissioning Instructions VMMC.EN0xx
VAMPSET User's Manual VMV.EN0xx

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